Aqua Insights

The Transformative Power of Digital Aquatech

›Powered by Aqua Spark

AquaSpark
› Investing in the Future of Aquaculture

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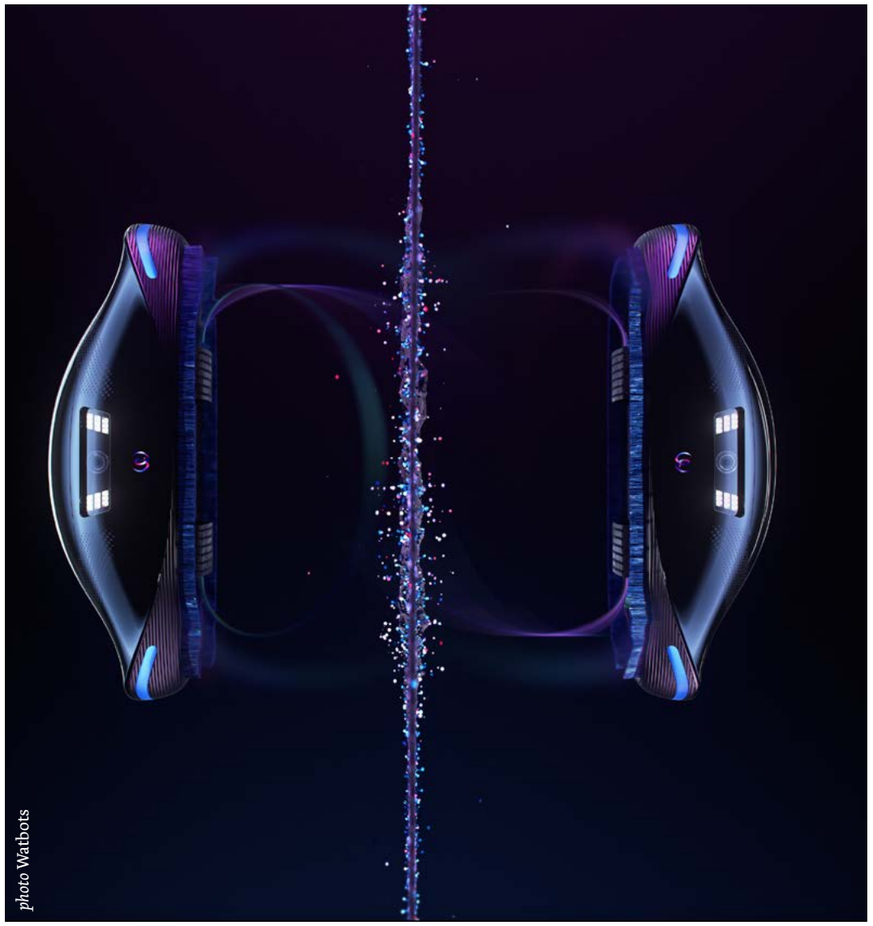
Contents



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Preface

Aqua-Spark made its first investment in digital aquatech in 2015, our first year of investing, when we participated in eFishery's seed round. At the time, there were very few startups trying to digitalize aquaculture operations and even fewer investors that wanted to fund these companies. 7 years later, in January 2022, eFishery closed its $90m Series C enabling the company to chase its ambition to improve the livelihoods of a million small-scale fish and shrimp farmers.

The value of our digital aquatech portfolio has reached $150m. Luckily, we haven't been the only ones investing. We've seen at least 100 investors joining us in the digital aquatech space, ranging from early-stage VCs to late-stage VCs, and from dedicated ocean funds to large corporate VC funds. A great start, but to accelerate the digital transformation of the aquaculture industry, much more investment is needed. We're therefore excited to present this second edition of Aqua-Spark's Aqua Insights Report Series: The Transformative Power of Digital Aquatech. We believe digital aquatech will enable more efficiency, transparency, and sustainability in the industry, while increasing a farmer's profitability and laying the framework for a resilient aquaculture industry in the future.

This Report provides you with an overview of the digital aquatech investment landscape, a series of inspiring interviews with CEOs of Aqua-Spark's digital aquatech portfolio companies, and a set of in-depth chapters on different segments of digital aquaculture technology. The scope of the Report is limited to the role of digital aquatech in cage- and pond-based aquaculture operations. We'll take you from data-driven platforms to smart feeding solutions, and from the latest generation of farm management software to the potential of satellite remote sensing and the rise of digital traceability solutions. You'll find an overview of some of the established and up-and-coming enterprises and startups that contribute to the digital transformation of aquaculture.

This Report wouldn't have been possible without the support of all the people at the companies involved in digital aquatech who've been willing to share their insights with us: your views have been of tremendous value for developing this Report. James Wright at Global Seafood Alliance, Matt Craze at Spheric Research, and Louisa Burwoord-Taylor at AgFunder, it was a pleasure to work together on some of the content of the Report. Also, to the whole team at Aqua-Spark, Editors Collective Amsterdam, and Detour: a big thank you for all your energy and hard work.

Willem van der Pijl, *Editor-in-Chief*
Amy Novogratz and Mike Velings, *Managing Partners*

Key Observations

- Nutritiously feeding our growing population without destroying the planet is going to take a redesign of our current food system and will require continuous innovation. Responsible aquaculture has a vital role to play in meeting the world's growing protein demand. Aquaculture is already the fastest growing agri-food sector globally, with big potential for future expansion.

- While historically rife with production challenges—including inefficiency, pollution, waste, and lack of transparency—the rapid rise of digital aquatech solutions is resolving production issues, increasing productivity and profitability, and improving fish health while, at the same time, reducing environmental harm and improving farmers' lives. It's truly starting to transform the industry into the resilient food system that will nurture future populations sustainably.

- This Report covers a range of digital aquatech solutions serving different geographies, different systems, and different species, but they all bring data to farming, moving it from an experienced-based industry to an insightful, data-driven industry, and showcasing how digitalizing an industry can mobilize a redesign of the full supply chain.

- In the salmon and wider cage farming industry, some of the most promising digital aquatech startups concentrate on IoT solutions, and use cameras and hydroacoustics to enable smart feeding, health monitoring, and biomass estimation. Advanced cameras and hydrophones allow these startups to develop algorithms that recognize both appetite and symptoms of disease. Based on real-time data analysis, the software platforms provide farm managers with suggestions about when to start and stop feeding, and when to intervene to prevent unnecessary losses. By creating 24/7 vision underwater and having advanced algorithms analyze real-time data streams, cage farming operations are becoming more efficient as they minimize the use of feed, reduce the impact that diseases can have on survival, and help to optimize the overall performance of farming operations.

- In more fragmented parts of the industry dominated by small-scale farmers, IoT solutions and farm management software providers are developing platforms that use production performance data to develop additional services that provide these predominantly small-scale farmers with access to affordable inputs, markets, finance, and insurance. The IoT solutions (think of smart water quality management and smart feeding solutions) and farm management software alone help farmers to become more efficient and profitable, but it's the additional services that these platforms provide that can *really* transform traditional supply chains and truly level the playing field between small-scale and larger farms. Some of these platforms are among the most successful startups in terms of fundraising within the digital aquatech space and they provide a clear example of how digitalization can democratize an industry.

- A lot of digital aquatech startups develop Hardware-as-a-Service (HaaS) and Software-as-a-Service (SaaS) business models. "Service" models reduce the upfront capital investment for farmers and drive market adoption among small-scale farmers—mostly in developing countries—thus helping these small-scale farmers to overcome the challenges of access to capital and finance they face. In general, larger farmers prefer to have hardware or software solutions on the balance sheet and keep operational expenses low. However, also for larger farms, if farmers are not yet fully convinced of the new technology, service models allow for close cooperation and a lower entry barrier. While service models drive market adoption, from the tech supplier perspective, developing a HaaS or SaaS model requires significant upfront investment. We see startups struggling with that.

- Looking downstream, digital traceability solutions and B2B and B2C e-commerce have great transformative potential. Digital traceability solutions don't only help to prevent food waste by enabling more efficient product recalls in the case of food safety hazards, but also allow trust to be built between supply chain partners, and between aquaculture producers and fish and seafood consumers. Whether blockchain will become the dominant tech solution that enables these digital traceability solutions remains to be seen. But it is clear that digital traceability solutions will increasingly be used to verify the stories about the origin of the fish and seafood we consume.

- While tech adoption amongst farmers isn't completely straightforward, increasing market demand for traceability combined with increasing concern for environmental impact from numerous stakeholders (including investors and financial services) creates pressure for farmers to utilize these solutions. However, enhancing access to markets, better production results, and profitability will be the ultimate drivers of widespread adoption.

- Though the recent aquatech boom has brought us from almost zero to over a hundred active digital aquatech solutions in the past decade, we're still in the early stages of this transformation. With only a very small percentage of global farming operations deploying digital tech solutions and a number of production challenges still requiring further solving, we need to urgently scale what's working now, expand to additional markets, bring in more farm data, and continue to evolve these technologies to deepen and expand their functionality while broadening the farm services they bring access to like finance, insurance, and the market. This will take a massive increase in investment.

- This space has been slow to bring in investment but that's also starting to change. With the recent close of eFishery's Series C round—the first Series C in the digital aquatech sector—and a number of other companies preparing for upcoming funding rounds, investors are finally seeing enough proof points to back this aquatech opportunity, resulting in a growing number of funds and investors entering or expressing interest in this space.

WE NEED TO TRANSFORM THE WAY WE FARM FISH AND SEAFOOD

Digital Aquatech Will Play a Crucial Role in Doing So

With our growing world population, we're placing the earth's natural resources under severe pressure. One of our most pressing challenges will be to feed everyone a balanced and nutritious diet while keeping our impact on the environment to a minimum. Fish and seafood play an important role in meeting future demand for healthy and sustainable food. Today, fish and seafood already account for 17% of all animal protein consumed around the world.[1] This share is growing because of rising incomes among consumers accompanied by increased demand for healthy proteins. By 2030, the world is expected to eat 20% more fish than in 2017—this increase can only be achieved through aquaculture, because we're already exploiting wild fish stocks to the max.

In recent years, aquaculture has been growing faster than any other major food production sector. But achieving further growth means making demands on our increasingly stressed environment. Although aquaculture is, in many ways, more resource-efficient than other animal production systems, it still has a long way to go. We need to do much better.

We at Aqua-Spark believe that reliably meeting the world's growing demand for fish—while simultaneously sustaining our environment—will require a radical transformation of global aquaculture. The rise and adoption of digital aquatech will play a crucial role in that transformation.

[1] FAO, *The State of World Fisheries and Aquaculture: Sustainability in Action* (Rome: FAO, 2020), 5.

FROM SEED TO C
GROWING AQUA-SPARK'S PART IN THE DIGITAL AQUATECH REVOLUTION

2015 Together with IdeoSource VC, Aqua-Spark invests in eFishery's seed round

2017 Aqua-Spark joins Vodia Ventures as an investor in Ecto

2017 First in-person encounter of Aqua-Spark with XpertSea's team at World Aquaculture Society conference in South Africa

2018 In March, Aqua-Spark invests in Hatch accelerator 1.0 in Norway

2018 In April, Aqua-Spark joins Obvious Ventures, edō Capital, and Real Ventures in XpertSea's Series A

2018 In October, together with Breed Reply, Aqua-Spark invests in CageEye, nowadays known as Bluegrove

2018 In November, other investors—such as Wavemaker Partners, 500 Startups, and Maloekoe Ventures—join Aqua-Spark in eFishery's Series A

2019 Aqua-Spark makes its first investment in Ace Aquatec

2020 Go-Ventures, the VC arm of Indonesia's Gojek and Northstar Group, join Aqua-Spark in eFishery's Series

2021 In July, Aqua-Spark invests in Ecto's Series A with new investors such as Rabo Ventures

2021 In August, Aqua-Spark co-invests in XpertSea's Series B with new investors such as QED Investors, Investissement Quebec, and Brazil's Atlantico Partners

2022 In January, Aqua-Spark proudly co-invests in eFishery's Series C with Softbank, Sequoia Capital India, and Temasek; some of the world's largest tech investors

By: Amy Novogratz, Managing Partner Aqua-Spark

In 2011, my partner Mike Velings and I set out to educate ourselves on how to transform the global aquaculture industry into one that is healthier, more sustainable, and more accessible. While exploring the industry, we were struck by the lack of technology in the sector and, by extension, the lack of data. Aquaculture seemed to rely on guesswork when it came to feeding, disease battling, harvesting, etc., which results in inefficiencies and errors that are financially costly and could negatively impact fish health, the environment, animal welfare, and productivity. Even then, it seemed as if digitalization and automation would be the next big thing to transform the industry, the way it had already begun shifting agricultural practices across so many other sectors.

Our research surfaced a few innovative companies solving production challenges, mostly serving Northern Europe, or very large farms, and at a premium. At the time, it was difficult to see how these seemingly unaffordable technologies were going to scale in this tech-nascent industry. We were looking for innovations that would be affordable to smallholders and medium-sized companies who made up 95% of the market. Given our self-induced mandate, this didn't happen overnight. Still, even then, we could see the industry changing, and we've since invested in several incredible tech companies, including eFishery, XpertSea, Bluegrove, Ecto, and Hatch, among others.

Cut to 2014—though we hadn't officially launched, we had been making a lot of noise about the need to invest in sustainable aquaculture. We were building our pipeline and were closely following eFishery—an Indonesian tech startup that had been winning many awards—when they became a finalist in Rotterdam School of Management's "Get in the Ring" business plan competition and we were able to meet Gibran Huzaifah, Co-Founder and CEO, who, beyond the multiple awards, impressed us with his clarity, drive, and level of commitment. Our team began to sense we'd found our first investment in aquatech. At the time, eFishery's focus was on smart feeders with sensors to measure when fish or shrimp are hungry and feed accordingly, saving 24% of feed each cycle. They already had a few affordable units in the field and farmers saw the value in paying for their product. With 3.5 million fish farmers in Indonesia, there was a clear market.

Getting to know this company strengthened our conviction that bringing technology into aquaculture was imperative. The aquaculture industry is opaque, and aqua farming can be literally "opaque;" it's hard to see what's happening underwater, especially in the case of murky, earthen ponds. These sensors and data insights provided a real picture of what was happening in ponds for the first time.

Farmers working with eFishery were ecstatic about the service they provided. In hindsight, it was more about the support, taking them on a journey to a new frontier of aquaculture. But the product also worked.

We invested in 2015 when eFishery was manually producing one unit a day, and there were less than 100 units in the field collecting feed and other production data—yet that was likely more farm data than any other single source. Gibran understood the value of data and he had a clear vision of a data-driven industry driving change. With an eye towards the future, we participated in the seed round with Ideosource, an Indonesian VC. As we hadn't invested in Indonesia before and this company planned to focus solely on the Indonesian market, we knew we needed a local co-investor. We've continued to participate in each subsequent funding round and recently closed eFishery's Series C with some of the largest tech investors in the world.

"By 2016, there was an industry shift happening that included a focus on business competitions like Fish 2.0 and the Blue Economy Challenge. The digitalization of the industry was being supported in new ways, and advancements were rising to the surface."

By 2016, there was an industry shift happening that included a focus on business competitions like Fish 2.0 and the Blue Economy Challenge. The digitalization of the industry was being supported in new ways, and advancements were rising to the surface. We had yet to see a company prove itself, but the energy was right, and innovation and the solutions were becoming more focused.

We first encountered XpertSea in the field—a company we'd been following from university stage—on a visit to our sea cucumber farm in Madagascar. My partner noticed a high-tech bucket and the excited hatchery manager explained: "That's the magic bucket—it does in seconds what used to take a full day." The XpertCount uses AI to count and measure early-stage aquatic organisms, and uses that data to provide insights on feed, disease, and optimal harvest time, for example to increase efficiency, productivity, and profitability, and to create better conditions all around. The global hatchery market was still small, and the tech wasn't cheap, but the team was impressive, mission-driven, and ambitious around industry potential. We all knew the tech could expand beyond hatcheries to drive tech costs down and that their vast data collection had incredible potential. After meeting the XpertSea team at the World Aquaculture Society event in Cape Town in 2016, we embarked on 9 months of negotiation and due diligence in which we partnered with Obvious Ventures, a US VC investing in world-changing solutions with a great track record of investing in future food tech. We've been working with XpertSea to expand into enterprise support and develop a data-driven shrimp trading platform that supports farmers in increasing the value of sustainable production while bringing sustainable, fully traceable shrimp to the global market.

Both of these human-centered, deep-tech solutions developed by eFishery and XpertSea have revealed that farmers don't want tech for the sake of tech. For farmers to adopt new technology, it must increase access—and both eFishery and XpertSea improve financing and market access. Our experience with both of these pioneering aquatech companies helped further develop our strategy for investing in tech.

We invested in CageEye, now part of Bluegrove, in early 2018 because we wanted to drive innovation in coldwater species, in particular salmon. We were blown away by the company's sonar tech that studied fish behavior and optimized feeding, with a similar impact and yield win as eFishery. In fact, it felt like we'd found the eFishery of open water cage farming and wanted to be a part of their growth. We joined CageEye in their Series B round with our co-investor Breed Reply, a UK-based early-stage IoT investor.

We also observed that the technology had to solve something specific and offer farmers a clear benefit that would increase profitability and plug into additional value in other segments of the supply chain, for example increased traceability.

Especially in those early days, it was common for the perceived value of a company to morph with the fast-changing industry. We met Ecto at Fish 2.0 in November 2017. At that time, the company was positioned as a reproductive breeding platform to speed up and improve selected breeding resulting in more efficient, more disease-resistant fish. While making great progress with genetic data in salmon production, Ecto realized it wasn't just the quality of the broodstock but, in fact, every step along the supply chain that affected the growth and well-being of farmed fish. Thus, Ecto pivoted into a decision-making platform that aggregates data from different sources. Ecto raised a Series A with strategic co-investors in the summer of 2021 to grow this platform.

Knowing the challenges to scaling tech solutions in different aquaculture markets, it became even more imperative to continue to foster innovation in aquatech and to support an early-stage financing solution. So, in 2018, when our colleague Carsten Krome split off to start Hatch, the first accelerator for aquaculture, it was great news for the industry, and we proudly invested initially in the first cohort and later in the holding company. Hatch has since invested in over 40 early-stage companies, of which around 10 are focused on digital aquatech.

Aquaculture's development and adoption of technology in the last decade is worth noting. The industry has proven itself to be nimble and eager for tech-based solutions that address pain points throughout the production process. Our portfolio of 24 companies is currently about a third of clear digital aquatech companies working across animal welfare, feed optimization, trading, financing, and more to digitalize the industry one farm at a time. As data continues to be one of the most valuable tools for farmers, we anticipate the technologies and innovations will grow with the industry—and we'll continue to give these solutions lift-off.

IMAGINE 2030
THE NEW NORMAL

A Small Shrimp Farmer in Odisha, India

Early in the morning, Savitri, who has over the past couple of years expanded her shrimp farm from just 2 to 10 ponds, looks at her smartphone to see whether all is okay at her farm. The sensors in her ponds monitor the water quality and if anything goes wrong the app sends an alarm to her phone. Luckily, the alarm didn't ring last night. If it had, the aerators in the ponds would've switched on immediately to save the crop. And, even in the case of crop failure, Savitri would've been insured. Based on her track record and continuous satellite monitoring, the insurance company provides her with full coverage.

When arriving at her farm, her smart feeding machines are shooting pellets into the ponds. This means that the acoustic sensors in the pond have determined that the shrimp are hungry. This is a system that reduces feed use and increases profit. Savitri smiles, proud of what her animals are eating: they get feed for optimal health at the lowest footprint. In the market section of the app, she sees that farm gate prices are on an uptrend and that the best time to harvest is in 7 days—taking into consideration prices, biomass, and production costs.

Just before harvesting, Savitri takes a few shrimp out of the pond and snaps a picture with her smartphone. She uploads specific details about the crop to the online marketplace and offers her shrimp for sale. Within a couple of minutes, three processors are bidding on her product. Once she's accepted the best bid, Savitri immediately receives her balance payment into her online wallet. This allows her to pay for the new inputs that she pre-ordered 2 weeks ago at a discounted rate.

The app's digital farm advisor tells Savitri that she could consider stocking at higher densities for the next crop. Other farms in her vicinity did so during the previous crop and performed better. As the app doesn't report disease issues anywhere close to her, she feels confident to commit to slightly higher stocking densities. Ah, being a shrimp farmer today is so much less stressful!

A Large Integrated Salmon Farmer in Norway

Jorgen, manager of 4 salmon farming sites, always told vendors that he'd rather trust his own eyes and experience than their futuristic technologies. Today he has fully adopted digital technology. He smiles, because his margins have increased significantly while his risks have been reduced to the bare minimum.

The 4 sites that Jorgen's company operates are nowadays managed by 4 operators sitting in a control room in the corporate office in Bergen. They monitor 40 fully automated near-shore cages. The operators don't have to interfere in any part of the farming process unless the system tells them to do so. Cameras and acoustic sensors installed in every cage provide data to a software application that continuously monitors fish behavior and notifies the feeding system when the fish have an appetite. Carefully developed algorithms look for patterns in the data that might mean the fish are feeling unwell and need special additives or disease treatment. Jorgen smiles again, thinking of how well he thought he knew his fish before adopting all the tech.

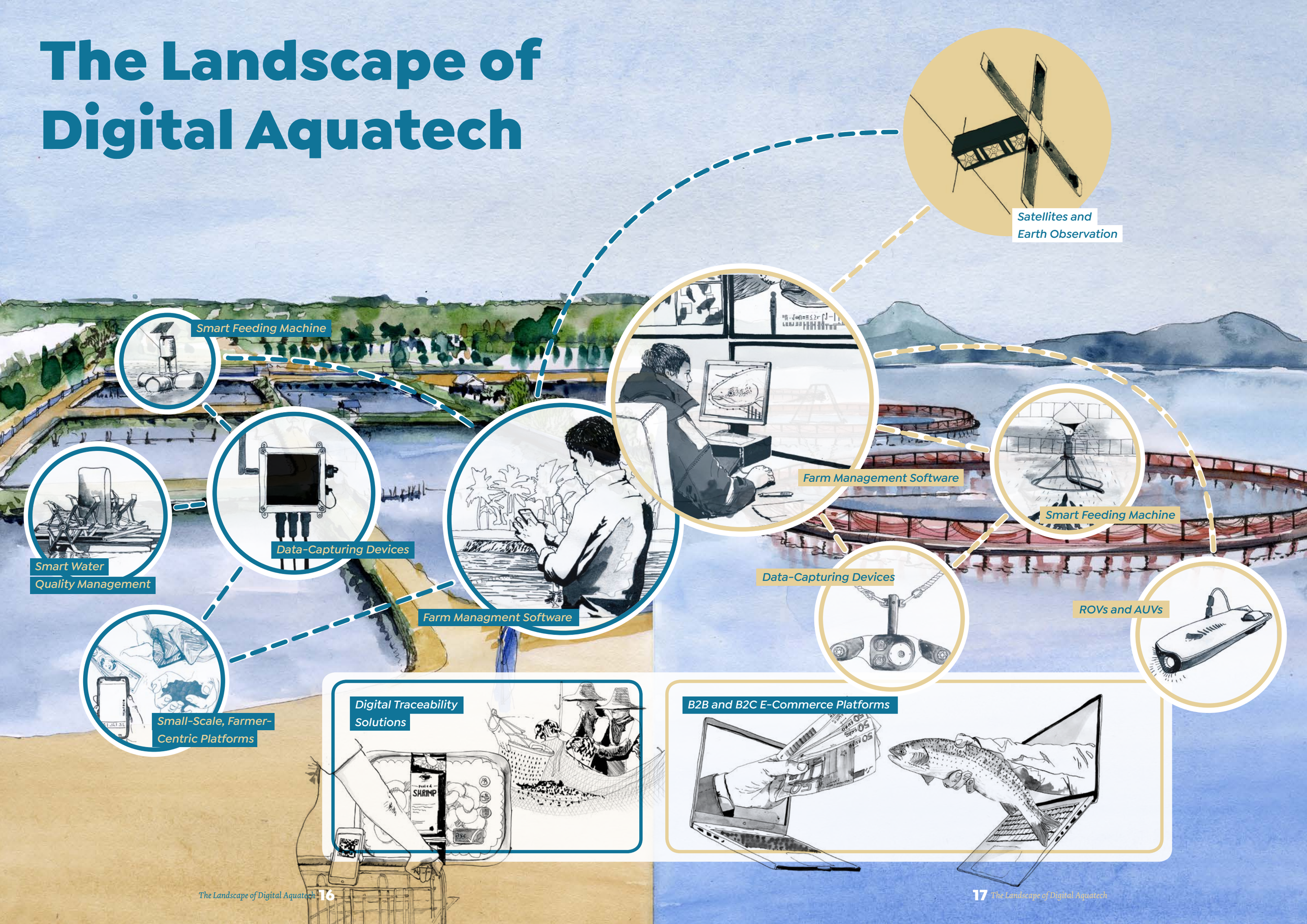
Underwater drones clean, inspect, and repair his nets and remove waste from the bottom of the cages. While Jorgen used to battle sea lice most of the time, today a combination of factors including feed, genetics, digital solutions, and cage design have minimized lice occurrence: they aren't even a worry anymore. Advanced farm management software provides Jorgen with continuous feedback on how to further optimize and plan his farming operations to make sure that his cages are always stocked with growing fish and his workers are always spending their time efficiently. Data enables him to accurately track fish performance from egg to harvest and discover new operating procedures to improve his next crop.

Jorgen's appreciation of data doesn't stop at the farm gate. He also continuously shares data with external service providers who aggregate it from all of Norway's salmon farms. This gives farmers advance warning of disease prevalence or other adverse conditions. This also allows the logistics to be streamlined (for example, with the feed companies and other service providers for the supply and collection of materials to and from the farms at the right times). For Jorgen and his co-farmers, all of this results in dramatically improved efficiency, reduced risk, and more profit.

A Consumer in the US

When Lucía, a customer of one of the main supermarkets in the US, buys her shrimp or salmon and scans the QR code on the package, she's provided with full blockchain-enabled traceability: she can read about the product's history (tracing it all the way back to the inputs used to produce the salmon or shrimp) and information about Jorgen's and Savitri's farms. In the case of a product recall, the supermarket can easily find all the products that have been directly affected and, as a result, Jorgen's and Savitri's products may be unaffected by the recall.

The Landscape of Digital Aquatech



The Investor Landscape

AgFunder has provided historical data on investments in digital aquatech to shape this publication.

Investments in aquaculture are surging, and this includes significant investment in digital aquaculture farm and supply-chain technology. The analysis presented in this overview of the investor landscape is based on 48 digital aquatech companies that have publicly disclosed the capital they've raised since 2015. These companies are just the tip of the iceberg: many of the early-stage investments—i.e. pre-seed and seed investments—haven't been publicly disclosed. Aqua-Spark estimates that the 48 companies we've identified have together raised around $250m since 2015—this amount is likely a pretty close estimation of the capital that's actually gone into this space so far, as most larger investments have, in fact, been publicly announced. Here, we want to provide you with some insights into the current state of play concerning the investor landscape by looking at the main investors in this area.

DISCLAIMER

1) We report on a best-effort basis. The data used for this chapter is provided to Aqua-Spark by AgFunder and complemented with data from Crunchbase, Aqua-Spark, and other investors and their portfolio companies. It is limited to what has been disclosed in the public domain and what investors and companies were willing to share for the purpose of this Report.

2) Although e-commerce is part of the scope of this Report, we exclude it from this overview. E-commerce has been attracting lots of investment recently but only a few are aquaculture-focused. Including these numbers would overshadow investments in digital aquaculture farm and supply-chain technology.

Innovation Competitions and Incubator Programs as Sources of (Pre-)Seed Funding

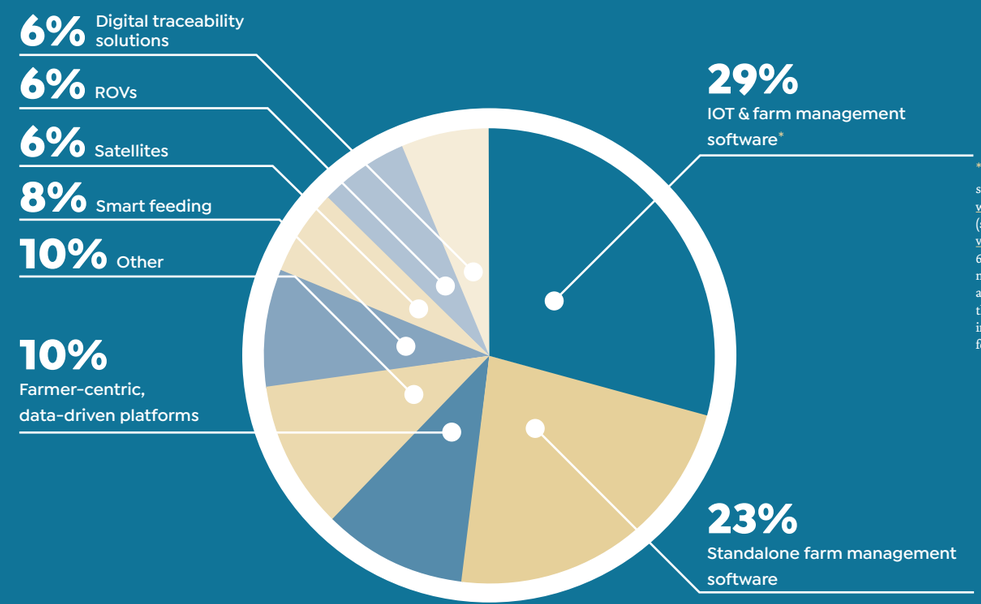
Fish 2.0 was the first large global seafood and aquaculture-oriented innovation challenge. From 2013-2020, Fish 2.0 organized a biannual program and established a network of 500 investors and 50 sponsors that supported 600 entrepreneurs with in-kind support, grants, and exposure to develop their innovations into investable enterprises. Other competitions followed, including InnovationXchange's Blue Economy Challenge and The Yield Lab Asia Pacific's Global Aquaculture Challenge.

These competitions are a great source of leads for potential investors. The earliest-stage investors are mainly angel investors, innovation hubs—such as Innovation Norway—and the funds that run startup incubator and accelerator programs.

Accelerators usually offer a combination of in-kind support, grants, equity, or other types of financial support. Hatch[2] is the first fully dedicated aquaculture accelerator program. It was founded in 2017 and over three cohorts has invested in 10 digital aquatech startups that fall within the scope of the Aqua Insights Report on Digital Aquatech. These companies are located around the world and their propositions range from satellites to sensors, from farm management software to B2B e-commerce. But Hatch isn't on its own. Well-known early-stage tech and ocean investors, such as Techstars, Katapult Ocean, AgFunder, and Innovacorp, have—via their accelerator programs—also made investments in digital aquaculture farm and supply-chain technology startups.

[2] Aqua-Spark has been an investor in Hatch since 2017.

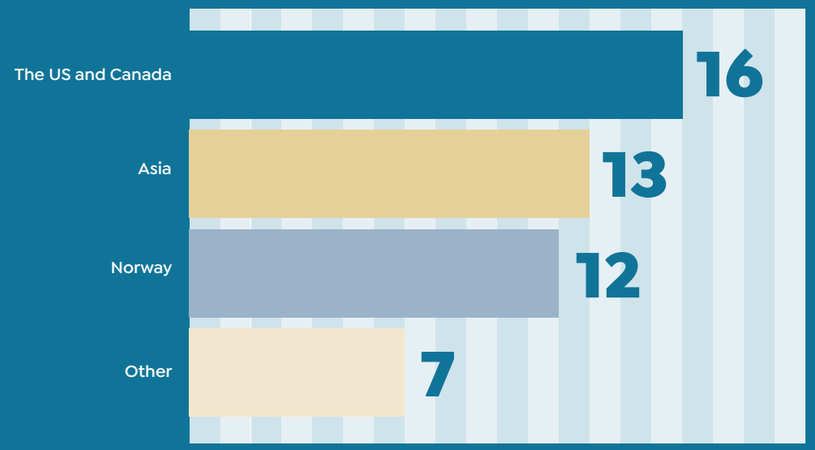
IoT solutions & farm management software, and farmer-centric, data-driven platforms raise the most investment rounds among the 48 companies within the scope of this analysis



* "IoT & farm management software" refers to smart water quality monitoring (see p. 42) and machine vision applications (see p. 60), and to connected farm management software applications (excluding those related to smart feeding—see separate "smart feeding" category).

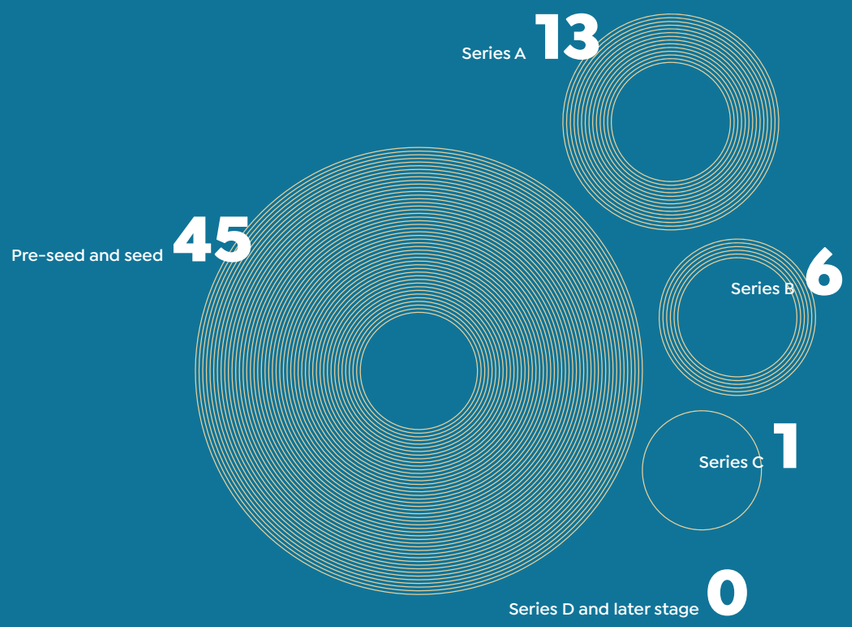
Source AGFUNDER, CRUNCHBASE, AND AQUA-SPARK

Of the 48 companies, startups in the US, Canada, Asia, and Norway raise the most investment rounds



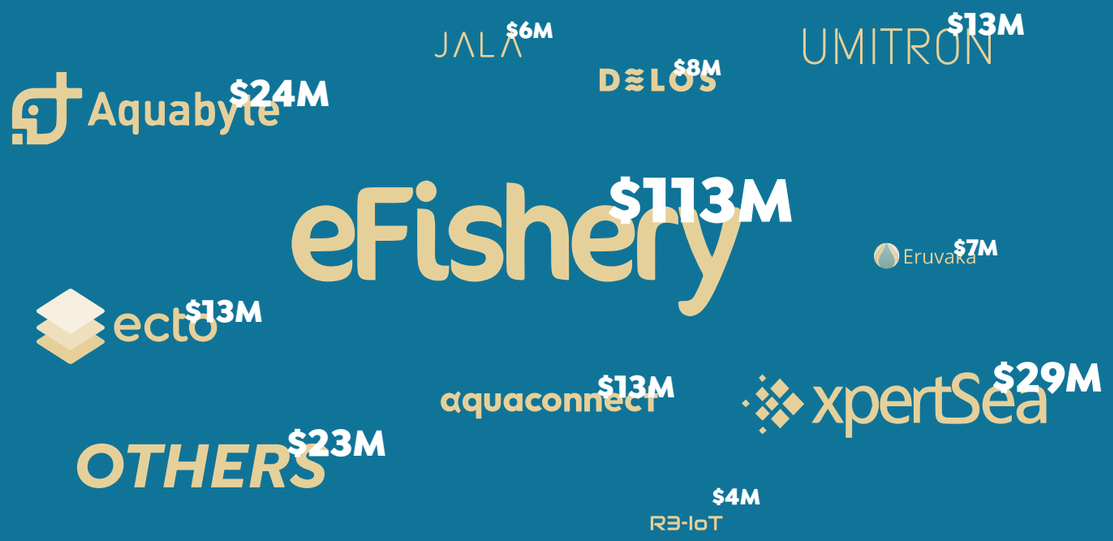
Source AGFUNDER, CRUNCHBASE, AND AQUA-SPARK

Between 2015 and 2021, the 48 digital aquatech companies disclosed 65 investment rounds



Source AGFUNDER, CRUNCHBASE, AND AQUA-SPARK

Top 10 companies in terms of investment raised among the 48 companies



Source AGFUNDER, CRUNCHBASE, AND AQUA-SPARK

Between 2015 and 2021, Almost 100 Venture Capital Funds Were Involved in Early-Stage Investments in Digital Aquatech

For those companies that raise early-stage investment and go beyond participating in accelerator programs, there's a whole host of impact investors and venture capital funds that have started to invest in digital aquatech as well. Aqua-Spark estimates that the number of investors involved in the early-stage funding of digital aquatech has increased from just over 10 in 2015 to just under 100 by 2021.

According to the data compiled for this article, early-stage investors with more than one investment in the space include Aqua-Spark (5 investments), 500 Startups, AgFunder, Boost VC, Hatch (excluding the investments through the accelerator program), Innovation Norway, and Omnivore (each with 2 investments). There are a host of other impact and (early-stage) venture capital funds out there that have only made one investment in the space so far, and we expect more funds to follow. Of the funds that have already made their first investments, many have really got a taste for it and are looking to their next investments.

Several Startups Have Made It to Later-Stage Funding Rounds

Until recently, no digital aquatech companies had raised funding rounds beyond a Series A. But this all changed when XpertSea raised its Series B and eFishery its Series C.

Both XpertSea and eFishery have evolved into farmer-centric, data-driven platforms. They provide farmers with tech, as well as access to inputs, financial services, and markets. Both target small- and medium-scale farmers and aim to improve their incomes; they can transform fragmented supply chains allowing these comparatively smaller farmers to compete with more consolidated parts of the industry. Both companies have been successful due to their product/market fit, and have enjoyed a strong sales performance (including growth of sales and margins). Crucially, they also both have the potential to scale globally.

Investments in digital aquatech only really started in 2015. Fast forward to 2022 and eFishery has netted its Series C with some of the largest investors in the world. It's raised $90m. This marks a huge success for digital aquatech. And it's also a promising sign for other digital aquatech startups that aim to raise more capital: with large institutional and venture capital funds (such as Temasek, Sequoia Capital India, and Softbank), more later-stage investors may well become excited by this, potentially resulting in more companies raising their Series B and C, and—who knows—we may even see a Series D at some point in the not too distant future.

Corporate Venture Capital Investors Getting in on the Act

Another interesting trend is that several of the large corporate players in the aquaculture industry have also invested in digital aquatech startups, either directly or through their corporate venture capital (CVC) funds. Normally, these companies invest in technologies that strengthen their market proposition but are not necessarily the core of their business.

Examples of CVC investments are those of Bosch in AquaEasy (a company that uses sensors to monitor water quality and connects to proprietary farm management software), Nutreco (and Skretting) in Eruvaka Technologies (a company that has developed smart automated feeding solutions for the shrimp industry), Thai Union in HydroNeo (an IoT-based farm management software provider), and Akva Group in Observe Technologies (a company that develops smart feeding solutions for the salmon industry).

In the short term, we don't expect to see the same degree of acquisitions in *digital aquatech* by corporates and their CVCs as we've seen in *digital AgTech*, where large corporations are acquiring many of the tech startups. This is due to the relatively small size of the aquaculture industry and the scale of the majority of producers. But as the industry grows, we do expect to see more investments and acquisitions, and companies like Thai Union (also with its SPACE-F Incubator Program) and Nutreco (with its NuFrontiers CVC) play an increasingly important role.

Ocean- and Aquaculture-Dedicated Funds Likely to Further Drive the Amount of Investment Entering Digital Aquatech in the Not Too Distant Future

While Aqua-Spark and Hatch are still the only two funds fully dedicated to aquaculture, there are now other funds that have significant amounts of capital available for the area as well. Four funds dedicated to sustainable oceans have recently been established. They are:

- Mirova's Althelia Sustainable Ocean Fund: final closing at $132m, August 2020;
- S2G Ventures' Oceans and Seafood Fund: final closing at $100m, January 2021;
- Ocean 14 Capital Fund: initial closing at $80m, November 2021; and
- Swen Capital Partners' Blue Ocean Fund: second closing at $100m, February 2022.

While the focus of these funds is broader than just aquaculture alone, aquaculture is certainly within the scope of all four, and an increasing number of digital aquatech startups are likely to become part of their deal flows and portfolios soon.

Some Final Thoughts on the Current State of Play

It's fair to say that, in comparison with the AgTech industry—or even other parts of the aquaculture industry—the number of digital aquatech startups that have raised significant investment remains small. But that number is growing. Our data shows that it's growing steadily and that it may well accelerate soon.

It's also fair to say that COVID-19 hasn't done the industry any favors and investments slowed down in 2020 and 2021. But, as with any downturn—pandemic-related or otherwise—it's mostly followed by an upturn, and that's exactly what we expect to see over the next couple of years. While so far the majority of investment in digital aquatech has been pre-seed and seed funding, more companies will be preparing for their next investment rounds. What's sure for now is that these newly established dedicated ocean funds and the wide range of VC's and CVC's that are getting involved will certainly help the digital aquatech sector to grow in the long run.

SEQUOIA

Sequoia helps daring founders build legendary companies. Sequoia India partners with founders to push the boundaries of what's possible. Startups benefit from 50 years of knowledge and lessons learned working with companies like Airbnb, Alibaba, Apple, Dropbox, Google, LinkedIn, and Stripe early on.

HQ	There's not one HQ
Geographical scope	India and Southeast Asia
Sectoral focus	Tech-enabled businesses across sectors such as Web3, Fintech, Software-as-a-Service (SaaS), EdTech, HealthTech, direct-to-consumer (D2C), etc.
Investor type	Across stages—from idea to IPO (seed, venture, and growth)
# of companies in portfolio	250+
# of companies in aquaculture	2
Companies in digital aquatech	eFishery, since 2022, and Aqgromalin (India) as part of Surge 06 (Sequoia Capital India's rapid scale-up program for early-stage startups), since 2022

"In Indonesia alone, aquaculture is a massive $20bn market where about 3 million farmers depend on the industry for a living. There's a clear and large unmet need to help such small-scale farmers succeed and that got us excited about the space. Sequoia Capital India has recently partnered with Indonesia-based eFishery. Its product offering is strategic and the most comprehensive to help revolutionize traditional farming through tech. With its strong, mission-driven founders, a unique and sticky business model, incredible momentum, and healthy unit economics, the company is well-placed to help farmers across Southeast Asia leverage the power of tech and, in doing so, emerge as a market-leading company in the region.
Akin to the rapid growth of the digitalization we're seeing in several other sectors, as aquaculture becomes more tech-enabled in the coming years, we're excited about the possibilities and are looking to partner with founders building enduring companies."

eFishery

GIBRAN HUZAIFAH, *CEO*

Interviewed by: Amy Novogratz, Managing Partner at Aqua-Spark

Founded	2013
HQ	Bandung, Indonesia
Capital raised	Seed: $0.45m (2014) Series A: $4m (2018) Venture round: Undisclosed (2019) Series B: $19m (2020) Series C: $90m (2022)
Aqua-Spark invested in	2014
Products on the market	eFisheryFeeder (automated feeding solution) eFisheryFeed (input marketplace) eFisheryFund (credit facility) eFisheryFresh (B2B seafood marketplace)

When you were starting your catfish farm there was no "tech" in aquaculture yet. What was your "Aha!" moment for optimizing feeding and bringing digital data into aquaculture?

The first moment was when I saw that the three guys that were each managing one section of my farm achieved very different results. They had the same fish, started at the same time, used the same water, but had different outcomes. Then I found out that one of the guys was stealing feed. He said he'd already fed the fish, but actually he was stealing some from each bag. I realized there was no easy way to keep an eye on what was going on.

I thought that larger farms would have better procedures, but they didn't. Even though they instructed their operators on the feeding protocols, none of the operators really seemed to keep records of what they were doing. That's when I became inspired and asked my fellow farmers: "What if I have a machine that can feed the fish automatically?" Everyone was excited!

I spent $200 on building my first automated feeding machine. You had to send an SMS to the machine for it to start feeding. Some of my fellow farmers wanted to try it and were really enthusiastic. Then there was a farmer who had 500 ponds. When we realized that he would have to send individual SMSs to each of the 500 machines, it

Tell us about what made you jump into aquaculture.

I studied biology and at my university there was just one class for aquaculture. The professor was very inspiring and told us about the role aquaculture could play in food production. He shared the story of catfish in Vietnam: how they successfully rebranded it as the "dory fish" and turned it into a popular species. He said that while today catfish in Indonesia was known as a cheap fish, in 5-10 years it would be sold as a luxury product. After that class, I decided to try catfish farming myself. With the little money I had I started with just 1 pond, but then grew it to 76 ponds 3 years later. In the beginning, I had a hard time selling my fish, so I started to sell it myself in a small shop on campus. I branded my fish "Dory," inspired by my professor.

Gibran next to one of the first prototypes of the eFisheryFeeder.

dawned on me that this wasn't going to work. As a result, and with the help of some engineers, I started to develop the next prototype.

Our first prototypes were just timer based. With these systems there was still a big chance of overfeeding. That's when we started to think about using sensors that measure the rippling effect in the water when fish are eating and the sound made by the water in the mouth of the fish when they eat. After applying this to a number of ponds, we used the data to improve our feeding algorithms.

Today, more than 80,000 ponds are using our technology across Indonesia. Our latest equipment enables farmers to increase their production capacity by up to 26%. By increasing feed efficiency by up to 30%, farmers' incomes can go up by as much as 45%.

Everyone talks about how difficult tech adoption is, but you have tens of thousands of farmers using your feeders. How?

In the beginning it was easy to work with farmers that were close to me, but expanding our reach was more difficult. Most farmers wouldn't use any technology yet and didn't have a business mindset. They often didn't even have a clue about their profitability. I had to convince each farmer myself, which took a long time. I was visiting every pond and if I was rejected I would go back until I'd convinced them.

At a certain point, to reach scale, I started hiring feed sales agents. I told these guys that I was running a new company and asked them if they could help me reach my target. The feed agents themselves weren't particularly invested in, or interested in, the benefits of our technology but more in the commission that we offered. However, once they helped us to get more of our feeders into the field, we could start showing the impact on production. When farmers saw the reduction in feed use, they wanted to remain eFishery customers.

What led you to the marketplace for aqua inputs, financing solutions, and the B2B marketplace?

The idea to build other services based on the farm data we collected was always there, but we first had to understand the farmers' problems to make sure that we could solve those problems.

The first problem we identified revolved around feed distribution. 98% of our 20,000+ farmers lacked access to affordable feed. Our data allows us to make fairly accurate predictions about how much feed of a particular brand farmers in our network need at a specific moment in the future. We can then pre-order those volumes directly with the feed manufacturers to offer competitive prices. This means that we're able to offer feed at around 5% under the price that our farmers would normally pay, and as we increase our volumes and efficiency, we hope to reduce the cost by another 5%, meaning that our farmers could pay up to 10% under the regular price of feed. Our marketplace is called "eFisheryFeed" and today we're one of the largest—if not *the* largest—feed distributors in Indonesia.

The eFishery team in the early days.

Next we launched a credit facility, "eFisheryFund." Many farmers asked us whether they could buy the feed on credit. For most farmers, the cost of financing their inputs could be as high as 30-40% per year, which is devastating for them. We were soon convinced that we could do this better and so we developed a credit rating system through which farmers would get a certain amount of credit to procure feed through our eFisheryFeed marketplace. This facility is not financed by us but by financial partners. Since January 2020, we've approved nearly $31m in credit.

Another problem we identified was that when buying fish from farmers, middlemen weren't really adding value. Based on the data collected from our farmers, we built a prediction model that would allow us to estimate when and how much fish would be harvested. Once we knew we could predict these things pretty accurately, we started to sell this fish in advance to B2B clients through our "eFisheryFresh" platform. We started with a successful pilot of 2 MT. This model allows us to secure higher prices—up to 35%—for the farmers. Because all financial transactions run through our platforms, we can also ensure that farmers pay back their credits for the feed they procure before they're paid the balance on harvesting.

In your most recent Series C round you raised $90m and got some of the largest tech investors in the world behind you. How will that shape and influence your future trajectory?

I believe that by raising this round we've proven that aquaculture is finally gaining the interest of larger investors. Until recently, it's been extremely hard to have mainstream tech investors even glance at this sector. But times are changing, and more investors are now ready for aquaculture. We're excited that with the current funding we can be even more ambitious and not only target Indonesia but also other countries. With the new partners and resources on board, we now dare to say that we're ready and want to expand to China, India, Vietnam, and other countries in the region.

Where do you see all of this going? Just looking at the market potential in Indonesia, and in the region, your data-driven growth potential is limitless.

Many people expect that just like in the salmon industry we'll see a lot of consolidation and smaller farmers disappear. I don't believe that this will happen in the freshwater aquaculture sector in Indonesia—or in most other Asian countries—as the sector is too fragmented. Instead, I think that small farmers will continue to drive a major part of production. To make them more successful, we have to aggregate their needs and support them in becoming more productive and improving their practices through adopting tech. In turn, this will also improve their livelihoods. This is the work we're pioneering in Indonesia.

We want to be the largest digital cooperative for fish farmers in the world and we aim to have at least one million small farmers join us. Legally, we're not a cooperative, but we have the cooperative mindset. We want to preserve the spirit of cooperation with small farmers: rather than help a handful of corporations improve their revenues, we want to improve the livelihoods of one million small farmers. I believe we can achieve this by 2030.

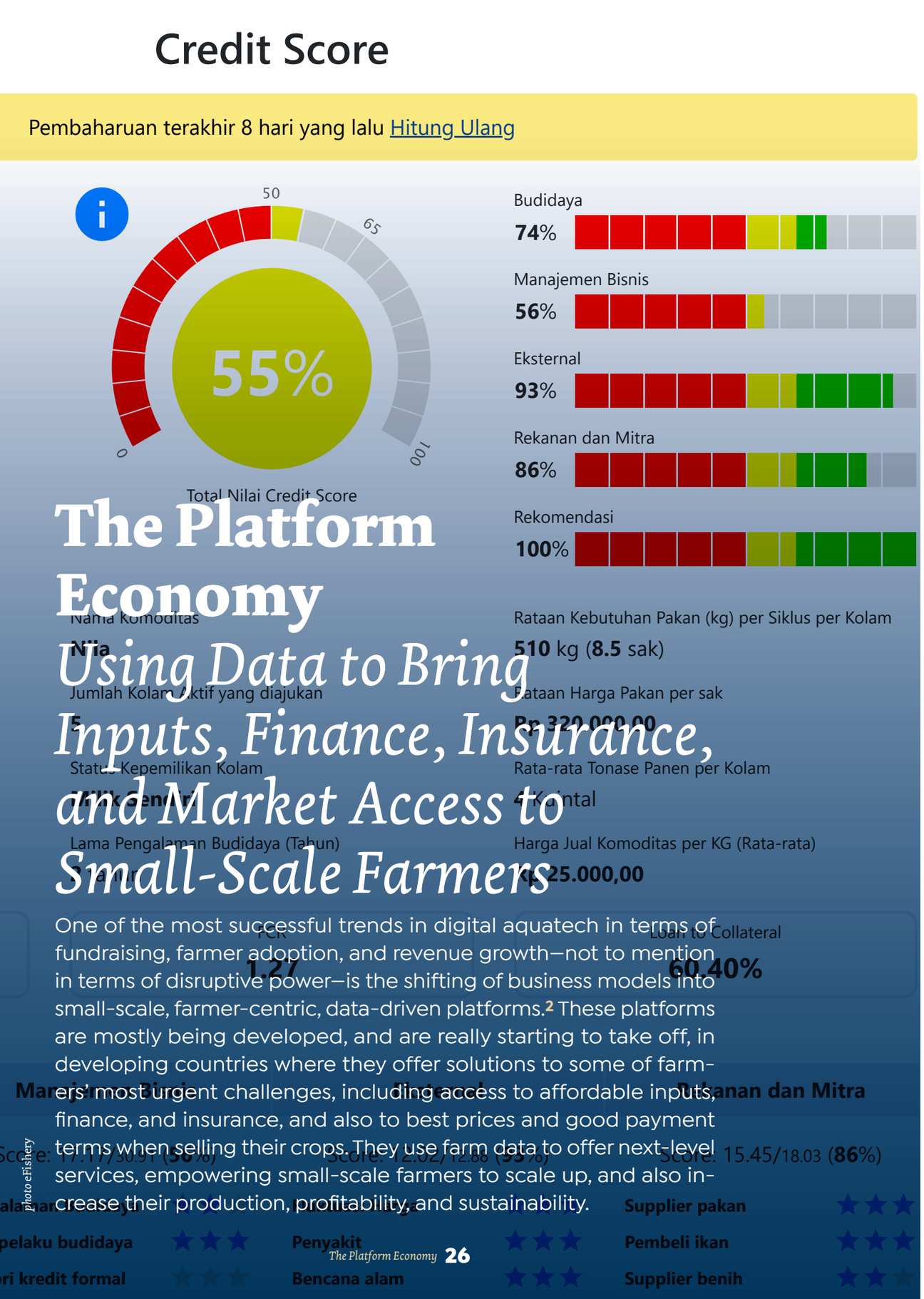


photo eFishery

The Platform Economy

Using Data to Bring Inputs, Finance, Insurance, and Market Access to Small-Scale Farmers

One of the most successful trends in digital aquatech in terms of fundraising, farmer adoption, and revenue growth—not to mention in terms of disruptive power—is the shifting of business models into small-scale, farmer-centric, data-driven platforms.[2] These platforms are mostly being developed, and are really starting to take off, in developing countries where they offer solutions to some of farmers' most urgent challenges, including access to affordable inputs, finance, and insurance, and also to best prices and good payment terms when selling their crops. They use farm data to offer next-level services, empowering small-scale farmers to scale up, and also increase their production, profitability, and sustainability.

> "In the quest to transform into platforms, organizations must shift from a culture of dollar absorption to a culture of data absorption."
> *Sangeet Paul Choudary, author of "Platform Revolution: How Networked Markets Are Transforming the Economy—and How to Make Them Work for You"*

The popularity of platforms isn't unique to aquaculture. In agriculture, farmer-centric platforms such as DeHaat and Farmers Business Network (FBN) are growing rapidly. India-based DeHaat raised $115m in a Series D in 2021, bringing its total capital raised to $165m. Even more impressive, FBN became a unicorn back in 2019 and raised $300m in a Series G in 2021, bringing its total funding raised to $870m.

Farm Management Software and IoT Solutions Generate Data That Can Be Used to Develop Other Services

The platforms with the most disruptive potential are those that develop close relationships with the farmers: these platforms are innovating how data about farmers' operations and performance can be captured, and they use that data to develop services that will increase profitability while, at the same time, reducing negative environmental impact.

To build relationships—which in turn will give these companies access to even more data—most small-scale, farmer-centric platforms start with farm management software (see p. 36), initially offering data-driven insights to farmers so as to optimize production. Sometimes these solutions are integrated with IoT solutions. Through the farm management software, these companies are then able to generate a continuous stream of data about farmers' operations and performance, for example about the need for inputs such as feed, how a crop evolves, and when farmers are ready to harvest and sell. Such data then allows the platform to develop a range of other services more tailored to farmers' needs.

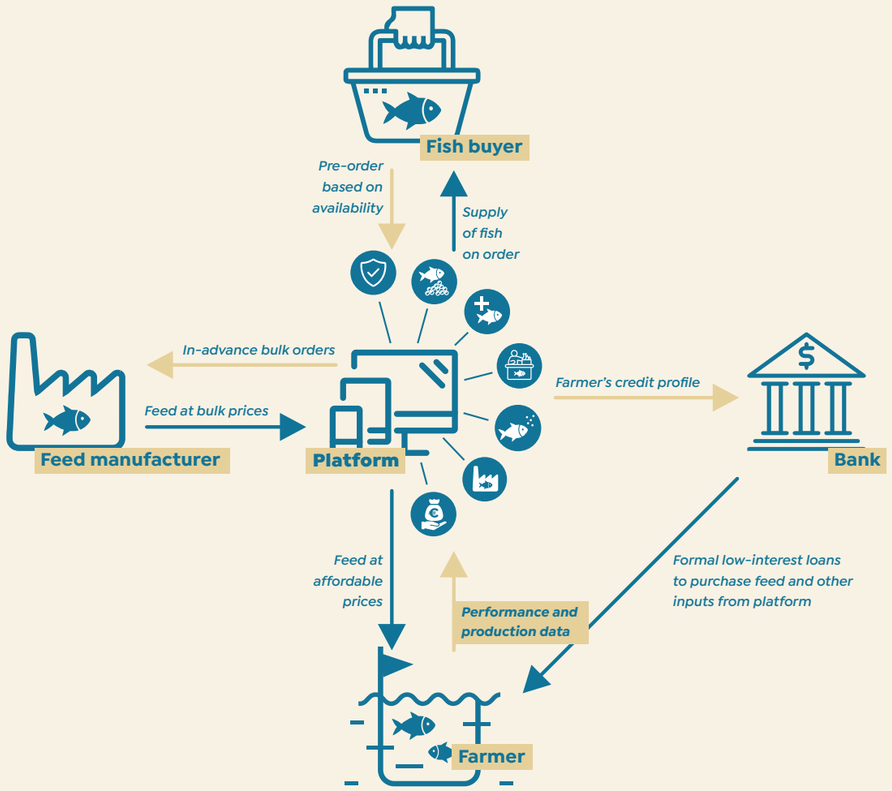
By developing a large network of farmers, these platforms have great leverage with feed companies, banks, insurers, and buyers alike: platforms can aggregate farmers' supply and demand. This model results in access to better prices and more favorable payment terms. It also gives farmers additional services—such as access to finance and insurance, services which are offered by companies like eFishery (see p. 23), XpertSea (see p. 81), and Aquaconnect—and drives both the adoption of tech and of sustainable production practices.

[2] The type of platforms discussed in this chapter are mainly relevant for fragmented parts of the aquaculture industry such as shrimp or exotic fish. In other parts of the industry, such as in salmon, the scale of individual companies means that they don't require this type of service.

Making Systems "Smart": The Use of AI in Digital Aquatech

Throughout this Report, you'll read about how the use of data, algorithms, and artificial intelligence (AI) will make solutions and aquaculture operations "smart." An *algorithm* is an instruction programmed by a human to have a computer solve a specific problem or to perform a computation. *AI* refers to the way in which we use computers and software to analyze data; produce actionable insights and recommendations; and automate parts of the decision-making process in aquaculture operations. Machine learning, deep learning, and machine vision are examples of AI disciplines.

The role that platforms start to play in fragmented aquaculture supply chains



Mapping and Aggregating Demand for the Right Inputs at the Right Time and Place

More often than not, small-scale farmers don't buy their feed or other inputs directly from the manufacturer, unlike most larger farms (larger farms can often buy inputs in cash or can access formal credit). In many cases, small-scale famers buy inputs through a network of distributors—also referred to as middlemen—who function as demand aggregators and farm financers.

As you can probably guess, distributors' margins can be significant without adding much value: they receive bulk prices from feed manufacturers and then sell at higher prices to farmers. And if farmers buy from distributors on credit, they pay even more. A distributor often requires farmers to sell their harvests back to them, and not always at the best prices. In this type of agreement, when input is supplied on credit and a farmer is obliged to sell their harvest back to that same distributor, a catch-22 situation arises: the distributor pre-financing the input will only do so next time if that farmer has sold their previous harvest—from the previous pre-financing situation—back to that same distributor. Failing to do this would leave farmers with no cash or financing option, and therefore no next crop. As a result, small-scale farmers end up in exploitative relationships and pay considerably higher prices for their inputs than larger farms.

Platforms aggregate demand for inputs from large numbers of small-scale farmers, the aim being to provide farmers with better prices and payment terms: through the data they collect from farmers, they know what inputs their farmers need and when they need them—eFishery is a great example of this (see p. 23). This contributes to improved incomes and livelihoods.

photo eFishery

Providing Farmers with Access to Markets, Better Prices, and Better Payment Terms

For a small-scale farmer who has bought inputs on credit from a distributor, often the only option available is to sell their crop back to the distributor. Other farmers can sell to the highest bidder. They face a dilemma between opting for a higher price but a longer payment term from a processor, or a lower price with faster payment term from a distributor. Most have to choose the latter—waiting for their money likely means consequences for things like their outstanding loans, or when they can stock for the next crop. Under-financed, small-scale farmers are often in a terrible position. And this doesn't only harm them directly, but inevitably results in negative effects on the environment as they just can't afford to make sustainable choices.

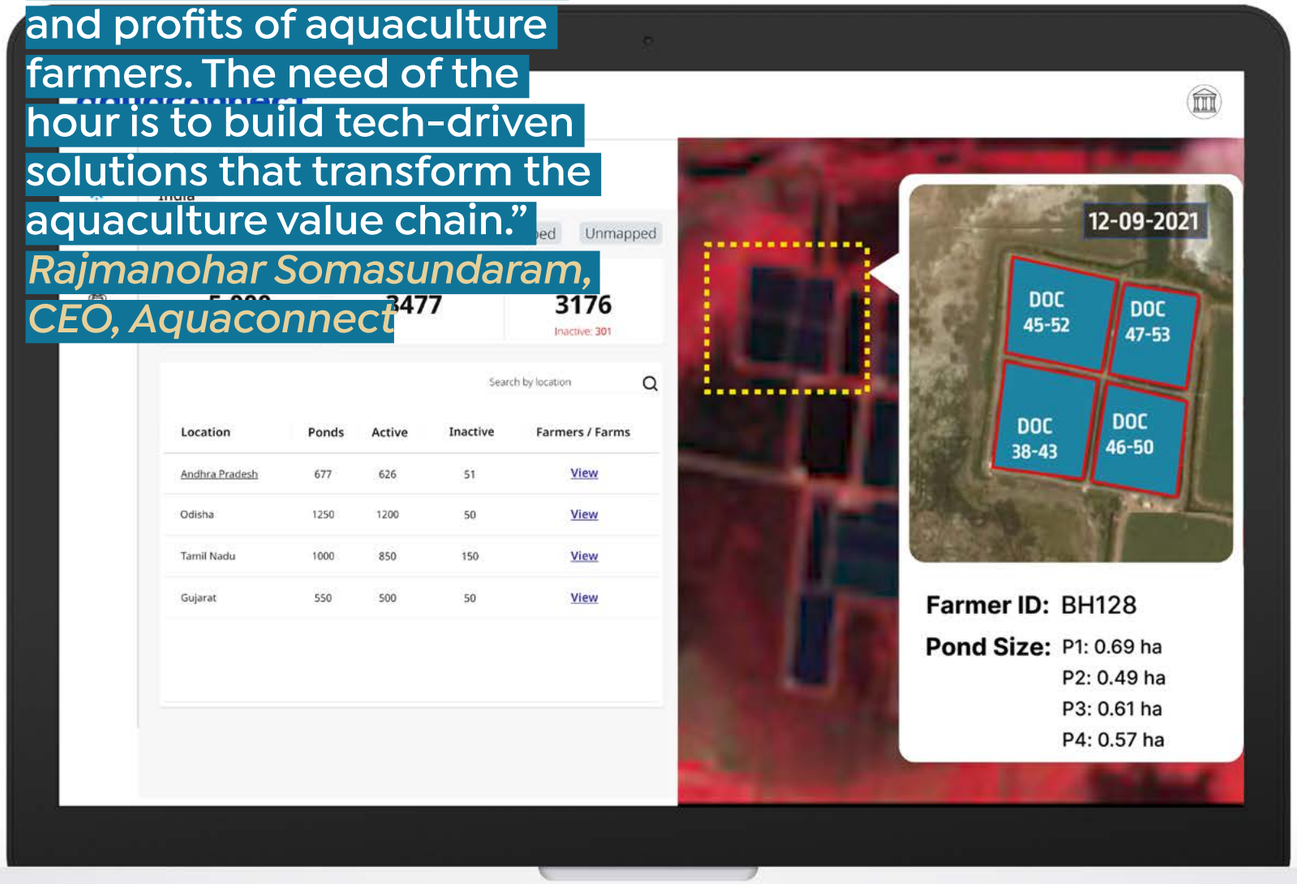
This is where platforms are coming into their own—many have set up marketplaces where farmers can sell their harvested products to approved buyers. Data is the enabling factor in all of this: it allows platforms to predict and assure the quality, sizes, and volumes of a harvest. And, depending on the platform, the company takes more or less ownership of and responsibility for a transaction: sometimes, they buy the product and become its owner; sometimes, they offer a trusted environment where safe transactions are facilitated for both parties. Platforms are also starting to play a role in increasing transparency and traceability in seafood trading.

De-Risking Financing and Insurance

Expensive, informal loans and credit and a lack of insurance are often mentioned by farmers as some of their biggest challenges. Most financial institutions and insurance companies consider small-scale farmers to be too risky to engage with. But platforms are changing this and some have started to support financial institutions and insurance companies in a bid to de-risk doing business with these small-scale farmers. Platforms are doing this by evaluating the performance of individual farmers (using the data they capture through farm management software) and assigning them credit scores. With this credit score, farmers are given an "upper limit" for the amount of inputs they can procure on credit. The credit they receive can only be used to purchase inputs through the platform.

When a farmer harvests their crop and decides to sell it through the platform—because the platform offers the most favorable prices and payment terms—the platform can ensure that the farmer's outstanding loans are deducted before the balance is paid to them. Providing this "full suite" of services is a big win for farmers as they can access affordable inputs and buy them on credit, insure their crops, and sell their harvests at better prices with decent payment terms.

“India’s aquaculture market is traditionally driven by un-scientific farming practices and poor inclusion of tech-nology. Lack of access to formal credit and insurance undermines the ambitions and profits of aquaculture farmers. The need of the hour is to build tech-driven solutions that transform the aquaculture value chain.”
Rajmanohar Somasundaram, CEO, Aquaconnect



If Platforms Reach Scale, the Sky’s the Limit

If you think about the total value of fish and shrimp produced by small-scale farmers around the world, you can imagine that servicing these farmers with inputs, finance, and market access has huge potential for everyone involved. If a platform reaches scale, the margins it takes on these services can be much thinner than those of traditional distributors and middlemen while offering more affordable inputs and better prices for farmers’ crops. As such, while creating a huge improvement in terms of profitability for small-scale farmers’ operations, these companies also have huge potential to generate revenues… We wouldn’t be surprised to see some companies currently expanding their networks of farmers become the next unicorns in the digital aquatech arena.

Market Overview

At the moment, Aquaconnect, eFishery, and XpertSea are the main players that have developed into small-scale, farmer-centric platforms. But more startups are developing into similar directions. Examples include Indonesian startups Delos Aqua and Jala Tech, Indian startup Aqua Exchange and German-Thai startup HydroNeo. All of these companies have raised significant amounts of capital recently, proving investor appetite.

aquaconnect

Founded	2017
HQ	India
Capital raised	– Accelerator (2018): Hatch - Seed (2019): Omnivore (lead) and Hatch – Pre-Series A (2021): Rebright Partners (lead), Flourish Ventures, Omnivore, Hatch, AgFunder, and 6G Capital - Venture round (2022): Trifecta Capital

Aquaconnect has become the leading farmer-centric platform in India’s aquaculture industry. It offers a data-driven, context-specific, unbiased farm advisory service to increase farm productivity, and an omnichannel marketplace providing the doorstep delivery of inputs. Aquaconnect uses farmers’ data to provide them with access to finance and insurance. It also recently launched a B2B marketplace to improve farmers’ linkages to domestic and international buyers. Aquaconnect provides on-the-ground assistance to 5,700 farmers and remote advisory services to 60,000 farmers. Having raised $8M venture debt in March 2022, the company has raised $13M in total.

eFishery

Founded	2013
HQ	Indonesia
Capital raised	- Seed (2014): Aqua-Spark (lead) and Ideosource VC - Series A (2018): 500 Startups, Aqua-Spark, Maloekoe Ventures, Social Capital, Triputra Group, Unreasonable Capital, and Wave-maker Partners - Venture round (2019): InnoVen Capital - Series B (2020): Go-Ventures (lead), Northstar Group (lead), Aqua-Spark, and Wavemaker Partners - Series C (2022): Temasek (lead), Softbank (lead), Sequoia Capital India (lead), Northstar Group, Go-Ventures, Aqua-Spark, and Wavemaker Partners

eFishery is the largest platform for aquaculture producers in Indonesia and has raised the most investment of all digital aquatech startups. The basis of its services is its automated feeding system. This generates a continuous data stream that eFishery uses for its feed distribution service (eFisheryFeed), financing services (eFisheryFund), and B2B marketplace (eFisheryFresh). The company works with around 30,000 farmers across Indonesia, has so far provided loans worth over $30m to 7,000 farms, and has sold more than 38,000 MT of fish through eFisheryFresh. The company raised a $90m Series C in early 2022, which brought its total funding raised to around $115m. Read more about eFishery in an interview with its CEO on p. 23.

xpertSea

Founded	2011
HQ	Canada
Capital raised	– Accelerator (2015): FounderFuel – Seed (2015): FounderFuel, Real Ventures and YUL Ventures – Series A (2018): Aqua-Spark (lead), Obvious Ventures (lead), Bradley Horowitz, and Real Ventures – Series B (2021): Atlantico Partners (lead), QED investors (lead), Aqua-Spark, edō Capital, Future Shape, Investissement Quebec, Obvious Ventures, and Real Ventures

XpertSea started its business with a machine vision-enabled product focusing on the hatchery segment of the shrimp sector. Today, the company has pivoted into a machine vision-enabled farm management solution, and is a financing and market access provider. With its B2B marketplace, which uses data streams generated by its farm management software, the company works with around 300 shrimp farmers in Ecuador and finances transactions worth $30m. XpertSea is planning to introduce these services to several Asian markets soon. The company has raised $30m in capital since 2011. Read more about XpertSea in an interview with its CEO on p. 81.

DMITRY KOZACHENOK, *CEO*

Interviewed by: Flavio Corsin, Director of Partnerships at Aqua-Spark

Founded	2013
HQ	Atlanta, the US
Capital raised	Corporate Venture round: $5.5m (2017)
	Series A: $7.2m (2021)
Aqua-Spark invested in	2017
Products on the market	Aquaculture Operation Optimization Software
	Aquaculture Operation Planning Software

How did you get to invest so much of your time, effort, and energy into aquaculture?

When I was a graduate at Harvard Business School, I came across a project that was working on technology to raise fish on Mars. Believe it or not, it immediately resonated with me because of the intersection of technology and sustainability.

It was one of those sort of crazy projects that can only be contemplated at the Massachusetts Institute of Technology (MIT). But the theory was that if we're ever going to raise animals in space, it's probably going to be fish. Because, firstly, on Mars there's presumably access to water and, secondly, fish have the most efficient feed conversion ratio (FCR) compared to other animals. We know that small differences in FCR make a huge difference on earth, so imagine the difference it would make to farming fish on Mars. It's a crazy idea, but I wouldn't be surprised if it materializes in 100 years.

When I started looking into the aquaculture industry further, I became fascinated by it: I discovered that it's the fastest-growing animal protein sector in the world that's not only sustainable but also helps alleviate some of the pressures we're putting on the ocean. So it made a lot of sense to dedicate myself to it.

You started your company with a different technology than the one you're focusing on today. What made you take the company in a different direction?

We started in 2013 as a deep technology project in the Harvard Innovation Labs, and we spent a couple of years focusing on a technology related to using low temperatures to preserve salmon eggs. Fast-forward to 2018, we were handling nearly 10% of all Atlantic salmon eggs produced globally. We were helping breeding companies buy time to characterize the parents that they were using, and make better mating decisions. Today, we still provide this service; it allows us to see what the farmers' daily issues are.

What changed our business is that our customers started to ask for evidence showing that the fish we provide wouldn't be floating upside down in the cage within 2 years. This is challenging because the fish are moved several times between—and within—different farming sites. Each move is accompanied by unique risks, and a progressive loss of traceability about what happened at previous sites. For us to prove that what we did right at the beginning of the process to the eggs hadn't resulted in anything going wrong further down the line, we needed to trace the performance of our eggs from the moment they were created all the way to the time of harvest.

With so many factors affecting the outcome, our challenge was to validate that our product was having a positive impact, or at least not a negative one. There are just so many other things that could influence the production performance. For example, the raw materials in each feed batch are different. As a result, you have a different ratio of lipids and proteins in the feed, but who has that data? Only the feed company. Another example is the feeding equipment that's used as each system can have different results in terms of FCR. Then you have the labs that have tested the animals at different points in time, and have maybe also tested water conditions. They share this data with the grower, but it's not being used in a comprehensive way to gain real insights into the impact of decisions.

The challenge for us was to figure out what's going wrong and at which stage. For example, how can we explain a decline in fillet quality at the processing plant? Is it the genetics, the grow-out, the feed additives, or something else entirely? Our customers saw these kinds of questions as an unsolvable puzzle. But we realized that if we could structure all the data collected along the lifecycle of the fish—data that was already out there—we could create great insights. So we transformed into a data analytics powerhouse with the starting point that our grip on company and industry data would allow us to predict how to optimize farming operations.

Can you explain what Ecto's platform offers today?

With our farm optimization platform we identify opportunities to make aquaculture operations more efficient and profitable. Over the past few years, we've been developing infrastructure and algorithms to break down the data silos that we just spoke about. By using machine learning to analyze all this data, we're discovering patterns that were previously invisible. Our digital infrastructure supports deep integrations with over 100 different sources of data throughout the value chain. We use these data streams to generate significantly more accurate forecasts than were previously possible. These forecasts relate to general planning of harvest and growth, but also to very specific production risks.

We use existing data sets of previous crops related to production risks to train our models to detect patterns associated with those risks. For example, we've taught the model to predict dangerous algae blooms that regularly threaten salmon welfare. Last summer, the model successfully provided early alerts for such algae blooms. In another example, we discovered that a concentration of ash in feed is strongly correlated with higher mortality rates, but only at a specific growth stage of the fish. We didn't know anything about this relationship beforehand, but we discovered it in the data. This proved to us that the predictions work.

Do you think there's also a role for verification, certification, and transparency of production practices?

Absolutely. Our goal is for producers to be able to easily provide others with data on how they produce their fish. They can then share this with auditors, regulators, consumers, or any other relevant stakeholders. Some of the certification bodies are already suggesting producers share some of the important data on a continuous basis, so that there's not just a once-a-year verification that their production meets the standard requirements. With our systems this is possible. We might even want to take it a step further and remind producers of the things they need to do to stay—or to become—certified according to a certain standard, so that you're automating the compliance process.

Salmon feed producer goes digital with Ecto by capturing ~4,000 manual data points daily, previously recorded on paper spreadsheets.

In your latest investment round you've brought Rabo Ventures on board. How did conversations with investors change over time and how does this impact the way you operate the company?

When we started Ecto, when you said you were doing something in aquaculture, you were left with maybe a handful of potential investors to work with. In the early stages, we were primarily financed by family offices who are passionate about using technology to increase sustainability. These are very smart people who realize that they have the power to change the world, and they use this power intelligently. We were very lucky to partner with some of them. Vodia Ventures is the very first family office-based fund that wrote us a check, and it's been absolutely great.

Over the last 5 years, the scene has changed dramatically. More investors are stepping in. As we're now engaging with more venture-backed and institutional funds, it changes the game in a variety of ways. We have to be more disciplined about reporting requirements, audits, and things like that. But we're also focusing more on building a sustainable business that can be defensible and generate growth over a period of time, and thinking about what product lines and market segments we should be pursuing to achieve that.

Having Rabobank with us definitely has its benefits. It has such a deep understanding of the animal space. It works with and understands the agenda of many leading aquaculture companies, and brings that perspective into our boardroom.

Let's think about the future—perhaps not about 100 years from now or Mars... But if you think about 2030, how do you think Big Data will have changed aquaculture and what is your ambition for Ecto?

Over the last 15 years or so, the industry has seen a lot of innovation. And that innovation has come in the form of hardware, sensors, vaccines, genetics, and feed formulations, but there hasn't been as much innovation related to software and data. In fact, the majority of the industry data is still logged in spreadsheets and on paper, or software systems that don't communicate with each other. We believe that the future of aquaculture is one in which data and analytics will help humans to make better decisions and reduce preventable losses. Our goal is to build this analytical, connective tissue between all parts of the value chain, and use it to drive insights that are evidence-based and improve animal welfare, but also which reduce economic losses for producers, thereby advancing the sustainability profile of the whole industry.

AgFUNDER

One of the world's most active FoodTech and AgTech VCs.

HQ	San Francisco, the US
Geographical scope	Global
Sectoral focus	FoodTech and AgTech
Investor type	Seed and early-stage venture capital
# of companies in portfolio	53
# of companies in aquaculture	2
Companies in digital aquatech	Wittaya Aqua, since 2020, and Aquaconnect, since 2021

Michael Dean, *Managing Partner*

"The aquaculture market is enormous but fragmented, and although the vast majority of aquaculture farmers can afford at least some level of digitalization, it needs to be easy and intuitive to adopt solutions that are immediately materially and demonstrably beneficial.

As a venture investor, we're looking for outsized returns. There are definitely structural challenges for tech startups in aquaculture and there aren't many VCs investing in the space yet, so downstream financing risk is real. But there are so many problems to fix across the entire food system and aquaculture is no exception, so as more capital comes into the industry, I've no doubt we'll see entrepreneurs emerging with ingenious solutions in the same way they have in other sectors.

I like technologies that pull together multiple stakeholders and materially improve systems across multiple channels. Good examples of these are supply-chain technologies with platform potential and marketplaces that can create communities through sharing information. This way, they create the network effects that can really drive customer adoption."

omnivore

A VC firm that funds entrepreneurs building the future of agriculture and food systems in India. Omnivore pioneered AgTech investing in India, having backed over 30 startups since 2011.

HQ	Mumbai, India
Geographical scope	India
Sectoral focus	AgTech
Investor type	Seed and early-stage venture capital
# of companies in portfolio	30
# of companies in aquaculture	2
Companies in digital aquatech	Eruvaka Technologies, since 2013, and Aquaconnect, since 2019

Mark Kahn, *Co-Founder and Managing Partner*

"Prior to launching Omnivore, I worked for India's largest feed manufacturer, Godrej Agrovet, which was my first exposure to the aquaculture industry. Even a decade ago, the potential for digital transformation in Indian aquaculture was clear. So in 2013, we invested in Eruvaka, which was developing smart feeding and IoT solutions for shrimp farming. Now we also have Aquaconnect in our portfolio, and will announce more aquatech investments soon. Omnivore is excited to back more aquatech startups over the next few years!"

From Farm Diaries to Big Data Analytics

Smart Farm Management and Optimization Software Revolution

While farm management software might sound a bit dull, it isn't anymore. Today, it's integrated with IoT solutions, full service platforms, and big data sources. The new generation of farm management software is "smart." Making use of AI based on real-time analytics, these solutions provide actionable insights and facilitate the transition of aquaculture operations from art to science. They drive efficiency, profitability, and sustainability.

photo Wittaya Aqua

Digitalizing Farm Diaries and Record-Keeping

Traditionally, if farmers do any type of bookkeeping at all, they would use paper, whiteboards or Excel spreadsheets where they would record information about stocking, feeding, and growth. Where professionally trained farm managers are responsible for a farm's performance, some degree of bookkeeping is likely to happen. However, in parts of the industry where families run their own farms as a livelihood, bookkeeping is still a rare feat.

While farm managers often already made the first step of digitalization, small-scale family-run farms, especially in tropical fish and shrimp farming, haven't gone digital yet. For both, the range of farm management software available is rapidly expanding. Although such basic software solutions may be a good way for farmers to get a better grip on their farm's performance, they're not really revolutionary.

Smart Farm Advisory Services and Integration into Data-Driven Platforms

The real potential appears when farm management software becomes "smart" and starts using algorithms to analyze data to provide actionable insights about how a farm's performance can be improved.


photo Solidaridad Bangladesh

Small-scale family-run farms traditionally depend on feed or other input suppliers (or public extension workers) for farm advisory services. While visiting the farms, the sales and technical support teams would promote their products along the way. Even though farmers often have a healthy distrust of these company representatives, until recently they didn't have much choice. With a range of farm management software and digital farm advisory services now available to them it might be a no-brainer for these farmers to adopt one of these systems. However, in reality many small-scale farmers still tend to not be ready to implement such systems. Farmers are not yet convinced of their benefits or are simply not used to using digital solutions at all.

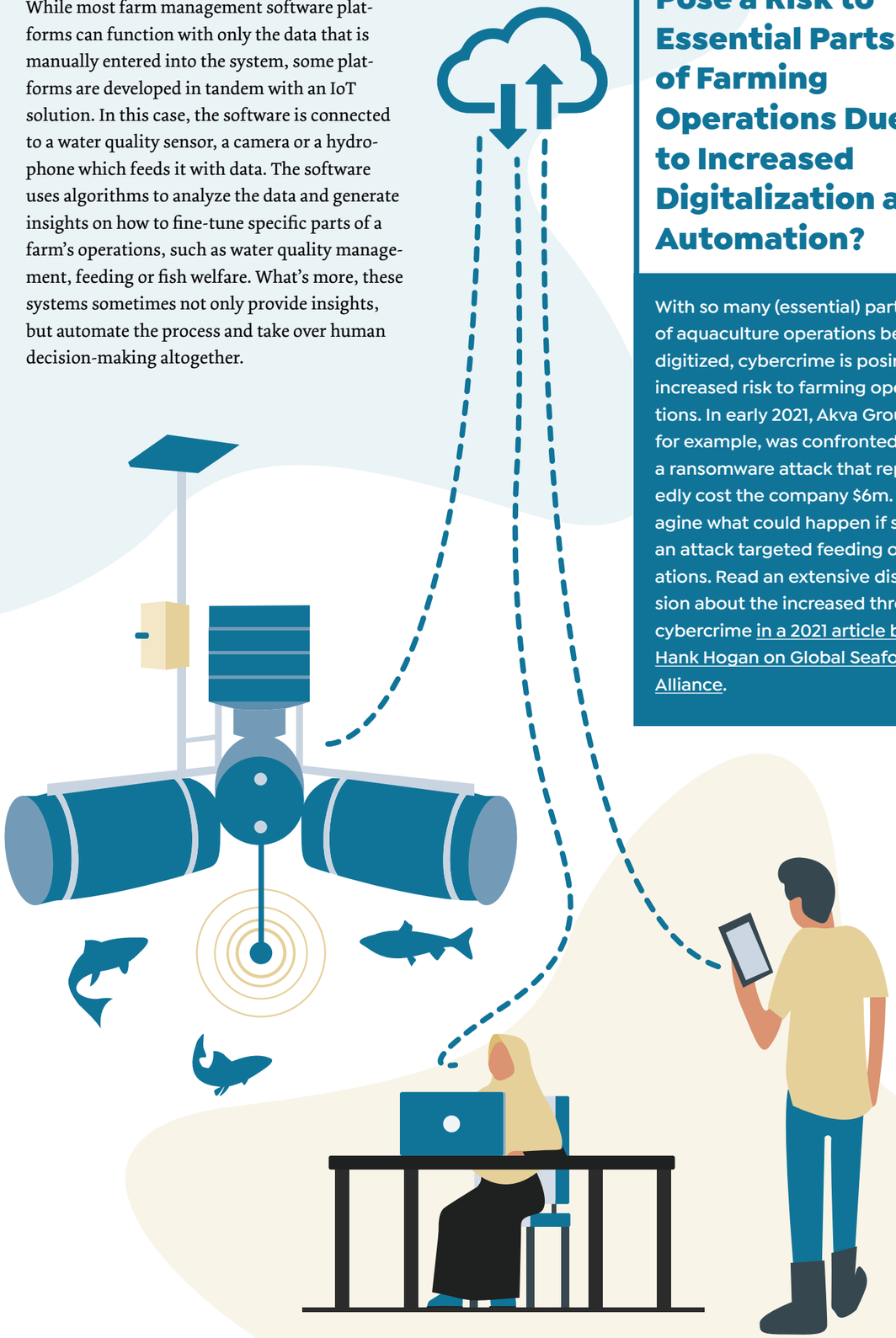
Many of the companies that develop smart farm advisory services for small-scale farms eventually launch farmer-centric, data-driven platforms (see p. 26), where the software generates a stream of data based on which a variety of services can be developed, such as the sales of inputs, access to finance and insurance, and access to markets. For such access, farmers need to use the farm management software. While doing so, they will recognize its benefits and no longer want to do without.

Fueling a Race to the Top: Benchmarking Farm Performance

Once a farm management software company increases its adoption rate among farmers, the opportunity to benchmark farmers' performance arises. The company can analyze what makes successful farms stand out from less successful farms and can provide actionable insights. This adds a lot of value for those farmers as they can optimize their production accordingly. Once sufficient farmers use the same platform, benchmarking can fuel a race to the top in terms of productivity, profitability, and sustainability.

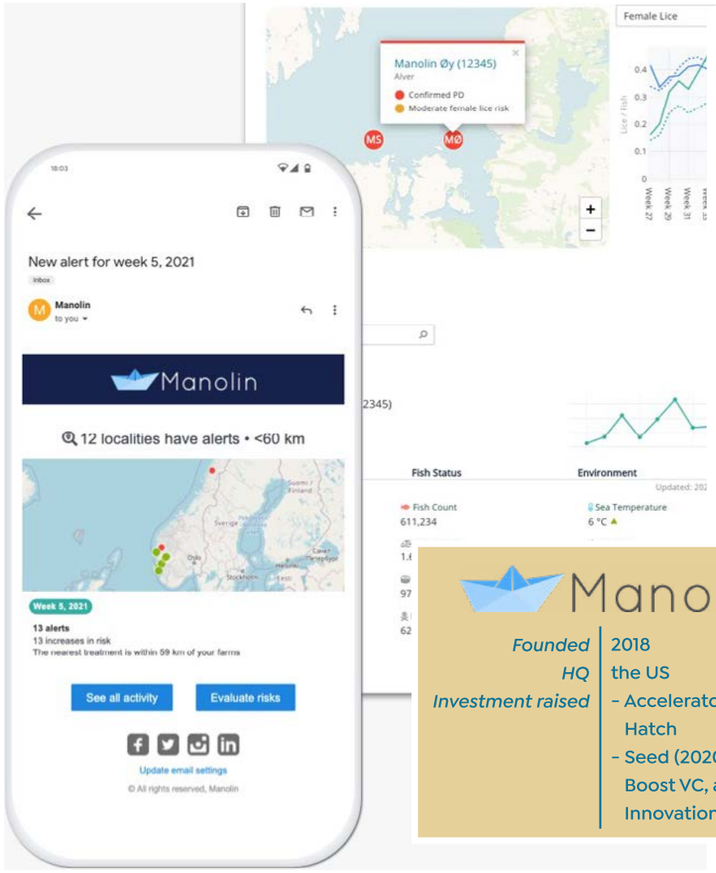
Integrating Data-Capturing Devices and IoT Solutions

While most farm management software platforms can function with only the data that is manually entered into the system, some platforms are developed in tandem with an IoT solution. In this case, the software is connected to a water quality sensor, a camera or a hydrophone which feeds it with data. The software uses algorithms to analyze the data and generate insights on how to fine-tune specific parts of a farm's operations, such as water quality management, feeding or fish welfare. What's more, these systems sometimes not only provide insights, but automate the process and take over human decision-making altogether.



Does Cybercrime Pose a Risk to Essential Parts of Farming Operations Due to Increased Digitalization and Automation?

With so many (essential) parts of aquaculture operations being digitized, cybercrime is posing an increased risk to farming operations. In early 2021, Akva Group, for example, was confronted with a ransomware attack that reportedly cost the company $6m. Imagine what could happen if such an attack targeted feeding operations. Read an extensive discussion about the increased threat of cybercrime in a 2021 article by Hank Hogan on Global Seafood Alliance.



Big Data Analytics: Aggregating All Data from the Fish's Life Cycle, from Smolt to Fillet

If the farm management software companies aggregate all the data generated on each farming site and also source external data on for example feed formulation, oceanographic conditions, weather forecasts, satellite images, and public animal welfare, the possibilities of smart farm advisory services increase significantly.

The large data sets that are created can be analyzed real-time. Advanced algorithms can discover patterns and opportunities to increase productivity, profitability, and sustainability of farming operations. For example, this type of farm management software could identify a correlation between a certain fingerling size stocked in a cage and later disease outbreaks, or a link between the use of a certain kind of feed ingredient and faster growth. These types of insights can transform the way in which farmers can boost their operations.

While many of the farm management software companies claim to already work on big data analytics, developing algorithms takes a lot of time, skill, and data (and to obtain that data you first need customers). It's unclear how advanced the different players in the market are compared to each other and how many are already tapping into the big data potential.

Integrating Location-Based Disease Outbreak Alerts into Farm Management Solutions

In Norway, farmers must notify the government about certain diseases. Non-notifiable diseases today account for between 5 and 10% of total mortalities in the Norwegian salmon industry.

Manolin

Founded	2018
HQ	the US
Investment raised	- Accelerator (2018): Hatch - Seed (2020): Hatch, Boost VC, and Innovation Norway

Manolin launched a software platform that provides Norwegian farmers with an automated alert when disease is detected at a nearby farm. It offers a free dashboard where anyone can track recent and historical notifiable disease outbreaks, lice counts, and respective treatments. A new service also alerts farmers to non-notifiable disease outbreaks in their vicinity. Farmers self-report disease outbreaks through a farmer-only application, which is then shared anonymously with nearby farmers. Via an early alert, farmers have more time to respond to non-notifiable disease outbreaks in their vicinity and limit the impact on fish health and mortality.

Manolin's system furthermore gives farmers a central platform from which to automatically pull their production data and combines that with publicly available and anonymized data from other farms. By doing so, Manolin offers farmers a way to monitor their own fish health, benchmark performance against others, and improve their farming.

Market Overview

The level of farm management software adoption differs widely between types of farms and between species. Companies that have integrated farm management software in IoT solutions are covered in the articles on water quality monitoring (see p. 42), machine vision (see p. 60), and "smart" feeding solutions (see p. 52). Those targeting small-scale farmers are covered in the article on small-scale, farmer-centric, data-driven platforms (see p. 26). Here, we profile some of the most active and up-and-coming companies involved in this segment of digital aquatech.

Salmon Farming Operations

The supply of farm management software in the salmon industry is mostly provided by companies that also supply equipment. However, some standalone data-driven startups are gaining market share, which forces the leading equipment suppliers to innovate their systems or acquire some of those startups that have started to compete for their clients.

Other Larger-Scale Farming Operations

The players above are primarily salmon-oriented. The companies on this page target mainly mid- and larger-scale farmers of other species, such as sea bass and bream farms in the Mediterranean and shrimp farms in Asia and South America.

AKVA GROUP

Founded	1974
HQ	Norway
Capital raised	Self-funded

Akva Group is one of two main equipment suppliers to the salmon industry (the other being ScaleAQ). The company offers farm management solutions, including: AkvaConnect (to digitally connect various farming sites to one control room), FishTalk (to provide salmon farmers with an overview of their fish from broodstock to harvest), and Observe Technologies (a smart feeding tech startup that Akva Group partly acquired).

Fiizk

Founded	1867
HQ	Norway
Capital raised	Unknown

Fiizk is another slightly smaller Norwegian supplier of equipment to the salmon industry. Today, it's mainly present in Norway (where it serves almost half of Norway's salmon farms) and Canada, and is expected to expand to other geographies. Its extensive digital product portfolio includes simple farm management software (Horizon) and more advanced farm optimization software (Ctrl).

Optimeering

Founded	2014
HQ	Norway
Capital raised	Seed (2019): bEarly Business Development

Optimeering Aqua is a startup focused on developing advanced farm optimization software for the salmon industry by using existing data streams and applying algorithms. Today, the company primarily has clients in Norway, but it's venturing out into Scotland, Canada, and Chile. In the longer term, Optimeering Aqua plans to expand to species other than salmon. It raised a $1.5m seed round and another $2.5m in grants from Innovation Norway, NTNU Discovery, and The Research Council of Norway.

ScaleAQ

Founded	2019
HQ	Norway
Capital raised	Self-funded

Steinsvik was originally founded in 1966. ScaleAQ was formed in 2019 after a merger between Steinsvik, Aqualine, and Aquaoptima, ScaleAQ is one of the two main salmon industry equipment suppliers (next to Akva Group). Its Mercatus platform integrates overall operation management, fish welfare and growth management, and financial management. ScaleAQ's "Vision" is a smart feeding solution. In 2021, it also acquired Panlogica, owner of farm optimization software "Neptune," widely used in the salmon industry.

ecto

Founded	2013
HQ	the US
Capital raised	- Venture round (2017): Aqua-Spark (lead) and Vodia Ventures - Series A (2021): Aqua-Spark, Rabobank, Seventure Partners, The Yield Lab Asia Pacific, and Vodia Ventures

Ecto supports fish farming operations worldwide by aggregating existing data streams from the fish's entire life cycle and external data streams from, for example, feed manufacturers, and then structuring and integrating that data into its platform. Ecto's platform uses algorithms to analyze that aggregated data and find patterns in it that can help to optimize productivity. Aqua-Spark invested in Ecto in 2017 and the company raised its Series A in 2021. Read more about Ecto in an interview with its CEO on p. 32.

Cargill

Founded	1865
HQ	the US
Capital raised	Self-funded

Cargill's iQuatic offers farmers a platform to digitalize their farming operations, and is interoperable with a variety of IoT solutions. Cargill tends to partner with smart feeding system suppliers like Jetfeeder in Ecuador and NextAqua in India. Offering this service helps Cargill develop closer ties with farmers and get better insights into farmers' performance.

aquaManager

Founded	1997
HQ	Greece
Capital raised	Self-funded

Focused mostly on species other than salmon, aquaManager caters to large cage farming operations in the Mediterranean, sub-Saharan Africa, the Middle East, and Latin America, and to multiple hatcheries around the world (one example being its partnership with a Benchmark Spring Genetics hatchery announced in early 2022). Over the past few years, aquaManager has expanded its portfolio to include IoT and smart equipment to complement its software solutions.

Skretting a Nutreco company

Founded	1899
HQ	Norway
Capital raised	Self-funded

The company's "Skretting 360+" solution aims to provide shrimp farms, especially in Ecuador, with a platform to digitalize their farm management. It can be integrated with Skretting's automated feeding solutions and water quality sensors. The data isn't only visible to the farm but also to Skretting's tech support team who can assist farmers in optimizing their farm management.

Wittaya Aqua

Founded	2017
HQ	Canada
Capital raised	- Accelerator (2018): Hatch - Accelerator (2021): GROW Impact Accelerator (AgFunder)

Wittaya Aqua focuses on medium-sized cage and pond farms. Besides its farm-level software (AquaOp Farm), it's also developed a software platform for the feed industry (AquaOp Feed). This platform includes a feed formulation tool, a tool to map raw material use, and tools to ascertain the value of feed ingredients. The farm management application focuses on digitalizing production records, providing growth and feed requirement forecasts, and real-time insights for improved decision-making, among other things.

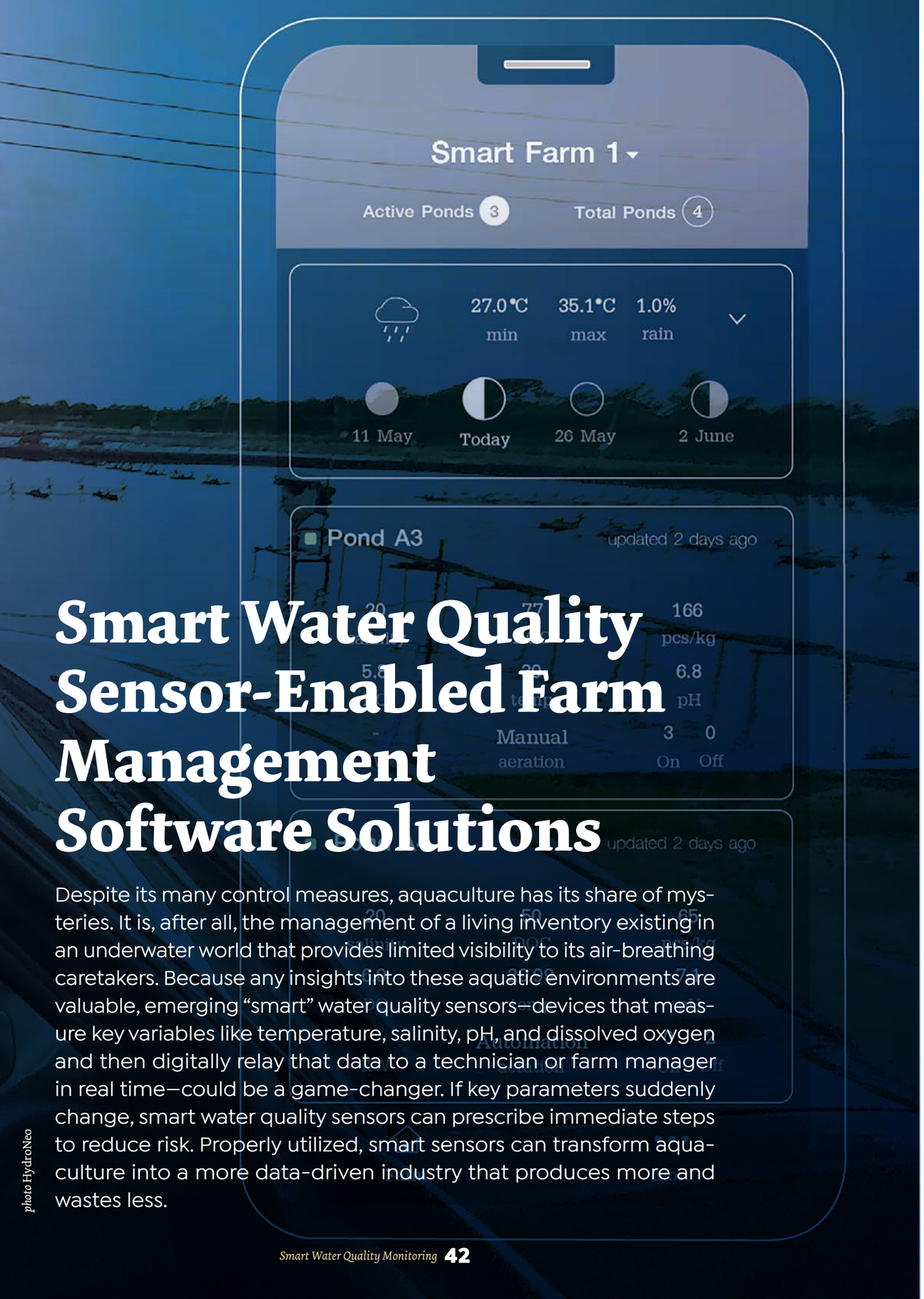


photo HydroNeo

Smart Water Quality Sensor-Enabled Farm Management Software Solutions

Despite its many control measures, aquaculture has its share of mysteries. It is, after all, the management of a living inventory existing in an underwater world that provides limited visibility to its air-breathing caretakers. Because any insights into these aquatic environments are valuable, emerging "smart" water quality sensors—devices that measure key variables like temperature, salinity, pH, and dissolved oxygen and then digitally relay that data to a technician or farm manager in real time—could be a game-changer. If key parameters suddenly change, smart water quality sensors can prescribe immediate steps to reduce risk. Properly utilized, smart sensors can transform aquaculture into a more data-driven industry that produces more and wastes less.

> "It's oxygen that makes aquaculture ponds productive and producers have devised ways to manage it", *Ph.D. Claude E. Boyd*

By: James Wright
James Wright has been covering seafood since 2000. He has been the editor of the Responsible Seafood Advocate, a product of the Global Seafood Alliance, since 2015.

Dissolved Oxygen Is by Far the Most Important Parameter to Measure

Regular review of production data informs producers when to anticipate problems and change procedures, says Prof. D. Allen Davis of Auburn University. But of all the water quality parameters that these products can monitor, dissolved oxygen (DO) is by far the most important, he argues, because farmers can act on it quickly. For the 16 fully automated shrimp ponds near the coast of Alabama that Davis oversees, DO changes are the only notifications he gets: "Alerts are for low and very low," he says.

Claude E. Boyd, Ph.D., one of the world's leading water quality experts, agrees about the importance of oxygen. "It's oxygen that makes aquaculture ponds productive and producers have devised ways to manage it," whereas pH levels—which fluctuate throughout the day normally, he adds—are less important, since little action can be taken. "A monitor could make you worry much more than you need to," he says.

Water quality sensors are more relevant for intensive producers, Boyd believes. To produce intensively, farmers need to use more feed, which cannot be done without mechanical aeration. Any sudden drop in oxygen may cause a crop failure. "To intensify, you have to put oxygen in the water," Boyd says.

Water Quality Measuring Probes Have Been Around for Decades, but Smart Sensors Ride the Wave of IoT Solutions

While water quality measuring probes for aquaculture have been available for decades—and are typically offered to farmers by feed manufacturers—today's smart sensors are riding the wave of IoT technology, offering farmers real-time data collection and analysis and sometimes even remote operability. Whereas the monitoring process has long been manual, analog, and prone to human error, smart water quality sensors can generate large amounts of data to feed algorithms and farm management software that can transform data into actionable insights. While it's exciting to envision how smart water quality sensors can help aquaculture to evolve into a truly modernized industry, real hurdles remain in terms of user aptitude and economics.

photo Jala Tech

Alban Caratis, aquaculture operations manager for consulting firm Fresh Studio based in Ho Chi Minh City, explains that in countries like Vietnam, 90-95% of shrimp farmers are small-scale with little technological know-how. Most of these producers, he adds, lack the money for expensive devices and would therefore be more likely to accept a monthly subscription fee: "The farmer looks at the market price of the shrimp and the potential profit and sees a device sucking up a lot of that. To invest, they need to understand the value," he says. By renting instead of leasing, and realizing the direct benefits of using these devices, farmers could be convinced to continue using the device or eventually procure one.

Tailor-Made Business Models Might Drive Adoption among Different Types of Farmers

Opinion is somewhat split on whether aquaculture ponds need fixed sensors that collect data on a continuous basis. Some shrimp farming experts in Asia argue that handheld devices that collect and upload data and which can be moved from pond to pond are sufficient, while others say such movement is a biosecurity risk for the animals and is simply prone to human error or carelessness. Further, while some view the price of permanently deployed water quality sensors as too high for small-scale producers or only feasible if packaged with another service, like automated feeders, others argue that smart farms' energy savings are significant for farmers of all sizes.

Larger producers could see high-level benefits from the technology if more detailed production data is required for certification programs or traceability initiatives, Caratis adds. "And if these tools can help independent farmers become more productive and use less antibiotics, that's less of a headache" for both larger suppliers and their marketplace partners, he says. If larger corporations provide sensors to smaller farmers in their supply network, it could benefit all parties.

David Kawahigashi, owner and founder of Vannamei 101, a shrimp-farming consulting firm providing technology and training opportunities to producers around the world, agrees that handheld devices may be more efficient than fixed sensors. They also may be best suited for larger operations. "If a farmer has 100 ponds, each pond would need a probe and then you'd have to wire it all up," he says. "And anything you leave in a pond gets covered with algae, which would affect the reading" and require near constant maintenance. "With a handheld device, you stick it in, take it out, go to the next pond. Automated equipment stays in the water all the time. And it's sending tons of data to your phone you may or may not be using."

Francois Vervial, COO at AquaEasy, an IoT solution for water quality management from tech company Bosch, seconds this notion. His company relies on trained personnel to carry out measurements with a handheld device ideally two or three times a day.

photo: HydroNeo

According to Vervial, most water quality parameters don't require real-time data. "It doesn't make sense. The physics of the pond don't move so fast," he says.

Fabian Reusch, founder and market development lead for HydroNeo, a smart aquaculture firm based in Thailand, disagrees and adds that energy savings for a fully automated farm cannot be disregarded: "Without fixed sensors, automation of the very energy-consuming aerators cannot be done. With our 24/7 system, we can save between 15-50% of energy. In changing weather conditions or towards the end of the production cycle when maximum carrying capacity of the pond is reached, monitoring two times per day might not be enough."

Liris Maduningtyas, CEO of Jala Tech in Indonesia, explains that her company offers a free farm management service for small farmers but admits that its Baruno smart water quality meter represents an investment: 28.4m Indonesian rupiah (roughly $2,000). This may be a steep price for many farmers, but she argues they need to realize that the benefits of a fully connected IoT-enabled farm go beyond better yields and profits. "For example, the collected data can be used as credit scoring to help the farmer financially or even precisely predict harvest volume. Some farmers secure deals from investors after showing their farms are online through our apps," she says. Obstacles of technology literacy, infrastructure, internet accessibility and overall trust can be overcome, she adds, "if [technology] makes their lives easier."

Flavio Corsin, director of partnerships at AquaSpark, takes it a step further and says that IoT-enabled technology can not only optimize farms, but it can also play a big role in preventing infectious diseases, which have cost the industry dearly over the past few decades. He emphasizes that the benefits of water quality sensors being a part of a farm management platform depend on what can be done with the data. "There is so much that we don't know about the causes of diseases and getting a better grip on the association between water quality and diseases or productivity would really help," he says.

The Benefits of a Fully Integrated IoT-Enabled Farm Go beyond Yields and Profits

While the appetite for a modern, digital solution like this may be out of reach for what AquaEasy's Vervial describes as the "first generation" of shrimp farmers, future generations, who will be used to doing everything on their smartphones already, may be more receptive. Reusch thinks that smart farm systems can make running the family farm more attractive to younger people, who prefer tech-related jobs. "We have several cases where the parents bought our systems for their children and then also handed over responsibility of the pond to them," he says.

During Corsin's Ph.D. research in epidemiology on shrimp farms in Vietnam in the 1990s, a focus was identifying the factors that caused white spot disease (WSD). His team noticed that drops in water temperature preceded outbreaks, despite temperatures remaining within the suitable range for shrimp. "At that time, we were not sure if temperature was the real cause or if changing the water, which may also reduce water temperature, was the trigger. Several years later, experimental studies in a lab found that lower temperature indeed increases WSD mortality and virus replication," Corsin says. "If we had water quality data loggers at that time, we would have figured this out and saved millions, if not billions, of dollars."

Market Overview

By: Willem van der Pijl

While smart water quality monitoring has become a common component of land-based closed recirculation farms, adoption among pond-based aquaculture operations remains low and there aren't many startups trying to increase adoption. Here we list three startups that have integrated water quality monitoring into their IoT solutions. Two of these startups, HydroNeo and AquaEasy, are connected to large industry players through their incubation programs, while the other, Jala Tech, has recently raised funding from venture capital funds. Interestingly, both HydroNeo and Jala Tech intend to develop into broader data-driven platforms (see p. 26) that offer a range of services aimed at improving farmers' incomes.

AquaEasy

Founded	2021
HQ	Singapore
Capital raised	– Corporate venture round (2021): Bosch and EDB New Ventures – Convertible loan (2021): Qian Hu Corporation

AquaEasy is a smart, IoT-enabled aquaculture solution that aims to provide an end-to-end solution for shrimp farmers. Its proprietary water quality probe sends data to its software platform. Farmers can upload additional data to an app, for example on feed use. The software analyzes real-time data to help farmers make better decisions, reduce operating costs, and increase yields. In 2021, the team obtained funding to establish the company.

HydroNeo Smart Aquaculture

Founded	2018
HQ	Germany
Capital raised	– Private fundraising (2019 and 2020): Unknown – Incubator (2019): SPACE-F (Co-owned by Thai Union) – Corporate venture round (2020): Thai Union

First launched in Thailand, HydroNeo's Smart Farm Management Solution constantly monitors the water quality of individual shrimp ponds and enables the smart control of motors, aerators, and pumps. The system allows farmers to reduce energy use by up to 50%, increase productivity, and better manage risks. HydroNeo plans to develop other data-driven services for farmers that use its Smart Farm Management Solution and is currently raising a $2m seed round to finance its next growth phase. Plans include an input marketplace, a trade platform where farmers can sell their harvest, and access to finance and insurance.

JALA

Founded	2018
HQ	Indonesia
Capital raised	– Accelerator (2018): Hatch – Seed (2019): 500 Startups (lead), Conservation International, and Hatch – Series A (2021): Mirova (Althelia Sustainable Ocean Fund) (lead), The Meloy Fund, and Real Tech Japan

Jala Tech started its business focusing on a smart water quality probe called "Baruno" and a connected farm management platform. Today, the company's focus has shifted to its platform. Jala Tech works with around 11,000 shrimp farmers in Indonesia, provides them with insights into their crop cycle through its farm management software, helps them improve their practices, provides market intelligence, and uses the data of farmers' crops to facilitate better market access to buyers. In 2021, the company raised $4m to finance its growth. Jala Tech is developing from merely an IoT solution into a fully-fledged data-driven platform.

wavemaker -PARTNERS-

A VC focused on B2B deep tech and sustainability solutions in Southeast Asia.

HQ	The US and Singapore
Geographical scope	Southeast Asia
Sectoral focus	Tech
Investor type	Seed and early-stage venture capital
# of companies in portfolio	140
# of companies in aquaculture	1
Companies in digital aquatech	eFishery, since 2018

Gavin Lee, *Partner*

"The aquaculture industry in Asia suffers from inefficiencies. For instance, we learned that feed accounts for up to 80% of the production cost and is still being distributed manually, resulting in wastage and water pollution. Despite the pain points, practical solutions are hard to come by in this industry.

Considering our investment in eFishery, the founders of the company were the best team we could identify to solve a sustainability problem we care about. With eFishery, we have the right combination of people, market conditions, software, and hardware to make a difference. eFishery has changed the lives of more than 30,000 aquaculture farmers by improving their operations, and it's exciting that we now have the opportunity to make an even greater impact.

The aquaculture sector is growing by double digits annually and the rapid adoption of eFishery's technology is testament to the market being ready to embrace such solutions. We're always on the lookout for scalable and sustainable businesses that solve meaningful problems, ideally ten times better than existing solutions!"

mirova

The Sustainable Ocean Fund is a US$132m close-ended impact fund focused on sustainable fisheries and aquaculture, marine conservation, and circular economy in emerging countries. It's part of Mirova's natural capital strategy. Mirova is a mission-based company, labeled B Corp, and an affiliate of Natixis Investment Managers.

HQ	France and the UK
Geographical scope	Emerging countries
Sectoral focus	Sustainability
Investor type	Early- and growth stage
# of companies in portfolio	12
# of companies in aquaculture	3
Companies in digital aquatech	Jala Tech, since 2021

Lisa Hubert, *Investment Director*

"Sustainable aquaculture is part of our strategy due to the important role it plays in meeting demand for healthy and protein-rich fish and seafood. The sector faces a range of serious challenges, and we view digital aquatech as a means—and not an end—to solving some of these. We think digital aquatech solutions can contribute to more efficient, fair, traceable, and sustainable aquaculture, especially in countries with fragmented value chains, weak legal frameworks, historical environmental challenges, and a multitude of players.

This brought us to investing in Jala Tech. Its ability to work with the entire ecosystem while on-boarding farmers with solutions that have a direct and tangible impact convinced us that companies like Jala Tech could be part of the answer. Of course, consumers, governments, and market players also have their role to play, but we definitely think that digital aquatech can be a very powerful tool when carefully designed and led by the right teams. We'll thus definitely consider other investment opportunities in the sector!"

BLUEGROVE

BENDIK S. SØVEGJARTO, *CEO*

Interviewed by: Flavio Corsin, Director of Partnerships at Aqua-Spark

Founded	2013
HQ	Oslo, Norway
Capital raised	Through funding and grants by Bluegrove and its subsidiaries: €30m to date
Aqua-Spark invested in	2018
Products on the market	Feeding Assistant (data-driven decision support for feeding) Echofeeding (autonomous feeding solution) Fish Farming Equipment, such as feed spreaders and underwater aeration systems Cleaner Fish Equipment, such as kelp systems and cleaner fish feeders

Tell me a bit about how your journey into aquaculture and your company started. And how are you improving salmon farming, a sector many think is already technologically advanced?

That's an interesting question. In 2007, at the age of 16, almost half a lifetime ago, I was doing an internship at the University of Oslo where I coincidentally got to know about an echo sounder-enabled smart feeding solution that resulted from a research project started in the late 80s, before I was even born! I immediately became fascinated by this technology, but I thought I was too young to be involved. In 2013, the company that later would turn into CageEye and then into Bluegrove was founded. Coincidentally, Joakim Myrland, who was the company's CEO at the time, headhunted me to work on the very project I'd seen in 2007, right when I started my master's thesis. I was quite surprised that, to get a sense of what was happening in salmon cages, an entire wall full of screens showing footage from underwater cameras had to be watched. Seeing the potential of technological improvement was really motivational. Joakim encouraged me to get involved more deeply and hired me in 2014 as CTO. I decided to pause working on my master's thesis to develop the third and fourth generations of our acoustic hardware platform while at the same time finishing my master's thesis by building an autonomous survey vessel to automate field work, such as the ecological monitoring of lakes.

It sounds like it took a long time between developing the first generations of the system and its commercial launch and adoption in the industry. When did you launch commercially?

When I started as CTO in 2014, we still didn't have any farmers as customers, only research institutes. Upon launching our system at Aqua Nor Trade Show in 2015 there was quite a bit of interest in it. However, we didn't dare to follow up on any of these leads at the time because we didn't feel ready. So, we worked on our system for 2 more years and relaunched in 2017, when I also became CEO and signed our first three commercial agreements. Today, our feeding system is used in Chile and Norway by some of the largest salmon farmers in the world. We also acquired two other companies: NorseAqua in 2019 (supplying fish farming and cleaner fish solutions to the salmon industry) and SEALAB in 2020, which develops underwater cameras.

We're not aggressively pushing our technology further onto the market at this stage. We prefer to show results, even though it can sometimes take a while as salmon farming cycles are long. But once farmers see what our solutions can do, our technology sells itself.

So far, you've focused mainly on salmon. Keeping in mind the level of maturity of the salmon industry, how difficult was it to get farmers to understand and adopt your technology?

Honestly speaking, although some people think salmon farming is close to perfect and optimally configured, when I started in the salmon industry I was amazed by how low-tech parts of the farming process still were, feeding for example. That being said, when I started looking around I felt really welcomed by the industry and found that most salmon farmers were interested in new technologies.

Still, there are many differences between and within companies. Sparking initial interest is often easy, but getting our system deployed and used properly is a lot harder. For many farmers, feeding is a sort of religion—and it's not always that simple to ask someone to change the way they're performing a core task, especially when they've been doing it that way for decades.

So we also often assist a company's staff to change the way they handle their operations. We really try to emphasize that we're bringing a new tool that can give them additional insights. But we do need to be tactful, because this also implies that the way they've worked for a long time might not have been ideal. Luckily, we have a research background and bring data. And data doesn't lie.

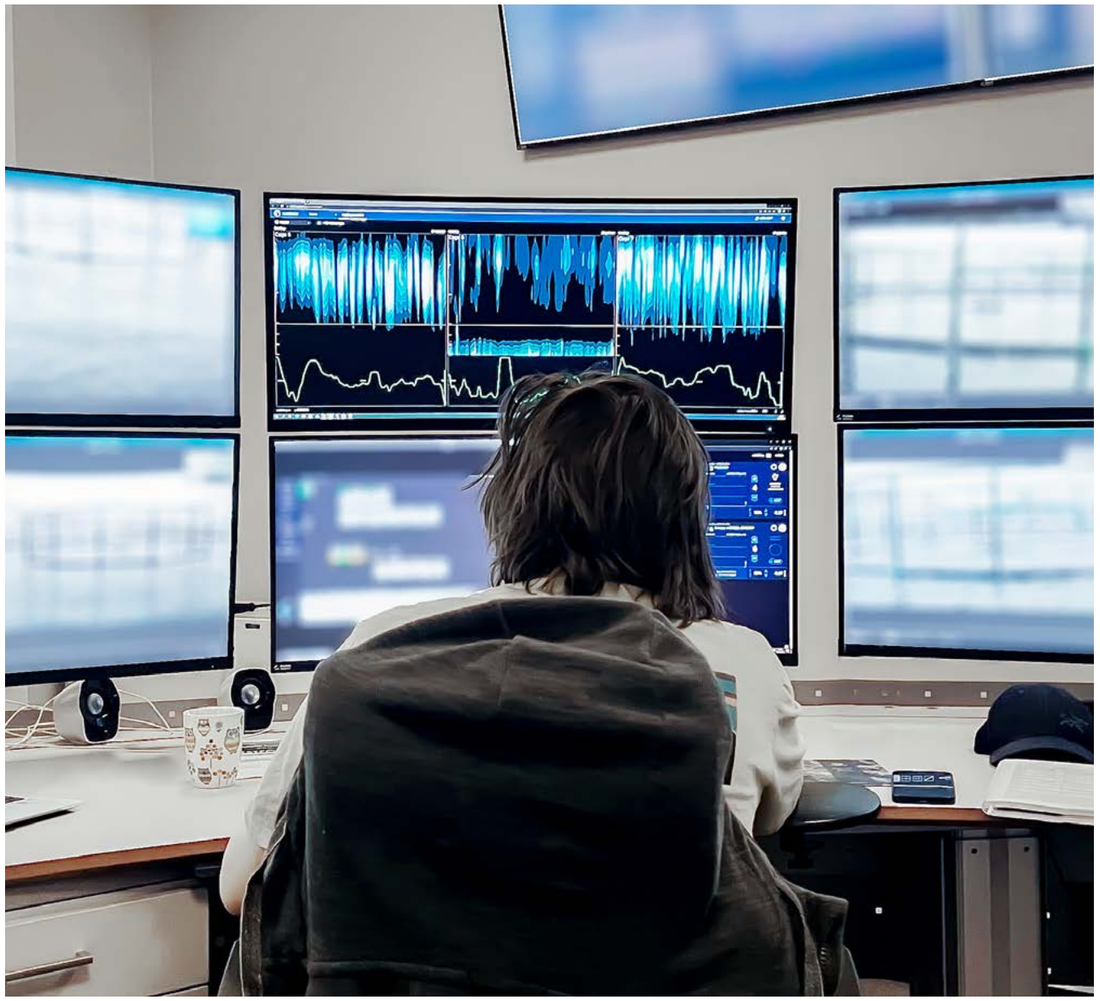
I think of Bluegrove as a fish-centric company: better feeding, welfare, and environments for fish, with concrete advantages for farmers. Is this how you see your company as well?

Yes, you're spot on. We're optimizing feeding practices first and foremost to benefit fish and nature. By doing so, we create value for the farmer as well. The first thing we do is observe. Then we analyze the datasets and gather insights that farmers can act upon. By doing that, we improve the whole ecosystem. We always work on long-term optimization, so instead of optimizing the next yield or next harvest, we're optimizing for what's sustainable over the next 100-150 cycles. This starts with understanding both nature and fish, whether for the feeding or welfare solutions we're developing. That's the key. And that's why we've focused heavily on acquiring world-class talent

and have staff with PhDs, including in salmon behavior, machine learning, and acoustics. It all starts with understanding.

You started in the salmon industry and have the ambition to move onto other species. Can you tell us more about that?

Considering the maturity of the salmon industry, it's a very good place to introduce new technologies. Once the fundamentals are in place, you can take all the knowledge acquired from the salmon industry and apply it to other segments of the aquaculture industry. One of our main goals is to take the tech we've developed within the salmon industry and apply it to other species. Of course, we need to make some adjustments, but much of the basics are the same. The aquaculture industry is so much larger than the salmon sector on its own, and it's astonishing to see that in most parts of the industry the technological level is far below that of salmon. Looking at the level of industrialization and the challenges other species are facing, our technology has huge potential.



Salmon is a high-value species and farmers might be able to afford your technology, but this might not be the case for small farmers of other species. How do you see the trajectory cost wise?

The beauty is that we're leasing out our systems, which gives farmers a return on investment from day one without having to actually invest anything upfront. Once they start using the system, farmers enjoy its benefits. As long as we can make our sensors and hardware cheap enough and can fund the required R&D, adoption by smaller farmers of other species should also be possible. Remember, the core of what we're doing is analysis—well, data science, i.e. building models based on the reality around us. The data models are highly adaptable and cost very little to replicate. We're currently transitioning from machine learning to deep learning, and are seeing patterns we didn't know existed. Other species can build on these models, extended with specific data related to the "new" species.

I was thinking of you sitting there with Joakim, doing your master's. If you had a piece of advice for that young Bendik, what would you tell him?

In hindsight, it's very easy to see the things you shouldn't have done. I would've given him a long list of dead ends that we shouldn't explore: you can go straight to the goal once you know where it is. But it's very hard to give that advice without knowing how things will unfold. In some areas, I'd give the general advice of being more aware and less naïve, understanding some of the market forces out there. Maybe we've lost years by being too nice and too naïve in those areas. I think if we'd started working and pushing in some areas sooner, it would've sped up our progress. Be present and more aware of what's happening right now. That's probably the best advice I could have given.

PATENTING TO PLAY AN INCREASINGLY IMPORTANT ROLE FOR PROTECTING INTELLECTUAL PROPERTY IN DIGITAL AQUATECH

By: Claude Kaplan

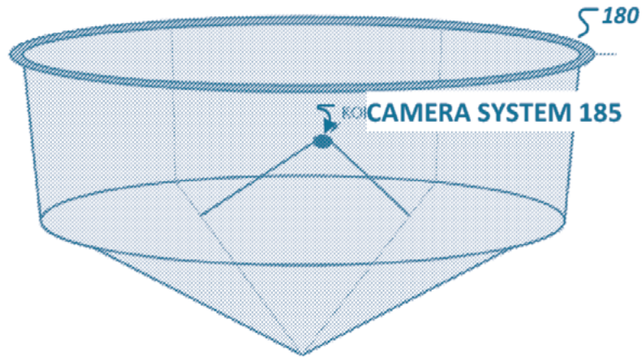
For the majority of businesses, their competitive advantage is underpinned by their intellectual property (IP). IP is the proprietary knowledge and expertise that allows a company to offer products or services that are cheaper, better, and quicker than those of its competitors. Unfortunately, IP has a major "flaw"—although it can take enormous amounts of resources to create IP, once created it is relatively easy to copy and share. Think of this in another way: if all your company's confidential knowledge was published on a website and freely accessible to your competitors, what would that do to your company's competitive position?

Patenting is the most common way to secure your IP. However, traditionally, aquaculture has had a low intensity of patenting compared to the tech industry. While the number of new patents registered for aquaculture grew from around 1,000 in 2011 to around 5,500 in 2020, it's still pretty low compared to other areas of technology where we routinely see over a million patents published annually. This is likely a result of different factors, such as the relatively low ROI for aquaculture inventions, the tendency of aquaculture companies to keep the secret sauce of their products confidential, and the difficulty of enforcing patent rights in China, Chile, and Central American countries.

While the aquaculture industry is not that used to patenting, the tech industry is. Now that tech is penetrating deeper into the aquaculture industry, we expect that the number of patent applications for aquaculture will continue to rise. Curious about the role of patenting in aquaculture? Read the Aqua Insights guest blog by Dr. Claude Kaplan, CEO of the microalgae development company Kuehnle AgroSystems, and Non-Executive Director of Hatch Innovation Services, who has been helping organizations evaluate, source, manage, and exploit aquaculture IP for over 20 years.

AquaInsights Blog

ALPHABET (GOOGLE'S PARENT COMPANY)'S X DEVELOPMENT'S IP PATENT WO2019/147346A1 FOR ITS FISH BIOMASS, SHAPE, AND SIZE DETERMINATION TECHNOLOGY



Bluegrove's dashboard with feeding recommendations for a salmon farmer.

Smart Feeding

Cameras, Hydroacoustics, and AI Change the Way in Which Farmers Feed Their Fish

Whether in cages or ponds, farmers have traditionally distributed feed manually. But nowadays, farmers are increasingly using machines to feed their fish or shrimp. Most of these feeding machines still use standardized timer-based schemes—this doesn't make them "smart," although they are autonomous. But the latest generation of feeding systems uses AI and algorithms to interpret inputs from cameras and hydroacoustics, as well as movement sensors to determine if the fish or shrimp are hungry. While there are different shades to what can be termed "smart feeding" that fall somewhere between traditional feeding and AI-enabled feeding, this latest generation of feeding machines is the only setup that can truly be termed "smart." When a smart system determines that the fish or shrimp are hungry, it tells the farmer to start and stop feeding, or even starts and stops feeding automatically. Smart feeding means the amount of feed needed to produce the same amount of fish reduces. In turn, this makes aquaculture operations more profitable and sustainable—it's what the future looks like for many of the world's aquaculture operations.

photo Bluegrove

Drive for Efficiency Led to Early Adoption of Feeding Systems in Salmon

Salmon farming is one of the world's most advanced aquaculture practices where efficiency and production economics have continuously been optimized to ensure margins. As a result, innovations to optimize feed management have been made along the way. Practical matters related to the harsh conditions at sea, the increasing number of cages per site, and ever larger cages have forced farmers to look for feeding systems that can manage such conditions and scale. The basic systems applied today involve considerable investments consisting of feed barges and control rooms, and a network of machines, pipes, and dispersers to transport the feed from the barge to the cages.

Adoption of Feeding Machines in Exotic Shrimp and Fish Ponds Spreads

In exotic shrimp and fish ponds, feeding machines have started to be adopted as well, but market penetration is happening at a much slower rate than in salmon farming. With feeding operations for ponds being logistically less challenging to manage than in the salmon industry, there has been less urgency for farmers to adopt feeding machines. However, with shrimp and fish prices increasingly under pressure and stiffer competition among producers, feeding machines are increasingly being seen as a way to improve the efficiency of pond farming operations as well. One such example can be found in Ecuador, where farmers recently started to double their productivity: feeding machines—in addition to higher stocking densities, aeration and improved water exchange—are regarded as a necessary part of intensified shrimp ponds.

Feeding machines for ponds mostly consist of a simple static plastic tank that holds the feed and a dispenser that distributes it into the pond. The feeding machine can be installed above or at the side of the pond, or it can float on the pond. Depending on the specifics of the pond and the type of feeding system, more than one feeding machine may be required. The earliest and simplest feeding machines are individually and manually programmed. But the latest generations have become "smart."

Underwater Cameras Playing an Important Role in Making Salmon Feeding More Efficient

Most salmon farmers started using underwater cameras years ago. Someone sitting in the farm's control room monitors fish behavior through a video control system to determine when the fish are hungry. While using underwater cameras is a big step compared to "blind" automated feeding based on fixed schedules as happened in the past, cameras still have their limitations. One of the main ones is that the feeding manager has to interpret what they see and then act on it. The capacity to monitor a larger number of cages simultaneously is therefore problematic. Using underwater cameras is an example of "smarter" feeding: if the system itself isn't "smart," human limitations remain at play.

Hardware as a Service

An increasing number of smart feeding and other IoT service providers supply their technology as a service. Selling hardware as a service makes it easier to penetrate the market when farmers aren't yet convinced of the benefits, or when they don't have the capital to make an upfront investment. Supplying technology as a service involves farmers paying a monthly fee, which covers the installation of the technology and its continued maintenance. The service provider works closely with the farmer to ensure that the technology delivers on its promise. At the same time, this close relationship also benefits the provider—it allows them to identify farmers' needs and offer other services that can help to improve their incomes.

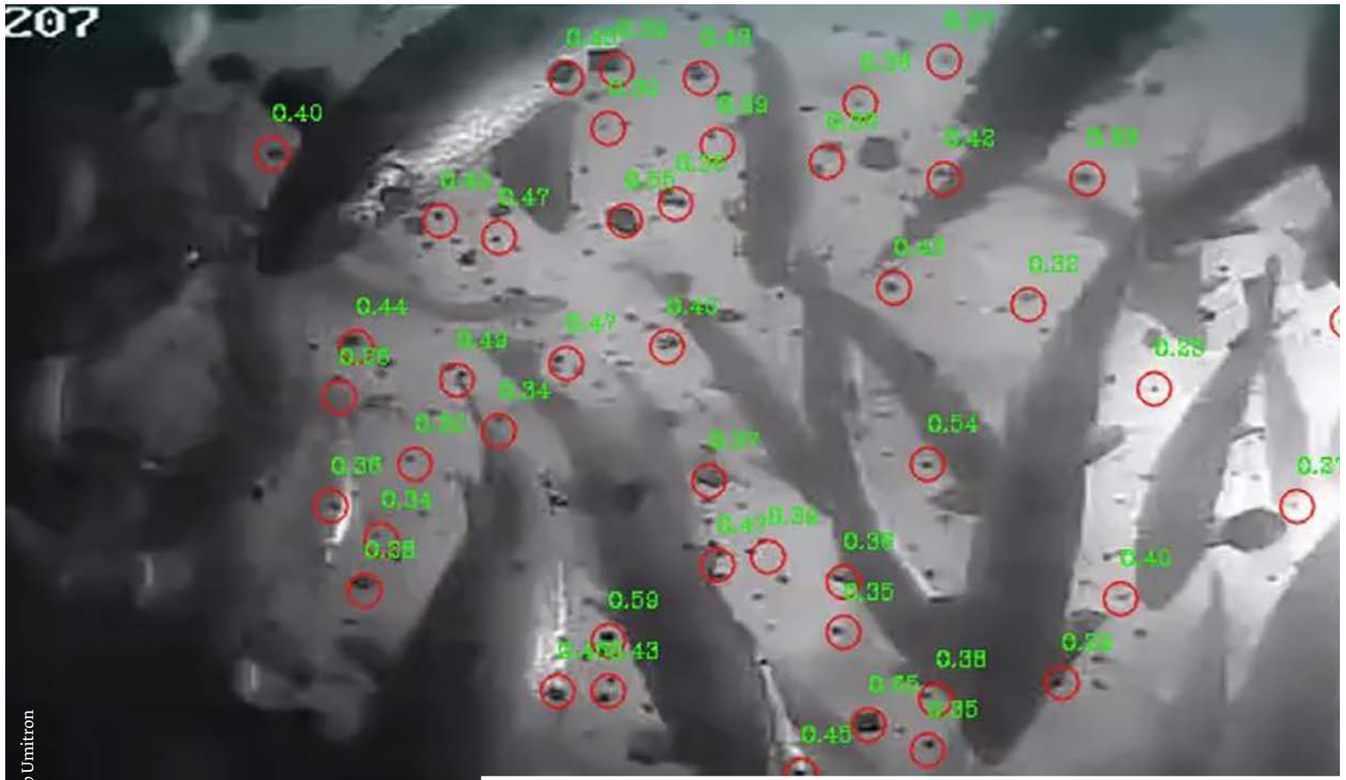


photo Umitron

Pellet detection software at work in a salmon cage.

AI is changing this. Technology providers have started to use camera footage and algorithms to recognize appetite by analyzing fish behavior to detect the moment at which pellets are no longer being eaten but start to fall through. This can be done across multiple cages at the same time. The software connected to the cameras and algorithms alerts the feeding manager when to start or stop feeding, or—if fully autonomous—starts and stops feeding automatically. While fully smart and autonomous systems are—in theory—possible, in the case of salmon farming it may take time for farmers to sufficiently trust computers and leave the entire process of feeding in the hands of AI. What is clear, however, is that AI-enabled feeding systems have the potential to contribute to more efficient feed management and to increase profitability while reducing the environmental footprint in the salmon industry.

photo Bluegrove

> "Farmers that use our acoustic feeding solution feel more confident to reduce or push feed at times when they would have been too afraid to do so before. As such, we prevent under- and overfeeding, and enable farmers to reduce feed waste, increase fish growth, and improve FCRs."
> *Bendik S. Søvegjarto, CEO, Bluegrove*

Acoustics Further Enable the Development of Smart Feeding Solutions

Using cameras in environments where the water is murky has its limitations. In cages, cameras play an important role, but vision is often poor in ponds. Instead of—but also in addition to—cameras and vision, hydrophones and sound have started to play a crucial role in developing AI-enabled smart feeding systems.

There are two different types of hydrophones: active and passive. Passive hydrophones are mainly used in shrimp and fish ponds. These sensors capture the sounds of the shrimp and fish, and send this information through the cloud to a computer that analyzes it to determine appetite. When appetite is high, the computer sends a signal to the feeding machines and feeding begins. Systems that use this approach are also referred to as "hydroacoustic feeding systems."

R3-IoT

Founded	2018
HQ	Scotland
Investment raised	Seed (2021): Scottish Enterprise, Scottish National Investment Bank, Space Capital, and University of Strathclyde

Overcoming the Challenge of Cellular Connectivity and the Need for Advanced IT Infrastructure

For smart feeding systems and other digital solutions to function, advanced IT infrastructure and cellular connectivity are required: sensors and cameras deployed in a cage gather large amounts of data that are sent to an edge or cloud to be processed and analyzed—data is compressed to stay within bandwidth limits. Farmers need continuous, live, and real-time insights without any interruptions. But imagine this scenario for a distant cage site in rural Norway or Chile where there's limited power or internet connectivity...

Satellites can play a major role in improving the cellular connectivity of remote farming locations. R3 IoT from Scotland is a good example of a company aiming to solve this issue. It offers remote farms the possibility to install transmitters that connect these sites to the edge or cloud by using satellite connectivity. Its platform enables the farms to digitalize their operations and manage farming operations remotely. In July 2021, R3 IoT raised $4.3m to further develop its services.

Active hydrophones use sonar. Sonar beams sent through a cage allow computers to map the movement of fish. Based on this information, a computer analyzes the appetite of the animals. Active hydrophones can collect much more information than passive hydrophones, including biomass estimations (see p. 60). But active hydrophones are significantly more expensive, and they're mostly used for large salmon cages that hold large amounts of fish and for which the cost of these active hydrophones is therefore relatively low. In these cages, together with cameras, they provide detailed data-driven insights. Should costs come down, they could also be used for the same purpose in ponds and cages that hold smaller amounts of fish.

Market Overview

Salmon and Other Cage Farming Sectors

A couple of large, well-known companies like Akva Group, ScaleAQ, Fluctus, and Innovasea, dominate the market for conventional feeding systems for the salmon industry. Other companies, such as Cadoma and Fisher Piscicultura in Brazil, have developed specific feeding machines for tilapia cage farms, and Umitron focuses on machines for Asian cage farming operations. In terms of smart feeding systems, the market is still much less developed, but a couple of startups—Observe, Bluegrove and Umitron—are leading the way. We expect some of the companies that are currently focused on biomass estimation solutions (such as Aquabyte) to enter this area as well, and vice versa.

Observe technologies

Founded	2016
HQ	the UK
Capital raised	– Seed (2017): AI Seed, Entrepreneur First, Sistema Venture Capital, and Tiny VC – Corporate Round (2021): Akva Group

Observe Technologies sells software that optimizes and automates feed management in real time. It unites and analyzes multiple data streams from cameras to sensors and extracts various features, including fish behavior and feed loss. Akva Group became a sales distribution partner in 2018 and, in early 2021, acquired a 33.7% share for an undisclosed amount, but Observe Technologies remains a standalone company.

UMITRON

Founded	2016
HQ	Japan and Singapore
Capital raised	Seed (2018): Mirai Creation Fund (lead), D4V (Design for Ventures), and The Innovation Network Corporation of Japan (INCJ)

Umitron has developed two products related to smart and autonomous feeding. The first one is Umitron Cell, a feeding machine suitable for individual cages and connected to farmers through an app. Its second product, Umitron FAI, makes feeding "smart." This software uses camera footage to detect fish appetite and tells farmers when to start and stop feeding. FAI is sold as a standalone software product.

BLUEGROVE

Founded	2013
HQ	Norway
Capital raised	Corporate venture round (2018): Aqua-Spark and Breed Reply

Bluegrove uses active acoustics to monitor fish behavior and detect fish appetite. While it's focused on the salmon industry so far, Bluegrove aims to apply its technology to other species as well. In 2018, together with Breed Reply (an Italy-based investor focused on IoT solutions), Aqua-Spark invested in Bluegrove and since then has made several follow-on, undisclosed investments. Read more about Bluegrove in an interview with its CEO on p. 48.

photo eFishery

Fish and Shrimp Pond Farming Sectors

The market for pond-based feeding machines is much more fragmented. Adoption is not that widespread and varies from country to country. While there are some larger players that are active globally, most suppliers operate in just one country—or a few countries. When looking at smart, autonomous feeding machines, a few companies are leading the way.

AQ1 SYSTEMS

Founded	1978
HQ	Israel
Capital raised	Unknown

AQ1 was an early mover in terms of the development and deployment of smart feeding systems. It has developed systems for both cages and ponds, and is primarily active in the shrimp industry. Depending on the system, AQ1 uses infrared cameras and acoustics to identify appetite and improve feeding efficiency. In terms of pricing, at least in the shrimp industry, AQ1 is often positioned as a premium product.

marine instruments

Founded	Unknown
HQ	Spain
Capital raised	Unknown

Marine Instruments supplies acoustic sensors to, among others, Jetfeeder, a company that produces automated feeding machines in Ecuador. Marine Instruments also has its own system and a complementary software service.

eFishery

Founded	2013
HQ	Indonesia
Capital raised	See p. 31.

eFishery sells both conventional and smart automated feeding solutions, and gives farmers the option to lease machines instead of buying them. Its smart feeding solutions use hydroacoustics and movement sensors. eFishery is active in Indonesia and is expected to expand to other countries soon. Read more about eFishery in an interview with its CEO on p. 23. See also a more extensive company profile for eFishery on p. 31.

Eruvaka

Founded	2012
HQ	India
Capital raised	- Series A (2013): Omnivore - Series B (2018): Omnivore and Nutreco

Eruvaka has been selling automated feeding machines since 2012. It also offers a smart, passive, acoustics-enabled system named ShrimpTalk. India-based investment fund Omnivore got on board in 2013 and in 2018 Nutreco, the parent of aqua feed producer Skretting, acquired a major share in the company. Eruvaka sells its feeding machines to Skretting customers and independent farmers.

bioFeeder

Founded	2016
HQ	Ecuador
Capital raised	- Series A (2018): Undisclosed - Series A (2020): Undisclosed

Biofeeder sells both conventional and smart feeding systems. In Ecuador, it has partnered with Claro—a major telecommunications company—to enable farmers to adopt its technology as a service without requiring an upfront investment. Farmers subscribe to Claro and are serviced by the team of Biofeeder. This partnership has given Biofeeder a significant market share among Ecuador's shrimp farmers.

OBVIOUS VENTURES

Andrew Beebe, *Managing Director*

Founded by, among others, Ev Williams—Co-Founder of Twitter and Medium—Obvious Ventures is a certified B Corp that invests in startups reimagining trillion-dollar industries through a world-positive lens.

HQ	Silicon Valley, the US
Geographical scope	Global
Sectoral focus	Sustainable systems, healthy living, and people power
Investor type	Early- and growth-stage venture capital
# of companies in portfolio	72
# of companies in aquaculture	1
Companies in digital aquatech	XpertSea, since 2018

"At Obvious, we're always looking around the corner for solutions to our world's biggest challenges. Food and low-cost yet sustainable protein supplies specifically are at the top of the list. Aquaculture looks like a great solution, but without thoughtful, sustainable approaches, we stand to shoot ourselves in the foot. That's what attracted us to the world of aquaculture broadly, and digital aquatech more specifically. But it was finding a great founder in Valerie Robitaille, Co-Founder and CEO at XpertSea, that really got us hooked. We're now putting more lines in the water to find our next digital aquatech deal—there's a lot more work to be done."

nutreco

Joost Matthijssen, *Director of Venturing and Business Development*

One of the world's leading animal feed producers and, through its subsidiary Skretting, an important global producer of aquafeed. Its CVC arm NuFrontiers is an active developer of tomorrow's new feed and food businesses, supporting them with industry-leading expertise and resources.

HQ	Amersfoort, the Netherlands
Geographical scope	Global
Sectoral focus	Animal nutrition and health, digitalization, aquaculture farming systems, and alternative proteins
Investor type	Corporate venture capital
# of companies in portfolio	10
# of companies in aquaculture	8
Companies in digital aquatech	Eruvaka Technologies, since 2018

"Based on the potential we saw to significantly improve the standard of shrimp farming feeding and operations, Nutreco invested in Eruvaka, an Indian tech company that offers smart shrimp feeding solutions, in 2018. Our experience in partnering with Eruvaka since then has fully underscored our digital aquaculture thesis. Generating and analyzing previously unavailable data on activity and appetite enables more precise shrimp feeding, and increased performance and farm profitability, as well as improved sustainability. This experience is also indicative of the potential for partnership in this space, as integrating Eruvaka's solutions with Skretting's feed expertise and farm access generates substantial value for farmers.

At Nutreco, we're optimistic about the potential of digital technology to make a significant and positive impact on aquaculture across various species and farming systems. We're actively exploring further digital aquaculture technology investments, at both farm and supply-chain level."

Tidal's underwater cameras and machine perception tools monitoring a salmon farm.

Machine Vision
Our Eyes Underwater

Machine vision has become a crucial part of automation in a variety of industries over the past 10 to 15 years. Cameras and optical sensors send images to a computer where algorithms analyze the data to produce actionable insights and automate parts of the production process. The application of machine vision in aquaculture is challenging because aquatic animals live underwater in places where light and visibility are often suboptimal. Besides, cameras must be able to withstand harsh underwater conditions. Despite these challenges, machine vision is increasingly being adopted by fish and shrimp farmers as part of smart feeding systems (see p. 52) for biomass estimation and for animal welfare monitoring, but also as a way to foster trust and fairer prices within the marketplace.

photo X, the Moonshot Factory

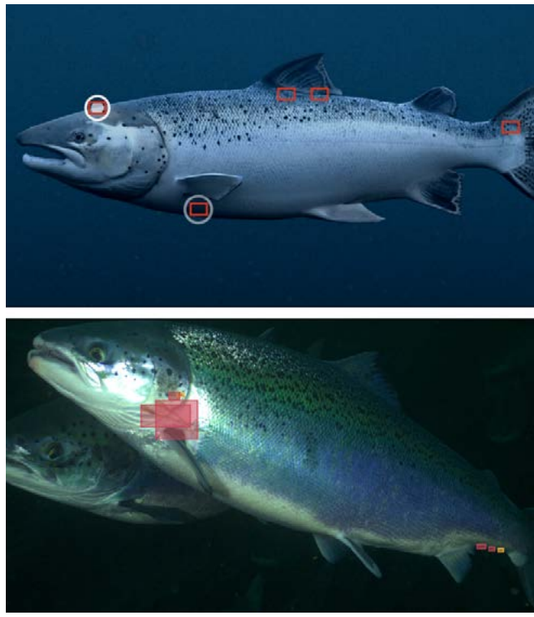
Monitoring Biomass and Animal Welfare in Cage Farming Operations

Accurate Biomass Estimations

Fish biomass estimation is one of the most common and important practices in aquaculture. It helps to optimize feeding, control stocking densities, and predict optimal harvesting times. Traditionally, during the life cycle of fish, farmers would periodically estimate biomass by taking samples of fish (accounting for mortalities) and multiply initial stocking densities with the average weight of the fish in the sample. The range of inaccuracy of manual biomass estimations is likely to be anywhere between 15-25%, and this undoubtedly leads to over- or underfeeding, which effects the efficiency, profitability, and sustainability of aquaculture farming operations.

> "In the early days, we'd need thousands of images to train the system; today, we just need around 100-200 images … then the system will take over. So it's really come on leaps and bounds in terms of the speed at which you can accomplish things."
> *Nathan Pyne-Carter, CEO of Ace Aquatec*

The newest generation of biomass estimation systems uses a range of (primarily) 3D camera technologies (especially applying stereo vision and time-of-flight) and algorithms that allow for extremely accurate biomass estimations. These technologies use facial recognition and draw 3D images. Once the fish are identified and their volume is known, and when we know the density of that volume, the computer can calculate the total biomass in the production unit. Most new solutions provide real-time biomass estimations, they detect when growth rates drop below what's expected, and they predict when fish will reach harvest size. But most importantly, they help farmers optimize their feeding schemes and improve feed efficiency.



Source AQUABYTE

Early Disease Detection and Continuous Sea Lice Monitoring Solutions

One of the most promising areas of application for machine vision—besides smart feeding and biomass estimation—is monitoring animal welfare. Most diseases that keep fish farmers awake at night have clear visual appearances. If an algorithm can be trained to detect visual disease symptoms early, this allows a fish farmer to mitigate the risks of a large-scale disease outbreak. The farmer can choose to treat the fish curatively and continue to grow the fish or, if the farmer knows the fish can't be treated, they can harvest the fish before it's too late.

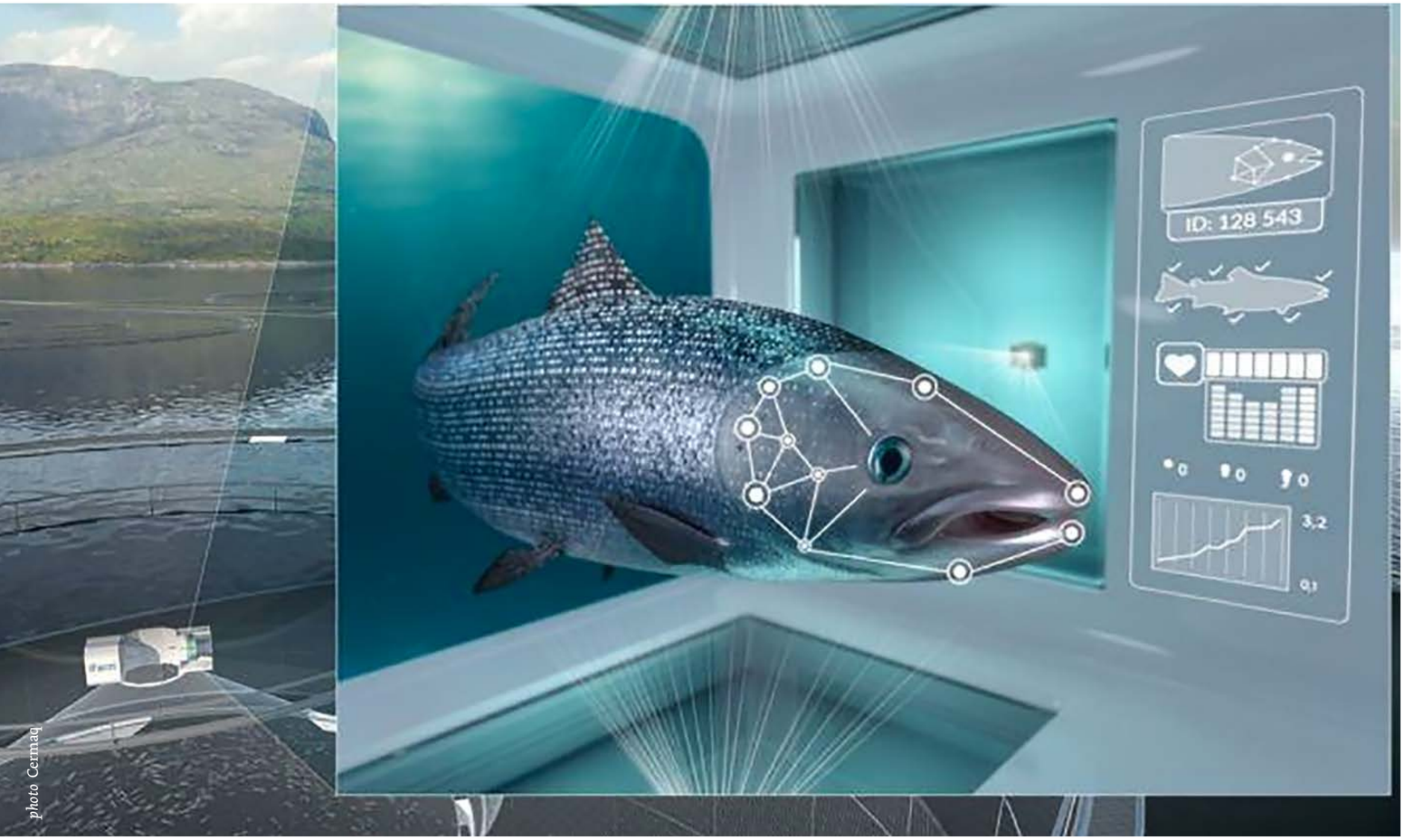


photo Cermaq

Some companies are using machine vision to provide specific solutions for fish welfare issues, one of which being sea lice. Companies operating in this area are developing sea lice-counting solutions to continuously monitor lice occurrence. In Norway, it's a legal requirement to count sea lice manually and report counts to local authorities on a weekly basis. But as more farmers have started to use machine vision technology, in 2020 the Norwegian authorities exempted salmon farms that equipped their cages with Aquabyte's machine vision-enabled automatic lice-counting technology from these obligations.

Challenges Ahead

Although combining the various solutions (automated feeding, biomass estimation, welfare monitoring) into one single solution sounds logical, each uses different camera technologies (or even a combination of cameras and hydrophones). A product that merges these requirements into one package, effectively addressing all areas in one go, would likely be expensive. Besides cost, there are other challenges associated with using machine vision underwater that limit wide-scale adoption. Importantly, most 3D camera technologies used in these specific solutions need light and clarity to work, and they would also have to withstand harsh underwater conditions.

Machine vision will likely play a bigger role in cages than in ponds: they're already available for cage farming environments, but the murky water of ponds makes using them in these environments more challenging, and therefore less likely. That said, there are still some possibilities to use machine vision in ponds...

Counting and Monitoring Shrimp at All Stages of Their Lifecycle

Despite the lack of light and clarity in ponds, machine vision is still playing an increasingly important role. It's already being used to count shrimp post-larvae (PL) and fish fingerlings when being sold from a hatchery to a farm—they used to be counted manually, often based only on sample. This inevitably led to high degrees of inaccuracy, and hatcheries tended to compensate by supplying an extra 10-20% on top of the count to the farm.

But new machine vision-enabled technologies are making it easier to accurately count PL in just a few seconds. All you need is an imaging device and a sample. This technology is leading to better practices when trading PL and fingerlings, and to more accurate stocking when PL is transitioned from a hatchery to a growout farm.

The companies involved are now broadening their scope and have started to apply machine vision technology to areas other than PL counting, too. For example, it's now also being used to obtain data about shrimp size and biomass at the growout farm. This is done by taking photos of samples that have been taken from a pond, and applying machine vision algorithms to estimate size and total biomass, and to monitor growth. These insights are then used to improve feeding practices. Just like in cage farming, other opportunities for using this technology—welfare monitoring, for example—are likely to emerge.

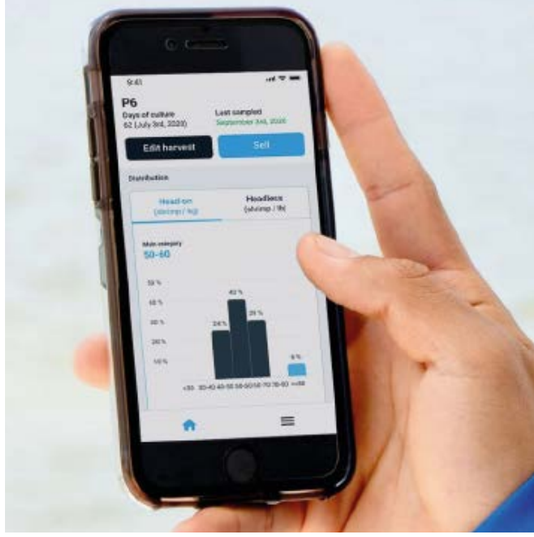
Fostering Trust and Fairer Prices in the Marketplace

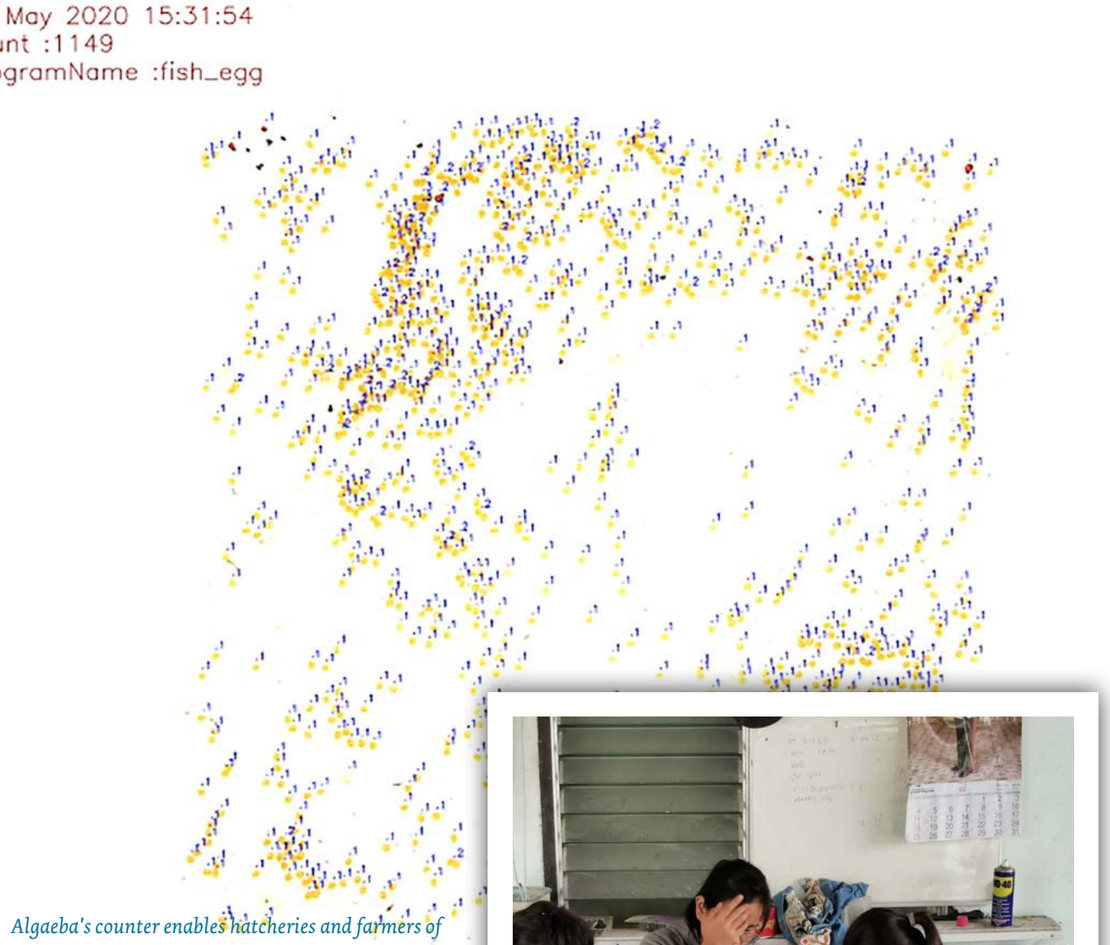
Often, especially in fragmented supply chains such as that of shrimp, a buyer will only decide to buy a harvest after visual inspection. At the pond side, the farmer and the buyer determine the price of the shrimp based on a mutually agreed sample method. The whole harvest is then weighed and the farmer gets paid on the spot, or maybe a few days or weeks later.

Processors and exporters often don't do business directly with farmers, among other reasons because they don't have the capacity to visit the thousands of small farms they source from to inspect the ponds. The processor depends on middlemen to aggregate supply. Once the product reaches the factory, the same process of sampling and price setting is repeated. If the requirements of the processor aren't met, they might even reject the product.

Although all parties in this traditional system agree to the price-setting mechanism, there are power disparities between the parties involved; there's a risk that one party will abuse the system to their advantage. Often, the disadvantaged party is the farmer.

XpertSea's marketplace is powered by a mobile app that simplifies the acquisition of crop data and connects farmers to potential buyers before concluding a deal.





Algaeba's counter enables hatcheries and farmers of different fish and shrimp species to accurately count the number of seed when carrying out their transactions—making manual counting redundant.

Although it's still early days, machine vision in some places has already started to change the way in which shrimp and fish farmers and fishermen sell their products. Several companies in the trade platform realm (see p. 26 and p. 90) use machine vision technology to determine species and quality, and to count and determine the size of the fish and shrimp harvested.

Buyers that use these platforms can check the samples and, based on whether the product meets their requirements, can then bid on the product, effectively cutting out the middlemen. Using machine vision like this has huge benefits for farmers: they can offer their product to buyers they may not normally have access to. Farmers also know the price they'll get prior to harvesting, allowing them to better plan cash flows and the next farming cycle.

Thanks to these platforms, a wide range of buyers can bid on products they've inspected visually—sometimes even when the product is still in the water—while keeping in mind the other useful and relevant information the platform provides about the products. This potentially means farmers will receive higher prices for their harvest.

[3] Although there are some companies that fit specifically within this segment, there is some overlap with the companies already described in the article on smart feeding (see p. 52). Both groups of companies have cameras in the water and it's therefore reasonable to expect that companies that aren't active in both fields of technology yet will be so in future.

Market Overview

Cage Farming

Machine vision solutions within the cage farming industry are currently focused on the salmon industry, but some companies are also moving into other species. This Market Overview looks at some of the established and up-and-coming companies that have developed different applications of machine vision, sometimes in combination with proprietary camera systems.[3]

GO SMART Precision Farming

Founded	2020
HQ	Israel
Capital raised	Unknown

GoSmart Precision Farming is a subsidiary of GiliOcean Technology, a company with more than 16 years of aquaculture experience. The GO Smart® BioCam calculates individual fish weight and distribution of the whole population across a cage. With integrated water quality sensors in the same housing, among other things, it enables farmers to correct daily feeding calculations and to stream video for fish observation. The system has been tested successfully in cages, tanks, and ponds, and is currently mainly supplied to cage farms in the Mediterranean Sea.

ACE AQUATEC

Founded	2007
HQ	Scotland
Capital raised	Venture round (2019): Aqua-Spark

The company started applying 3D cameras and machine vision to its predator deterrent system (Ace Acoustic Startle Response). The product allows to distinguish between different predators and only triggers a response for those that need to stay away from the cages. More recently, also using 3D camera technology, Ace Aquatec launched a biomass estimation product and plans to launch a sea lice product in 2022. Read more about Ace Aquatec in an interview with its CEO on p. 67.

OPTOSCALE

Founded	2017
HQ	Norway
Capital raised	- Pre-seed (2016): Investitude - Seed (2020): CoFounder - Series A (2021): Swen Capital Partners (Blue Ocean Fund) (lead) and Skagerak Maturo

Optoscale's machine vision-enabled platform that connects to its proprietary camera system offers three modules that allow clients to calculate biomass and lice, and to monitor fish welfare. In early 2022, Optoscale announced the sale of 9 of its cameras—7 with only the biomass module enabled and 2 with the biomass and welfare modules enabled—to Grieg Seafood's operations on Vancouver Island.

Aquabyte

Founded	2017
HQ	the US
Capital raised	- Seed (2018): Costanoa Ventures (lead), New Enterprise Associates (lead), and 7 co-investors - Series A (2019 and 2020): Alaya Capital, Alliance Ventures, Alumni Ventures, ArcTern Ventures, Costanoa Ventures, New Enterprise Associates, and Struck Capital

Aquabyte is a Silicon Valley-based tech company that uses machine vision to count sea lice and estimate biomass, mainly targeted at the global salmon industry. In Norway, its technology allows salmon farmers to be dispensed from their legal obligation to manually count sea lice. Aquabyte plans to launch a smart feeding solution in the near future. The company has raised over $20m, one of the largest amounts of capital raised in the digital aquatech segment.

THE MOONSHOT FACTORY

Founded	2020
HQ	the US
Capital raised	Unknown

Tidal is a team at X (Alphabet's research and development lab) working on protecting the ocean and preserving its ability to help feed humanity, sustainably. The team has a worldwide patent on a machine vision enabled biomass and smart feeding technology and is currently deploying its technology in Norway, Chile, and Japan.

UMITRON

Founded	2020
HQ	Japan and Singapore
Capital raised	See p. 56

The Umitron Lens is a handheld device that can be used in cages to estimate sizes and the biomass of a range of fish species common in Asia. Umitron Lens doesn't need to be applied to each cage and therefore becomes more affordable for farmers that manage smaller cages. See a more extensive company profile for Umitron on p. 56 and p. 74.

MINNOWTECH

Founded	2018
HQ	the US
Capital raised	– Accelerator (2018): Hatch – Seed (2019): University System of Maryland

Minnowtech is fully focused on bringing sonar-based technology for estimating biomass in shrimp ponds to the market. While sonar is not a camera, it does create vision and allows us to see what's in the pond. The product was commercially launched in early 2022. Minnowtech is part of the portfolio of companies of Early Charm Ventures, an early-stage venture capital investor that helps convert science into business.

Pond Farming and Other Applications
For pond-based farms, there are currently just a few companies working on machine vision and biomass estimation.

algaeba

Founded	2016
HQ	Thailand
Capital raised	Accelerator (2019): Hatch

Algaeba's SeaThru COUNTER can count up to 3,000 (shrimp) PL at a time, and has models for 15 different aquatic species. Although not yet commercially launched, the company is also developing its SeaThru CURRENT, a farm management IoT solution using machine vision technology to monitor and improve shrimp farmers' performance.

xpertSea

Founded	2011
HQ	Canada
Capital raised	See p. 31

Machine vision features in each of the company's products. Its XpertCount is used to accurately count PL and the company also provides farm management software and a trade platform. Using their smartphones to upload photos onto the platform, farmers provide XpertSea's systems with data that give the farmers actionable insights with which they can optimize their productivity and, with the B2B marketplace, this allows Xpertsea to provide farmers with market access. Read more about XpertSea in an interview with its CEO on p. 81. See also a more extensive company profile for XpertSea on p. 31.

ACE AQUATEC

NATHAN PYNE-CARTER, *CEO*

Interviewed by: Amy Novogratz, Managing Partner at Aqua-Spark

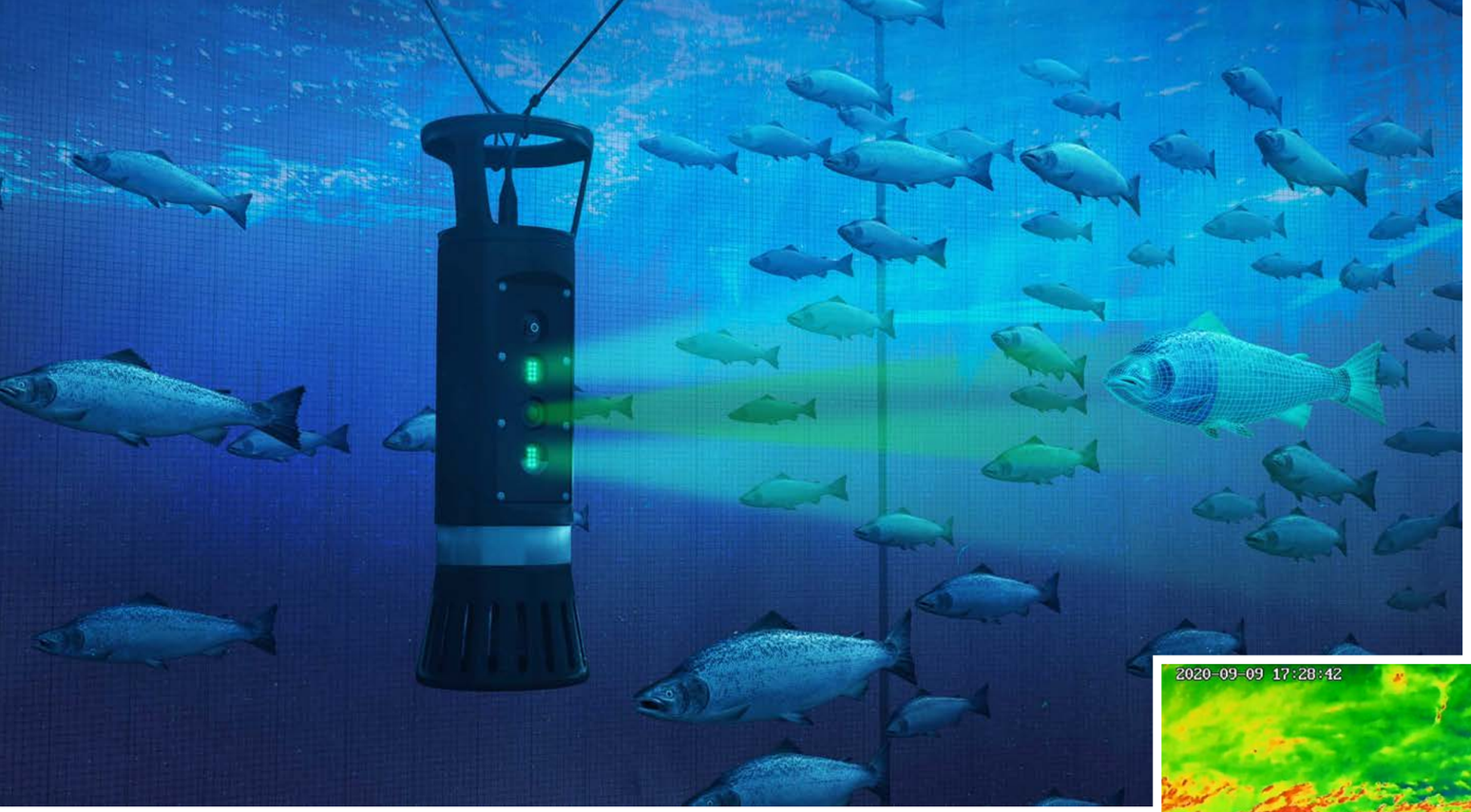
Founded	2007
HQ	Dundee, Scotland
Capital raised	Venture round: Undisclosed (2019)
Aqua-Spark invested in	2019
Products on the market	Ace Acoustic Startle Response (smart seal deterrents) Ace Humane Stunner Universal (in-water electric stunning of fish) Ace Bleeder (automated waterjet bleeding of fish) Ace Biomass (3D smart biomass camera)

Tell me about the origin of Ace Aquatec.
John Ace-Hopkins started the brand in 1999; he was a marine biologist. He tried to understand how predators such as seals interact with fish farms and how you can keep them away. He started to develop our first deterrent system that worked with an acoustic startle response to chase away predators which would otherwise cause stress to the fish. Ace Aquatec was turned into a limited company in 2007. That's when my mother also got involved with the business, as an investor. Then, sadly, in 2011, John died of a heart attack, and the business needed to adapt.

I came into the company in 2012. Before that time I was a screenwriter and actor, living in Leipzig. I had a completely different outlook than John. I'm not an engineer. Out of necessity I had to outsource work to experts in their fields to help us realize our ambitions. I took the route of writing grants to get funding to finance R&D projects for specific technologies, and to get those technologies developed with key subcontractors. Recently, we've started to bring that R&D capacity back in-house so that we can return to being experts ourselves.

Today, we have three main products. Besides the Ace Acoustic Startle Response, an acoustic predator deterrent system, we're well known for our electric stunning technology, which allows farmers to use electricity to render fish unconscious while still in water before slaughter. After years of development, we've also just commercially launched our biomass estimation solution—Ace Biomass—and insights platform.

From predator deterrents to electrical stunning to biomass estimation. That's quite a lot of pivots. Tell us about how you got there.
They are pivots, but all are connected to animal welfare and that remains our core focus. When we were deploying our deterrent systems and stunners on the farms, we saw that many farms were using a biomass observation system where fish had to swim through a frame that was permanently deployed in each cage. Farmers were unsatisfied because they found big fish would pass through the frame, but the smaller fish avoided it, leading to incomplete and inaccurate estimations.



So, back in 2012, I started to wonder whether we could use cameras and machine vision to do the same thing. We wanted to avoid the need for the fish go through these frames and instead monitor shoals of fish in the cage unobtrusively. I applied for—and won—a SMART:SCOTLAND grant. We used that funding to look at different camera technologies and began to focus on time-of-flight 3D cameras. We thought if Microsoft can create real-time 3D wireframes of gamers in their living rooms, maybe we can do the same with fish in, and predators around, our cages.

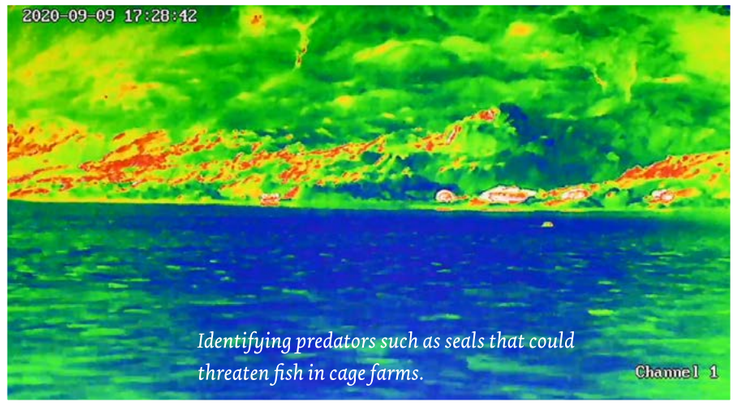
We started to work with image recognition algorithms. The first challenge was to have the system automatically separate fish from the shoal. Then the system had to be trained to determine whether an identified fish was actually large and far away from, or small and close to, the camera. Many iterations later we have a biomass system that is fantastic at identifying fish. It then triangulates each pixel and creates a 3D model of that fish. Once you know the density of the object and the coordinates of features, you then have an accurate biomass system. Now we're working on adding features related to disease recognition and feed optimization. In the early days, we'd need thousands of images to train the system; today, we just need around 100-200 images of fish infected with a certain type of disease and then the system will take over. So it's really come on leaps and bounds in terms of the speed at which you can accomplish things.

An important factor for us is that it's become much more accessible and a lot easier for companies like ours to work in this space because Big Tech companies like Google and Facebook have developed so many tools that others can use. The tools that are now available have significantly accelerated the speed at which these systems can learn. We strongly believe that these technologies will have a huge impact on animal welfare, productivity, and sustainability in the aquaculture industry.

Am I right in thinking that it didn't stop here? I understand you're developing a portal through which your customers can get insights from all the data you collect. Tell us more.

Currently, a large proportion of farmers still conduct hand weighing, where a vessel pulls up alongside a cage and takes random samples of fish to weigh them. This can be stressful for the fish, and provides only a limited sample of the distribution of fish growth across the cage(s). We want to give our customers real-time access to growth data from every pen. This will mean that framers have the data they need to ensure their customers are getting the sizes of fish they've requested, and that any issues with fish growth, such as disease or lice, are detected before they become serious economic catastrophes. Our platform not only provides information about weights, but is a central place where all data around fish, predators, and harvesting can be viewed. It also identifies where money can be saved. These features combined make the portal a key tool for farmers.

We began developing the portal in response to requests to monitor our stunners and deterrents remotely. Through our portal, farmers and their clients can view information gathered by our technology systems. And we've expanded the portal to include data from our surface deterrent cameras, as well as from our underwater biomass cameras. A user is granted access to the information relevant to their role. It's about allowing data to come together, giving insights across the business. We're now looking at expanding our data streams by plugging in water-quality sensors and we're also trying to plug in satellite data—we'll continue to expand according to our customers' needs.



Identifying predators such as seals that could threaten fish in cage farms.

One of the greatest digital minds in the world—Chris van der Kuyl, one of the founders of Minecraft—joined you as a co-investor as well. How is his involvement shaping what you do today?

The great thing about having Chris on board is that he has a fantastic understanding of user interface. He really helped us with the portal development to make sure that the user experience is as sleek as those of Apple or Tesla. It's very easy for companies like ours to present more information than is actually required. Farmers don't want to dig through data, they just want to know about the relevant insights and how they can act on those insights. A lot of the work actually concerns refining and making the messaging as simple and neat as possible, and to do it in the most user-friendly way possible, too.

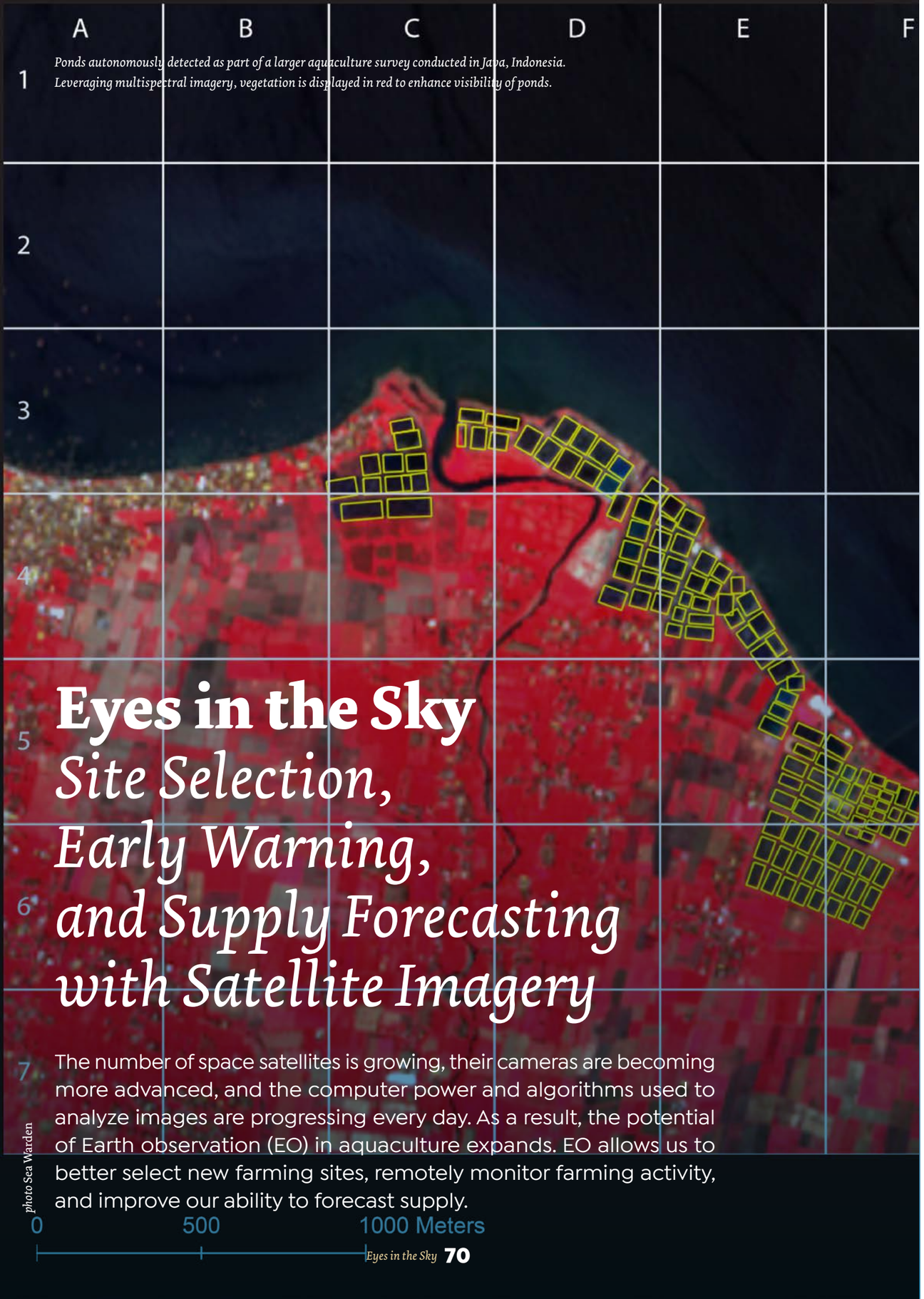
What fascinates me is that you have a background as an actor. When you took over the reins, did you see real value in your skillset as a storyteller? And did you also see a need there around tech adoption?

With animal welfare being a priority of most major retailers in northern Europe and the UK, there's impetus to improve it and to tell that story. Once we started to look at how underwater camera systems could automatically identify fish, we realized there's an opportunity to track all wildlife around the farms and to use that information to trigger an acoustic startle reaction in predators (when a seal's there, for example, but not when there's a non-target species like a porpoise). This is, of course, a great story to tell as it's much more animal friendly than traditional methods that use constant noise and have a negative effect on the animal's welfare. The same goes for our electric stunner: that's an important but easy story to convey.

By adding more data about—and insights into—the welfare of fish in the cages, we can give more visibility of the farms to regulators, consumers, and others. And this is needed. Farms today are increasingly installing CCTV in their harvest stations and allowing auditors access to their farms to carry out spot checks on random dates. That's a radical shift, and with that willingness to open up, our systems and the data we generate and disclose can play an important role. Much anti-aquaculture sentiment comes from a feeling that fish farming happens far offshore without us knowing what really goes on there. With these new technologies that constantly monitor the health and wellbeing of the fish, we believe the way fish farming is perceived will change in a positive way.

What can we expect from Ace Aquatec over the next 5 years?

We'll provide an AI and machine vision-enabled view to the farmer throughout the production cycle from in and around their growout cages all the way through to harvesting. Our portal will entice farmers to take that information and act on it to optimize fish welfare and the profitability of their farming operations.



Ponds autonomously detected as part of a larger aquaculture survey conducted in Java, Indonesia. Leveraging multispectral imagery, vegetation is displayed in red to enhance visibility of ponds.

Eyes in the Sky

Site Selection, Early Warning, and Supply Forecasting with Satellite Imagery

The number of space satellites is growing, their cameras are becoming more advanced, and the computer power and algorithms used to analyze images are progressing every day. As a result, the potential of Earth observation (EO) in aquaculture expands. EO allows us to better select new farming sites, remotely monitor farming activity, and improve our ability to forecast supply.

photo Sea Warden

0 500 1000 Meters

EO as a Source of Information for Location Intelligence and Site Selection

When looking for new sites to establish or expand cage farming operations, the area to cover is tremendously large. Site selection depends on the specific conditions under which aquaculture species thrive and farms can operate. These conditions include temperature, currents, wave heights, irradiance, and water quality. All of these parameters differ greatly over time and space and are hard to monitor across large swaths of ocean. Due to satellites' ability to map these conditions for large areas, EO will likely become a regular tool for site selection. Combined with other types of maps containing e.g. socio-economic data, EO is a powerful source of data for location intelligence services.

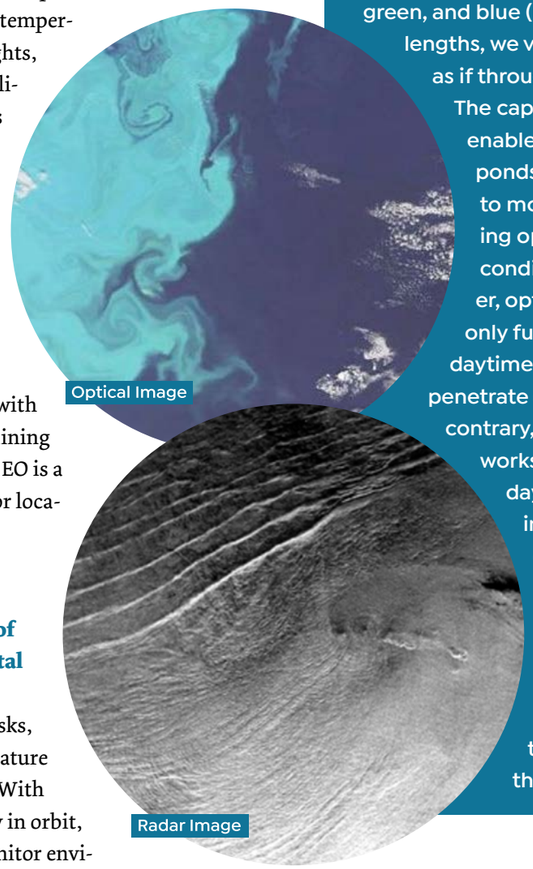
Satellites Improve Response Time in Case of Climate or Environmental Calamities

Fish farmers face many risks, including storms, temperature drops, and algae blooms. With the instruments currently in orbit, one can continuously monitor environmental and weather conditions to reduce risks for aquaculture operations. For example, having algorithms analyze the colors of ocean waters and chlorophyll levels allows us to anticipate harmful algae blooms, giving farmers time to harvest.

With ever-improving instruments on satellites in orbit and better capacity to analyze satellite data, satellite-based early warning systems could become much more accurate and completely automated in the future. Besides increasing the time for farmers to prevent or reduce losses in the case of calamities, having such systems in place could also prove to be beneficial for banks and insurance companies as one of the options to de-risk their services for the aquaculture industry.

Optical vs. Radar Images

Optical sensors work in much the same way as traditional cameras, only better. By analyzing red, green, and blue (RGB) wavelengths, we view the world as if through a human eye. The captured images enable us to identify ponds and cages, and to monitor farming operations and conditions. However, optical sensors only function during daytime and cannot penetrate clouds. On the contrary, radar imagery works during both day and night and in all weather conditions and can provide different insights, e.g. into the wave heights and temperature of the ocean.



Satellites Enhance Aquaculture Supply Forecasting Models

In India, Indonesia, Vietnam, and other countries in the region, there are hundreds of thousands of shrimp and fish farmers. It's very hard for anyone to monitor farming activities on such a large scale. Today, input suppliers such as feed manufacturers and hatchery operators may have the best view of what's happening in a certain geography and, through their sales operations, they can make assumptions about the overall situation. But, currently, supply forecasts in these geographies are typically based on incomplete information and rumors—not the most dependable grounds.

> "We're now able to identify and classify shrimp ponds and to measure their size and activity with 97% accuracy. This enables us to provide forecasts of Ecuadorian shrimp production 3 months ahead."
> *Hogne Andersen, CEO and Co-Founder of Dynaspace*

Satellite imagery may drastically enhance the ability to monitor farm activity and forecast supply. Algorithms can identify an individual pond, determine whether it's in operation, and estimate its productivity. The extracted data can be used to keep track of when ponds are stocked and to model future supply. A better understanding of cropping patterns and future supply will help farmers decide when to stock or harvest their crops and optimize their revenues.

There are many other possible products that service providers can develop. Sales prospecting is one of them. Satellite images allow for easy identification of farms that operate at a certain production intensity and therefore might be interested in a specific type of feed or input. Early warning of disease prevalence based on an observation of sudden harvests in a specific geography may help farmers minimize losses by either deciding not to take in any water from a shared creek or by also harvesting a crop before disease spreads further. These are just a few examples, but there's a multitude of EO-based farm activity monitoring services that may benefit farmers, input suppliers, banks, and even government agencies.

Remotely Monitoring Environmental Conditions Isn't Just about Satellites

While satellites are an important instrument to observe environmental conditions, they're not the only instrument that tech companies use. In 2021, Scoot Science, one of the companies involved in ocean analytics for aquaculture, launched its SeaState™ dashboard. SeaSate™ uses data from cage sensors and combines this with publicly available oceanographic and meteorological data. The company provides daily suitability scores for the environmental conditions at every cage farm worldwide, for the current day and for several days ahead. Just like the platforms that use satellite data, a platform such as SeaState™ allows farmers to better manage environmental risks that threaten their cage farming operations.

ScootScience

Founded	2017
HQ	the US
Investment raised	- Accelerator (2017): Santa Cruz Accelerates - Pre-seed (2019): Undisclosed - Seed (2021): Undisclosed

Monitoring and Verifying Claims about Farm Operations

Satellites can also track individual farm activity. Satellite images show whether ponds are used for stocking or water treatment. If used for stocking, satellites can monitor how the pond is managed in terms of the equipment used in and around ponds. Satellite imagery can also be used to monitor when ponds are harvested. This type of information may be of great value to regulators, certification bodies, or partners of the farm that want to verify claims that farmers make about their operations. What's more, imagine the value of these images for farmers themselves. If farmers were to offer satellite surveillance as a service to their retail buyers, this would provide retailers with visual proof of what happens at farms during the term of a contract and adds to the transparency of the products that the farmers are selling. The same information could be used by insurance companies to verify damage claims due to extreme weather or disease outbreaks.

Scratching the Surface of What Satellites Have to Offer

With researchers and startups alike working on applying satellite images and algorithms to aquaculture-specific applications, we're starting to see the potential to transform the aquaculture industry. The quality and frequency of available satellite images is becoming increasingly better while the cost of satellite images from commercial sources is expected to significantly decrease. With that, the value and accessibility of using satellite images in the aquaculture industry will grow as well. Eventually, when the quality of satellite images improves and we become even better at analyzing and interpreting the extracted data, EO may reduce the need for farms to apply data-capturing devices as our eyes in the sky can produce the same data at a much lower cost.

Umitron Pulse allows users to look at several parameters. The current view reveals levels of chlorophyll.

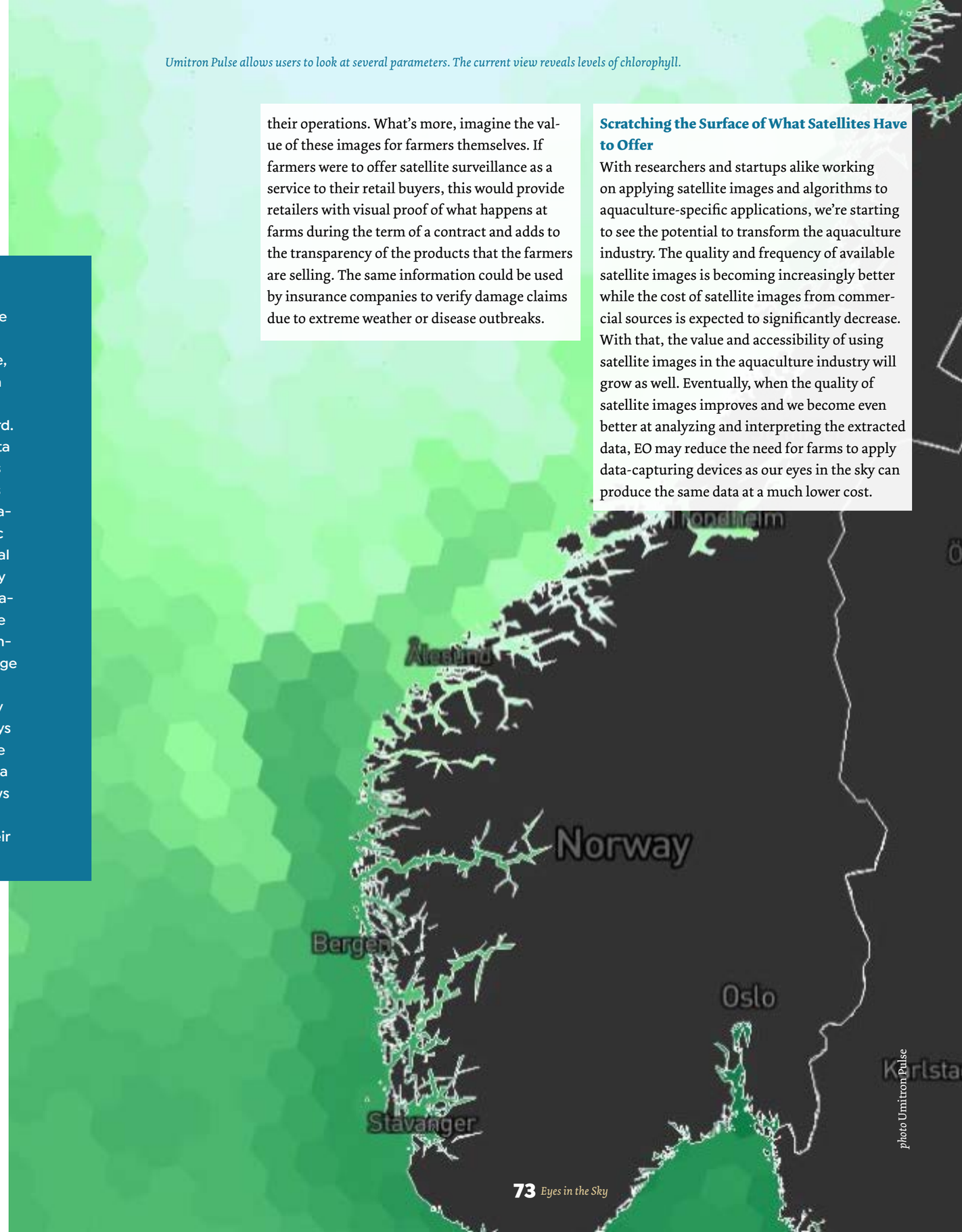


photo Umitron Pulse

"The challenge (for any satellite imagery-based application) has always been finding cost-effective ways to process raw data into useful insights. To overcome this challenge, we leverage AI to create 'helpers,' each with a specific task, such as detecting ponds, determining pond activity, and counting aerators."
Zack Dinh, CEO and Co-Founder of Sea Warden

Market Overview

The market for EO application in agriculture, mainly through development and sales of value-added services, is expected to reach $815m by 2030.[4] Adoption of EO in aquaculture is still lagging behind, but several startups have developed aquaculture-specific services. Here, we profile some of the most active and up-and-coming companies involved in this segment of digital aquatech.

[4] Euroconsult & TerraMetric, Earth Observation for Agriculture (Euroconsult, 2020), https://digital-platform.euroconsult-ec.com/product/earth-observation-for-agriculture

UMITRON

Founded	2016
HQ	Japan and Singapore
Capital raised	See p. 56

Umitron's satellite product, Pulse, was launched in 2020. It provides an easy-to-use dashboard where users can monitor a range of parameters relevant for marine fish farming—including water temperature, salinity, wave heights, and chlorophyll levels. Users can view historical data from up to 2 weeks previously and access forecasts for the next 48 hours. See a more extensive company profile for Umitron on p. 56 and on p. 66.

DYNASPACE

Founded	2018
HQ	Norway
Capital raised	- Accelerator (2019): Hatch - Seed (2019): VIS and Planet 9 Venture

Dynaspace's founding team members have their backgrounds in satellite engineering, remote-sensing, space physics, and fish farming. The company uses satellites to map global aquaculture and monitor aquaculture operations. In 2020, Dynaspace secured its first commercial contract, which involved providing data to forecast Ecuador's shrimp production for 3 months into the future. During 2020–2021, Dynaspace participated in a 2-year program of the European Space Agency. The startup regularly receives grants, the latest of which was a $400,000 contract from Innovation Norway in early 2022.

SEA WARDEN

Founded	2020
HQ	the US
Capital raised	Accelerator (2020): Hatch

The team at Sea Warden applies a Silicon Valley-innovation and problem-solving mindset to the aquaculture industry. The company develops solutions that support the shrimp farming industry with farm- and region-scale monitoring services. Sea Warden has gained interest from a variety of industry stakeholders and is currently trialing its solutions with Thai Union and Grobest (farm management and traceability), the Aquaculture Stewardship Council (farmer access to certification), and WorldFish (investment prioritization and disaster relief).

HATCH
Aquaculture Accelerator

CARSTEN KROME
Founder and Managing Partner

Interviewed by: Flavio Corsin, Director of Partnerships at Aqua-Spark

Founded	2017
HQ	Cork, Ireland
Capital raised	Fund 1: $8.4m (2020) Fund 2: Closing in 2022
Aqua-Spark invested in	2018
Products on the market	Hatch Accelerator Hatch Fund Hatch Innovation Services Hatch Innovation Studios The Fish Site

You were actually one of the first Aqua-Spark employees. Why did you leave?
During my PhD, my supervisor, David Little, introduced me to Aqua-Spark and not long after that I joined the team. Looking at the deal flow, I saw a lot of cool things coming in but much of it was not investable. These companies had good technologies, but they didn't have the business plans in place. That's frustrating—you want to make certain deals because of the technology, but can't because it's not good enough to pass on to the investment team.

I started to think about how to make these types of companies investable. The answer was to set up an accelerator. In tech or IT, people are normally really good at pitching and preparing business plans: they all sound super confident and professional, even though their ideas might not be great. In aquaculture—and especially at that time—it's often the other way round: there are some great ideas but a lack of entrepreneurial skills. The accelerator was supposed to fix that. And now we're here, 4 years down the line, having run four programs and set up our first fund. We're currently raising our second fund.

How has the accelerator program and Hatch as an organization evolved since its first program in 2017?
After onboarding 37 companies over three programs in just 2.5 years, we felt that we needed a break and didn't run an accelerator in 2021. Instead, we focused on raising our second fund. With the new fund, the role and focus of the accelerator and the way that we view ourselves has changed a bit.

Right now, we consider ourselves an early-stage venture investor. While we'll still run the accelerator, we've chosen to focus on fewer companies in more diverse stages of growth. In the past, we exclusively had very early-stage startups, but in our next programs we also want to have companies that already have a product on the market but that would still have much to gain from our accelerator program.

The accelerator remains a great tool for in-depth portfolio management. It allows us to work with the companies very intensely. It's a way and a means to add value to the companies while also enabling us to make better decisions about larger follow-on investments.

From all the early-stage companies out there, how do you select the most promising?
We always select based on the quality of entrepreneurs and how close they are to launching their product onto the market. We then assess the product/market fit of their solution. We tend to focus on companies that are locally embedded, so we would be more likely to invest in an Indonesian company than a German company to solve a problem in Indonesia. Looking at our most successful companies, they've all spent a tremendous amount of time with their clients to make sure they understand their problems. They've been flexible and agile, and pivoted their products until they've found a good solution for a problem their clients have had.

Actually, it's interesting to mention that we've stopped prioritizing digital aquatech for the time being because there's an overflow of companies in this segment. The early investments we made in digital aquatech in 2018 are possibly the most successful ones of our portfolio in terms of valuation increase and traction. We've placed our bets. If we were to invest in a digital aquatech company again, we'd first want to see that they have traction; just being innovative and having a talented team isn't good enough anymore.

Interesting! My next question is almost like asking "which one of your children do you like the most?"
Everyone in our team at Hatch has their favorites, and mine might be different to the other partners. Let me give three examples of portfolio companies involved in digital aquatech whose achievements I'm proud of.

Jala Tech has been great because they recently raised $6m. In my view, they were as good as any other company doing similar things, but they were struggling to raise funds, so we provided bridge funding several times. It doesn't feel good to drip feed companies financially. Sometimes, it might be better to pull the plug. But Jala Tech has proven that we were right to continue to support them. That was really good news.

Aquaconnect is the second one I want to highlight. When we first started working with them we thought, OK, let's just see what happens. We didn't necessarily think that this was going to become big, but now it is. Raj, Aquaconnect's CEO, has clearly lived up to the challenge and the working relationship has been incredibly good. Although our share in the cap table has become smaller with five or six additional investors on board, Raj still values our opinion. For us, as an early-stage investor, that's really cool.

The last one I should mention is Manolin. The team at Manolin consists of Americans who live in Norway. The Norwegian ecosystem is not easy to work in as a foreigner, not knowing the language and having to deal directly with salmon farmers. But they're biting their way through, and they now have a strong product/market fit.

Three to four years later and they've signed big contracts with some of Norway's leading salmon farmers. That's just really, really good to see too.

What do you think long-term success looks like for digital aquatech companies? Are there going to be IPOs or will they become the Googles of aquaculture?
Good question. I still struggle with the answer. When you really zoom in on the markets—of companies like Aquaconnect, which generates revenues through providing farmer finance and insurance as well as through the sales of inputs and outputs—it's unclear how big those markets actually are. How much revenue can you generate if you combine the margins for all their services? I do think that for each country, there's a sort of "winner takes all" play to be had. Eventually, the successful companies may be acquired by larger firms or private equity, or might indeed go for an IPO (initial public offering). Five years down the line, people will think, "I know what eFishery and XpertSea are and what they do, so I'm going to buy their stocks." Seeing some companies become a unicorn wouldn't surprise me at all.

What have you learned after the more than 30 investments you've made with the accelerator program?
One thing we learned as an early-stage investor is that we have to think carefully about the companies' potential to reach scale. At the time we invest, at such an early stage, we value the companies at around $1.5m on average. So, for us to get a return it needs to grow significantly. However, not every business is set up like that. Some companies are SMEs that will stay SMEs. That works for the people that run these companies, but it doesn't work for us as a venture investor. We learned that we need to make sure we invest in firms that have the ambition to build a large company.

So, when you started Hatch, your goal was to bridge the gap between the promising startups you encountered in the deal flow and companies that are at a stage that investors such as Aqua-Spark are looking for. Have you succeeded at that?
Yeah, I think some of the earlier companies from our 2018 program are now at a stage where Aqua-Spark would absolutely look at them. So, for us, it's just a matter of holding out long enough, which we did. I think—and hope—that several of our companies may in the future become part of the Aqua-Spark portfolio. But to be honest, you don't really feel like you've succeeded until some of those companies have made a real impact, and that's more than just a matter of how much funding they've raised. We're still at a phase where we can say we've successfully helped companies raise money from institutional investors, but now we also want them to succeed in the long term… So until more of our portfolio companies have established real revenues, I don't consider us to really be successful.

So what should we expect from Hatch in 2022 and beyond?
For 2022, we'll launch our second fund together with The Nature Conservancy, and we're extending our program activities working with aquaculture startups across different geographies. We're also aiming to intensify our collaboration with Aqua-Spark on several fronts to get closer to our joint vision of producing sustainable seafood while saving the oceans.

ROVs and AUVs

Relieve Divers from Risky Work around Cage Farming Operations

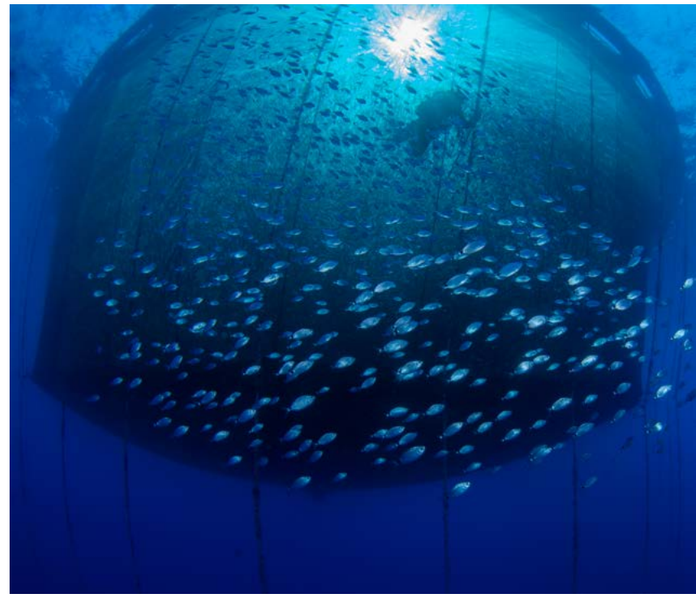
We often hear that robots will take over much of the tasks that used to be done by humans. Cage farming operations are not an exception.

photo Wat Bots

By: Matt Craze and Willem van der Pijl

Many countries still deploy divers for the unglamorous and hazardous activity of regular net cleaning—an essential task, since a clogged net full of marine debris leaves a net pen prone to collapse. At the height of Norway's summer, for example, nets need to be cleaned every 5 days. Instead of deploying divers, the salmon industry has found another solution.

There, a remotely operated vehicle (ROV) works underwater to perform the tough task of skimming away biofouling from salmon net pens. Created by Kystdesign, the Stealth Cleaner is one example of a robot that looks like an aquatic vacuum cleaner and a triangular version of Wall-E, the Disney robot character that becomes Earth's last "survivor." Like Wall-E, the Stealth Cleaner also collects debris.



The ROV army is making small but steady improvements to solving some of the salmon industry's biggest challenges, from net cleaning to digging bore holes. Advances in ROV technology, especially from the Norwegian oil and gas industry but also from a number of start-ups, have enabled this quiet revolution. "There were close to no ROVs 5 years ago. This has really exploded in the last 3 to 4 years. The ROV can work 24/7. It's expensive, but that's the way the industry is going," said Vignir Bjartsson, sales manager for ROV net cleaning at Akva Group.

Acquiring ROVs makes sense for a top 10 salmon farmer, such as Mowi, with an average revenue of about $930m, according to Spheric Research data. A basic ROV that provides simple net cleaning and inspection can be acquired for around $270,000. A full underwater kit with a drilling machine for mooring systems costs up to $700,000, according to Akva Group. Smaller firms can benefit from ROVs through service companies that offer them as a rental service.

While ROVs have already caused a silent revolution in Norway, autonomous underwater vehicles (AUVs) will soon take net cleaning to the next level. Watbots, a Norwegian startup, has announced the launch of an AUV that will fully autonomously clean and inspect nets. In January 2022, the company had already secured 200 pre-orders, according to Håvard Lilleboo, CEO of Watbots. Watbots' AUV is offered as a rental service at an annual cost of around $2,800.

The benefits of using ROVs and AUVs to relieve divers of their tasks are significant. Underwater human intervention can be dangerous, especially in harsh conditions. Sometimes it can even be lethal, for example when it leads to severe decompression sickness (DCS), also known as "the bends." Moreover, the use of ROVs allows cages to be maintained in optimal condition throughout the year, even during the winter season.

Market Overview

Today, the use of ROVs, and soon AUVs, in aquaculture is mostly limited to Norwegian salmon farmers. Besides being the world's largest salmon producers, they're also the most profitable. However, the use of ROVs is likely to soon expand to other geographies and species as well. Many of the companies involved in developing ROVs for salmon farmers have adjusted existing ROVs used in the oil and gas industry. Examples of such companies are Argus Remote Systems and Sperre, the robotics company acquired by Akva Group. But aquaculture-focused companies and startups develop ROVs as well. Here, we profile some of the most active and up-and-coming companies involved in this segment of digital aquatech.

aquaai
INTELLIGENCE BELOW THE SURFACE

Founded	2014
HQ	Norway and the US
Capital raised	Several (pre-)seed: GrowthX (2015), Kvarøy Fiskeoppdrett AS (2017 and 2018), Backstage Capital (2018), Boost VC (2019), Astra Ventures (2020), and Great Mountain Partners (2021)

Aquaai Corporation is a strange fish in the sea: it's not focused on the maintenance of cages but rather on a robotic fish AUV that swims in the water to collect data about the fish while using cameras and plug-and-play sensors. Its AUV is sold as a rental service. The company is raising a next seed round of $3m to deliver on signed purchase orders.

AKVA GROUP™

Founded	1974
HQ	Norway
Capital raised	Self-funded

Akva Group acquired Sperre—a robotics specialist for the oil, gas and salmon industries. The AKVA Sperre FNC8 ROV is becoming a leading device to clean net pens. The company also sells a rockdrill ROV that can operate in depths of up to 200 meters, digging bore holes for the moorings of salmon net pens in just 20 minutes—it would take three divers much longer to complete the same task.

WATBOTS

Founded	2019
HQ	Norway
Capital raised	– Seed round (2020): Private investors and Innovation Norway – Corporate venture round (2021): Valinor and Austigard Family

Watbots is a Norwegian startup that has designed an autonomous net-cleaning robot (AUV) for salmon net pens. Farmers need to install one robot per cage. Daily, it will clean the net inside and out, and inspect for damage to the net to prevent fish from escaping. Watbots has already raised more than $2.5m and plans to raise a next round of $3.5m in the first half of 2022.

SINTEF

Founded	1950
HQ	Norway
Capital raised	Unknown

SINTEF Innovation, one of Europe's largest independent research organizations, is working on several ROV projects among the thousands of projects it carries out for the private sector. One example is Eelume, a snake-like robot that can access pens through tight openings thanks to its flexible body. It's already being used on offshore wind plants and fishing vessels. Other clients include Argus Remote Systems and Remora Robotics.

ECA GROUP

Founded	1936
HQ	France
Capital raised	Unknown

ECA Group has supplied ROVs to civilian and military applications for more than 40 years, and launched an underwater drone in October 2021. The company made its first aquaculture sale in 2021 to Chile's Servicios Maritimos Integrales, which provides services to the salmon industry.

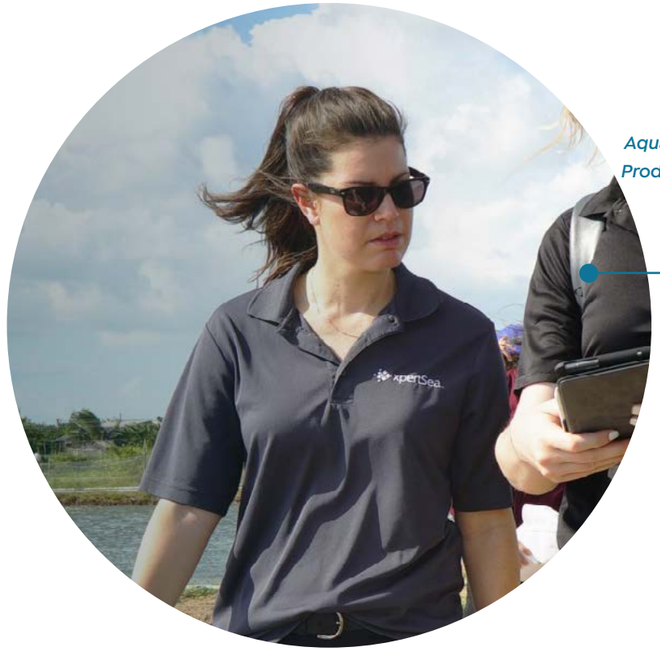
xpertSea

VALERIE ROBITAILLE

Co-Founder and CEO

Interviewed by: Amy Novogratz, Managing Partner at Aqua-Spark

Founded	2011
HQ	Québec, Canada
Capital raised	Accelerator: FounderFuel (2015) Seed: $1.25m (2015) Series A: $8m (2018) Series B: $20m (2021)
Aqua-Spark invested in	2018
Products on the market	XpertCount (post-larvae counter) GrowthPlatform (farm advisory software) XpertSea Marketplace (B2B marketplace and farmer financing solution)



What was it that really got you to dive in and focus on aquaculture?

I've always been passionate about the ocean. During my studies, I used optics and photonics in marine environments to get data and information about what was going on underwater. In the early days, we never thought about applying those technologies to aquaculture. Rather, we started to do some work for the military to detect unexploded bombs. But when we published an article about our work, a big shrimp company from Asia contacted us to ask if we could use optics and photonics to count shrimp post-larvae (PL). Having never thought about aquaculture at all, I found this super interesting and started to look into it. I soon began to understand how huge the shrimp industry is.

When we first went into the field, we realized that farmers bought PL worth tens of thousands of dollars with no way of counting them precisely. Instead, people were trained to visually estimate how many larvae were put in a bag. We visited a large hatchery and saw this giant whiteboard where all their operations information was written manually. That was the only data they had. Seeing our first shrimp farms and hatcheries was just like, "Wow, how big but how low-tech the shrimp industry is, and how much room for optimization there is." I realized this would be a very good place for me to try to make a big difference.

So at this point you're seeing shrimp farms and seeing how low-tech or even no-tech the industry is. Did you ever think, "Oh, it needs to be this deep-tech AI solution?"

In the beginning, we were hardware-focused and trying to solve the PL counting issue using optics and photonics as that was the immediate need that we saw. But in 2015, we did the accelerator FounderFuel with Real Ventures to push us to think about the largest impact we could have with our technology. In those brainstorms, we focused on the lack of data in the shrimp industry, and what we could accomplish with the path that we were on in creating more and better data and insights. These discussions

really opened our eyes and we realized this would be an industry-changing opportunity. It strengthened our belief and mission to bring technology and data to farmers so they can farm better, and so we can feed the world with sustainable protein.

We've been so impressed by how you've learned and modified your strategy along the way. Can you take us through some of these pivotal moments?
In 2018, I realized that while we were focused on bringing technology and data to farmers, a lot of these people had never had access to data before, and they didn't know what to do with this information.

We also realized shrimp is a highly relationship-driven industry. When we exiled ourselves to Vietnam for a few months, we discovered there would be a lot of karaoke, tea sessions, and family introductions involved if we wanted to have farmers trust us enough to start working together. Although these were great experiences, this isn't a very scalable way to build a company.

To reach a larger number of farmers, we established a number of partnerships with feed and other input suppliers who have a lot of feet on the ground and work with farmers on a regular basis. The companies' field teams use our GrowthPlatform—a machine vision and deep learning-enabled tool—to help farmers with actionable insights to optimize their production. The data we collected through these partnerships really allowed us to better understand the ground reality.

This saw a shift from the PL counter (XpertCount) to the GrowthPlatform. What next?
A 2019 conversation with engineer, designer, entrepreneur, and investor Tony Fadell about how important business model innovation had been for a lot of AgTech companies encouraged us to look more at the business models AgTech companies had developed. When studying some of the successful AgTech marketplaces like the Farmers Business Network and Indigogo, we saw that there are a lot of similarities between aquaculture and agriculture in terms of the challenges around access to cash flow and markets. And the data we were creating around the shrimp in the farmers' ponds allowed us to create a business model around providing farmers with access to the market and better payment terms. In turn, this would allow them to farm more shrimp and allow us to encourage them to adopt better production practices. This is when we started to develop our marketplace.

At this point, you realized you can launch a marketplace and help to facilitate transactions between farmers and their buyers. Tell us more.
One of the things that keeps shrimp farmers up at night is access to markets and finance. Since the samples we collected through the GrowthPlatform already had all the data and information about their crop (sizes, volumes, quality), we knew we were in a position to help them better market their crop to buyers and negotiate prices: we could strengthen their bargaining position and provide them with a better idea of what price to accept, based on what they really had in their pond.

It's easy to be here in Canada and visualize a great marketplace where farmers and processors can sell and buy shrimp, a platform that would benefit the farmer in particular. The reality is, again, that the shrimp industry is relationship-driven, and trust is the main driver of any transaction. Farmers in Ecuador would only sell to one or two buyers in their area because they were the only ones they would trust to pay. Unfortunately, these buyers didn't always offer the best price or payment terms and would only pay weeks after a crop was sold. Buyers, however, were unsure about what they were going to get from a farmer or didn't have the financial capacity to pay farmers right after harvest—they had to wait for payment from their clients.

By making the data we collect through the GrowthPlatform available to both parties we can overcome many of these issues. Buyers from across Ecuador can assess the product quality based on our sample data before they agree to buy the product; farmers can now sell to buyers throughout Ecuador without worrying about payment. XpertSea pays 80% of the crop's value straight away. We want both processors and farmers to see us as allies and enhancers as opposed to competitors.

What are the financial services you offer right now, and what are those in the pipeline?
Right now, we're really helping farmers get paid at harvest. We make sure that we understand what they have in their pond, so that when they sell to the buyers, we can give them up to 80% of their crop value right at harvest.

But we're also looking to invest in the farms at the start of a cycle to drive sustainable production methods. When speaking to smaller farmers, we notice that they want to be more sustainable since it's also their land, but sometimes there are a lot of barriers for them. Smaller farmers often lack the finances to invest. We've started

The XpertSea team presenting their digital marketplace, trade financing, and other products at Aqua Expo Guayaquil, Ecuador.

working with some of these farmers to provide them with financing to invest in equipment, certification, and other aspects of production. The goal is for them to be more sustainable and more profitable—we see ourselves as a solution to help smaller farms meet the growing consumer demand for sustainable and traceable seafood.

The financing comes from a debt facility you raised. First, you entered Ecuador and you've had more than a year of growing this marketplace. Tell us where you are now.
We launched our XpertSea Marketplace in January 2020. Today, we're financing many millions of dollars of shrimp every month, and it's growing at a very rapid pace. We started with our own capital and then raised investment from individuals and groups looking for ways to support (smallholder) farmers. Understanding that this debt facility would be used to capitalize the farmers to help them do the right thing made it easy to raise the amount we envisioned. Now the plan is to keep growing this facility with more investors that want to support what we do. Slowly, we'll try to institutionalize the debt facility to attract larger investors because our ambition is to be financing hundreds of millions of dollars for the shrimp industry in the coming years not only in Ecuador, but also in South and Southeast Asia.

What do you think your biggest challenges are as you move forward?
Localization—understanding how to do this in the different markets. And talent—we have big ambition, there's a lot to build, and we've got to build the right team to get there.

Enhancing Traceability, Transparency, and Consumer Confidence

There's a ton of reasons why regulators, companies, and consumers want fish and seafood to be traceable and supply chains to be transparent: a company's ability to respond to food safety-related product recalls, a government that wants to prevent fraud with regard to the origin of products, consumers who want to be sure that what they eat isn't related to any environmental or social misbehavior, to name but a few. Documentaries like Seaspiracy and recent salmonella-related recalls in the UK and US only increase the pressure to solve these issues.

News

All news

Home & garden ▸ Shopping, food & drink

Food recall: Asda, Co-op, Sainsbury's and Waitrose recall certain seafood products*

12 different chilled and frozen seafood products pose a salmonella risk

By Christina Woodger 25 Jan 2021

Asda, Co-op, Sainsbury's and Waitrose have recalled a number of chilled and frozen seafood products due to fears that they may be contaminated by salmonella.

People who have purchased any of the products listed below, are strongly advised not to eat them. Instead, they should return them to the store for a full refund.

Read on to find out which products have been recalled and what to

More on this

Supermarket prices compared

Best and worst supermarkets

Your rights when there's a recall

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* SOURCE: Christina Woodger, "Food recall: Asda, Co-op, Sainsbury's and Waitrose recall certain seafood products," *Which?*, January 25, 2021.

Legal traceability requirements used to require companies in the supply chain to be able to trace a product one step up and one step down, a principle allowing a product to be traced back to its source. Over the last few years, regulations have become more stringent and markets such as the EU and US now require that when aquaculture products are imported, documentation must be provided to identify the farms from which the product in each lot has been sourced. Governments in countries like India or Vietnam, which supply large volumes of shrimp to the US, have responded by tightening the traceability regulations that their exporters have to comply with. While this has improved the situation, the fragmented nature of the shrimp supply chain continues to pose a risk to actual farm-to-fork traceability.

Besides regulators, consumers have also started to demand more transparency. They want to be sure that the products they buy are authentic, safe, and don't involve any unsustainable practices or human rights violations. To give consumers confidence, aquaculture producers will need to become more transparent about the inputs they use, and how they farm and process their fish or other seafood.

Applying Digital Traceability Solutions in Food Supply Chains

The industry has started to respond. Pre-competitive partnerships—such as the Seafood Task Force and the Global Dialogue on Seafood Traceability—are working to develop strategies, solutions, and data standards to increase transparency and data-operability in seafood supply chains. Meanwhile, individual companies that emphasize the traceability of their seafood products are popping up all over the place. But how can regulators, retailers, and consumers trust all

Revealed: seafood fraud happening on a vast global scale*

Guardian analysis of 44 studies finds nearly 40% of 9,000 products from restaurants, markets and fishmongers were mislabelled

- **Is your fish a fake? How to spot seafood fraud and what to do if you're suspicious**
- **Fish detectives: the sleuths using 'e-DNA' to fight seafood fraud**

A Guardian Seascape analysis of 44 recent studies of more than 9,000 seafood samples from restaurants, fishmongers and supermarkets in more than 30 countries found that 36% were mislabelled, exposing seafood fraud on a vast global scale.

Many of the studies used relatively new DNA analysis techniques. In one comparison of sales of fish labelled "snapper" by fishmongers, supermarkets and restaurants in Canada, the US, the UK, Singapore, Australia and New Zealand, researchers found mislabelling in about 40% of fish tested. The UK labelling in that study, at 55%,

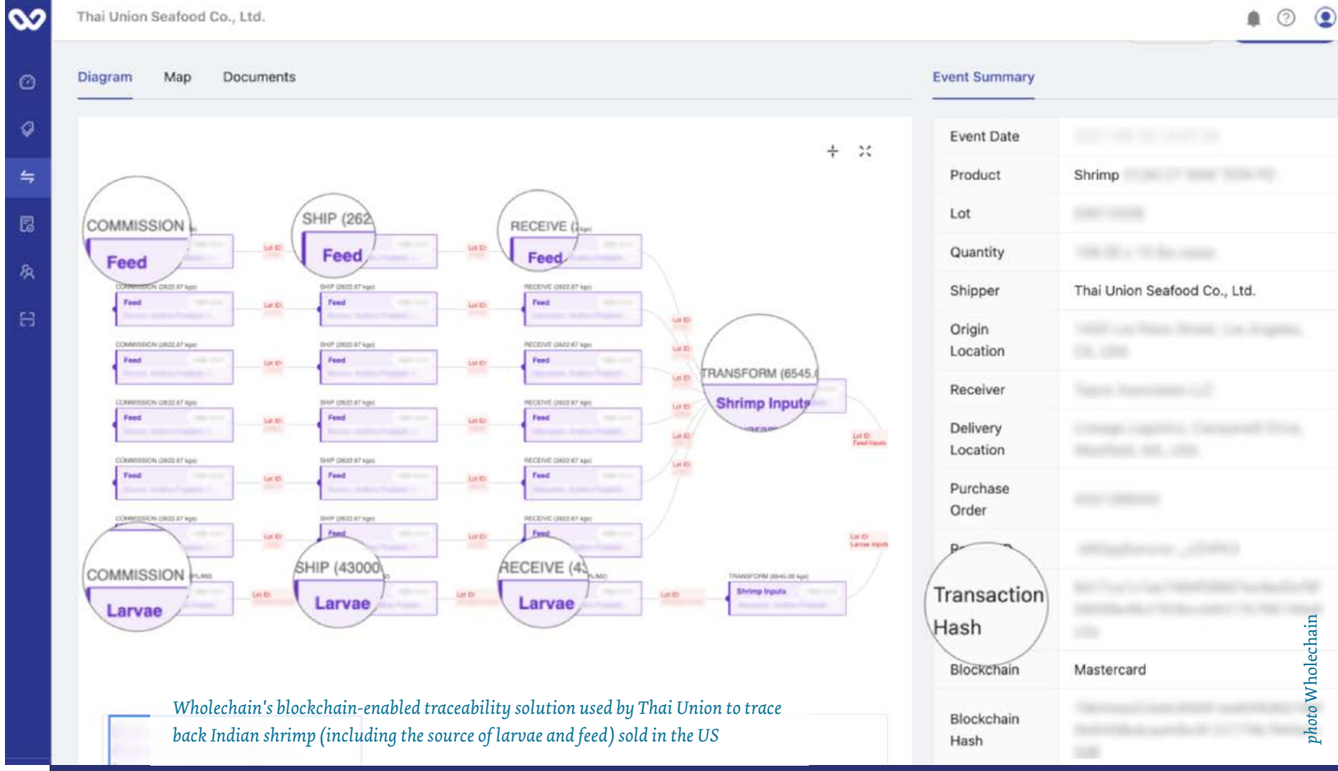
* SOURCE: Stephen Leahy, "Revealed: seafood fraud happening on a vast global scale," *The Guardian*, March 15, 2021.

"The traceability of aqua-culture products should no longer be a novelty. Rather, it should be an assumption that every consumer can make."
Jayson Berryhill, Partner at Wholechain

the claims made by these (groups of) companies? This is where digital traceability solutions come in: they have the ability to transform a tradition-al, opaque industry into one consisting of traceable and transparent supply chains.

For some retailers and wholesalers, the primary reason to implement digital traceability into their fish and seafood supply chains isn't necessarily consumer confidence, but rather their ability to respond swiftly when a product needs to be recalled. If relying on the legally required traceability documentation only, it could take days or even weeks to trace products back to their origins. And quite often, as a result, a greater amount of the product has to be recalled than is really necessary. But if every transaction in a product's life cycle were to be recorded in a digital traceability solution shared by all supply chain participants, the product could be traced back within minutes. That way, product recalls become more efficient, saving costs, and also preventing excessive wastage.

At present, consumer-facing digital traceability solutions are (often) not used for entire product assortments. Instead, they're primarily used for premium product ranges as they provide increased transparency and a way to verify the claims the companies selling these products are making about these premium products. Such ranges often come with a QR code on the package. Scanning this allows consumers to find out more information about the background of the product in question. The level of detail shared with the consumer varies hugely: some companies simply provide a "product journey" visualization while others may go so far as to give specific information about the time each transaction took place in the product's life cycle, as well as information about specific claims brand owners are making about the sustainability and social responsibility of the product.



Wholechain's blockchain-enabled traceability solution used by Thai Union to trace back Indian shrimp (including the source of larvae and feed) sold in the US

photo Wholechain

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Blockchain Overcomes Trust Issues

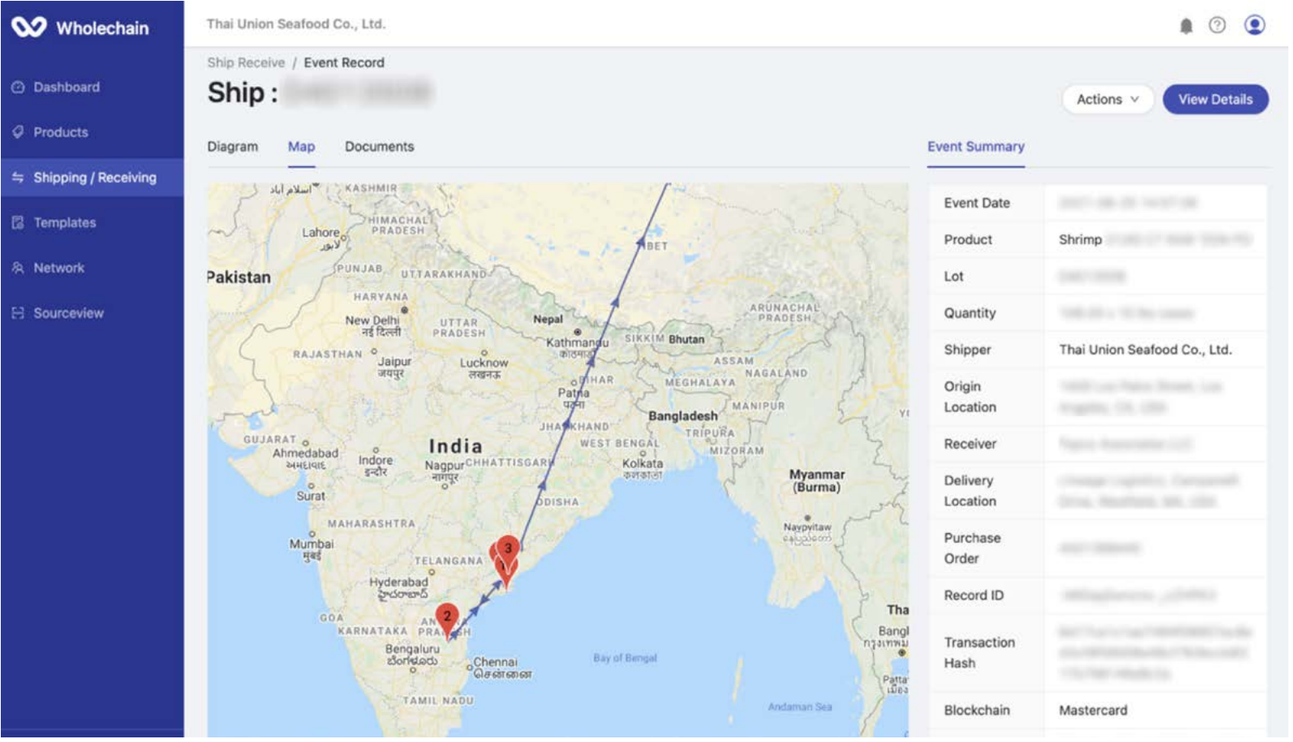
Today, most digital supply chain solutions are centralized systems using conventional database technology. Although these systems are relatively easy and affordable to develop, there are concerns, among other things, about the confidence that people have in the reliability of the data in these systems and the willingness of others to share information with these systems. Blockchain-enabled solutions have the potential to overcome these challenges.

Blockchain is a shared ledger and once data is entered into the system, it's permanent and can't be altered anymore. Every blockchain solution uses a technology called "hashing." With this technology, every piece of information, before entering it into the blockchain, is encrypted in a code of a fixed length. If the initial piece of information would be tampered with, the hash would no longer match. This is the most widely used argument to promote blockchain as a technology to increase consumer confidence in digital traceability solutions.

There are two types of blockchains: (1) public and (2) private or permissioned blockchains. In public blockchains, anyone can join the blockchain network; in a private or permissioned blockchain, participants are invited to join the blockchain network. Both public and private blockchains are decentralized, meaning they don't run on a single server but on a network of servers; there's not one single owner of the system, but everyone who's part of it owns it.

Private blockchains are currently mostly used in the food industry where hashing has the potential to increase the willingness of supply-chain partners to share data with each other. All data entered into the system is encrypted and shown as hashed code and, as such, remains confidential. But the owner of the data can choose to give certain blockchain participants access to the unencrypted content. In this way, an end buyer can be given a certain piece of information while preventing competitors that are part of the same blockchain from having access to that information.

In the end, blockchain is just the data carrier. Blockchain-enabled solutions are only as good as the data that is entered into them. Garbage in means garbage out.



Integration of Data-Capturing Devices and Enhancing Interoperability of IT Solutions

In any system—whether blockchain-enabled or a more traditional system—the system itself does not validate the quality of the data when it enters the system.

As extensively described throughout this Report, sensors, cameras, and other IoT devices that capture data across the supply chain are becoming part of aquaculture operations worldwide. If these technologies feed data into digital traceability solutions without human interference, the data becomes much more reliable. In other words, if an IT system is connected to data-capturing devices on one hand and is developed with blockchain technology on the other, both the reliability of data at the point of entering the system as well as the reliability of data exiting the system drastically improves.

To foster the full potential of digital traceability solutions, it's of the utmost importance that all existing software solutions and related data-capturing devices operated by supply chain participants can communicate with each other. In an increasingly digitalized industry, the interoperability of IT systems becomes extremely relevant. If systems can communicate, there's no need for human interference, and this reduces the chances of human error or willful misconduct. As a response to this need, several digital traceability solution providers and industry stakeholders are working together within the framework of the Global Dialogue on Seafood Traceability to align software development in the seafood industry in a globally accepted language, such as the GS1 standard. When all stakeholders apply the same coding standard, interoperability becomes the new "standard."

A More Reliable Future?

There's no doubt that digital solutions will dictate the future of accurately tracing aquaculture products: they have the potential to increase traceability in supply chains and offer a competitive advantage when striving to meet regulatory requirements as well as consumer expectations about transparency. Blockchain-enabled solutions integrated with existing farm management software and data-capturing devices would be the ultimate setup for a company. This kind of integrated system would give companies a real competitive edge, because you can't get more reliable than that.

Market Overview

To understand the market, it's important to understand how digital traceability solutions work. Every traceability solution needs a database or blockchain in which all the data is stored. If blockchain is used, the Blockchain-as-a-Service (BaaS) provider is the first type of company involved. The second type of company involved is the company that develops the applications that communicate with the blockchain and offer user interfaces to enter data into—and view data from—the blockchain.

The main BaaS providers are Amazon, Microsoft, IBM, and Mastercard. Besides IBM Food Trust and VeChain, companies that are developing digital traceability solutions on these existing platforms are at present mainly smaller players and startups such as US-based Wholechain and ripe.io. Here, we'll briefly look at three of the companies mentioned above that have applied blockchain-enabled traceability solutions to the aquaculture industry. But we're also including Trace Register, possibly the largest B2B traceability software provider to the US seafood industry.

trace register™

Founded	2006
HQ	the US
Capital raised	Self-funded

Contrary to the solutions mentioned above, Trace Register, with its TR5 product, focuses on B2B traceability software that enables seafood buyers and sellers to meet customer and regulatory requirements, such as those of the US's Seafood Import Monitoring Program. The company is part of the Global Dialogue on Seafood Traceability (GDST), and its system is interoperable, based on the GS1 standard. Currently, TR5 is probably the most used B2B seafood traceability system among US buyers.

Wholechain

Founded	2018
HQ	the US
Capital raised	Unknown

Wholechain uses the Mastercard blockchain and develops tools through which seafood suppliers can manage traceability information and consumers can view product histories by scanning a QR code. Its seafood customers include Topco Associates, a large supermarket purchase organization in the US, and Thai Union, one of the world's largest seafood corporations. In 2021, Wholechain partnered with Global Seafood Alliance's Best Aquaculture Practices (BAP) to integrate certification information into its blockchain solution.

IBM Food Trust™

Founded	1911
HQ	the US
Capital raised	Self-funded

IBM Food Trust is the platform through which IBM makes blockchain-enabled traceability software accessible for the food industry. It offers a host of applications, ranging from data entry tools to supply chain intelligence dashboards. Among others, IBM has partnered with Ecuador's Sustainable Shrimp Partnership and Norway's Seafood Association. The company aims to provide traceability solutions that give consumers detailed information on a product's journey and verification of claims about its sustainability by scanning a QR code.

vechain

Founded	2017
HQ	Singapore and China
Capital raised	Self-funded

VeChain was founded by Sunny Lu, the former CIO of Louis Vuitton China. What started as a subsidiary of Bitse, one of China's largest blockchain companies, is one of the largest B2B blockchain solution providers today. VeChain's seafood clients include Norwegian market promotion company Norway in a Box, Walmart China, and Singapore-based Blue Aqua International. Walmart China has committed to having at least 12.5% of its seafood traceable through VeChain's blockchain solutions.

B2B and B2C E-Commerce *to Overhaul India's $50bn Fresh Meat and Fish Market and Supply Chains*

Worldwide, B2B and B2C e-commerce is transforming the way that consumers and restaurants buy, and how aquaculture producers and fishermen sell, fresh fish and seafood. Traditional retailers and wholesalers are losing market share as B2B and B2C e-commerce platforms disrupt traditional supply chains. Digital technologies—whether digital traceability solutions or big data analytics algorithms to predict demand—are often an integrated part of e-commerce platforms. The amount of funding these platforms are attracting is also increasing rapidly. In India alone, hundreds of millions of dollars of capital has been raised recently by e-commerce platforms to fuel the further transformation of its $50bn fresh meat and fish market and the associated supply chains.

India's traditional fresh fish market and supply chains were dominated by wet markets and characterized by a lack of freshness and traceability. Curious about how B2B and B2C e-commerce is transforming all that? Read our blog post!

India's Two Largest Fresh Fish and Meat E-Commerce Platforms Jointly Raised Almost $500m in Just 2 Years

India's two largest fresh meat and fish e-commerce platforms—Licious and Fresh to Home—have raised $244m and $121m respectively over the last 2 years alone. The total capital raised since the inception of the two companies now stands at $339m and $152m respectively. Fresh to Home is the largest in terms of the home delivery of fish and seafood, while Licious dominates the home delivery market for fresh meat. Other B2B and B2C e-commerce platforms—such as Captain Fresh and TenderCuts—raised an additional $52m and $15m in 2020 and 2021. All of these e-commerce platforms aim to overhaul India's $50bn fresh meat and fish market in a country where consumers still largely depend on traditional wet markets and long, fragmented supply chains

ankur capital

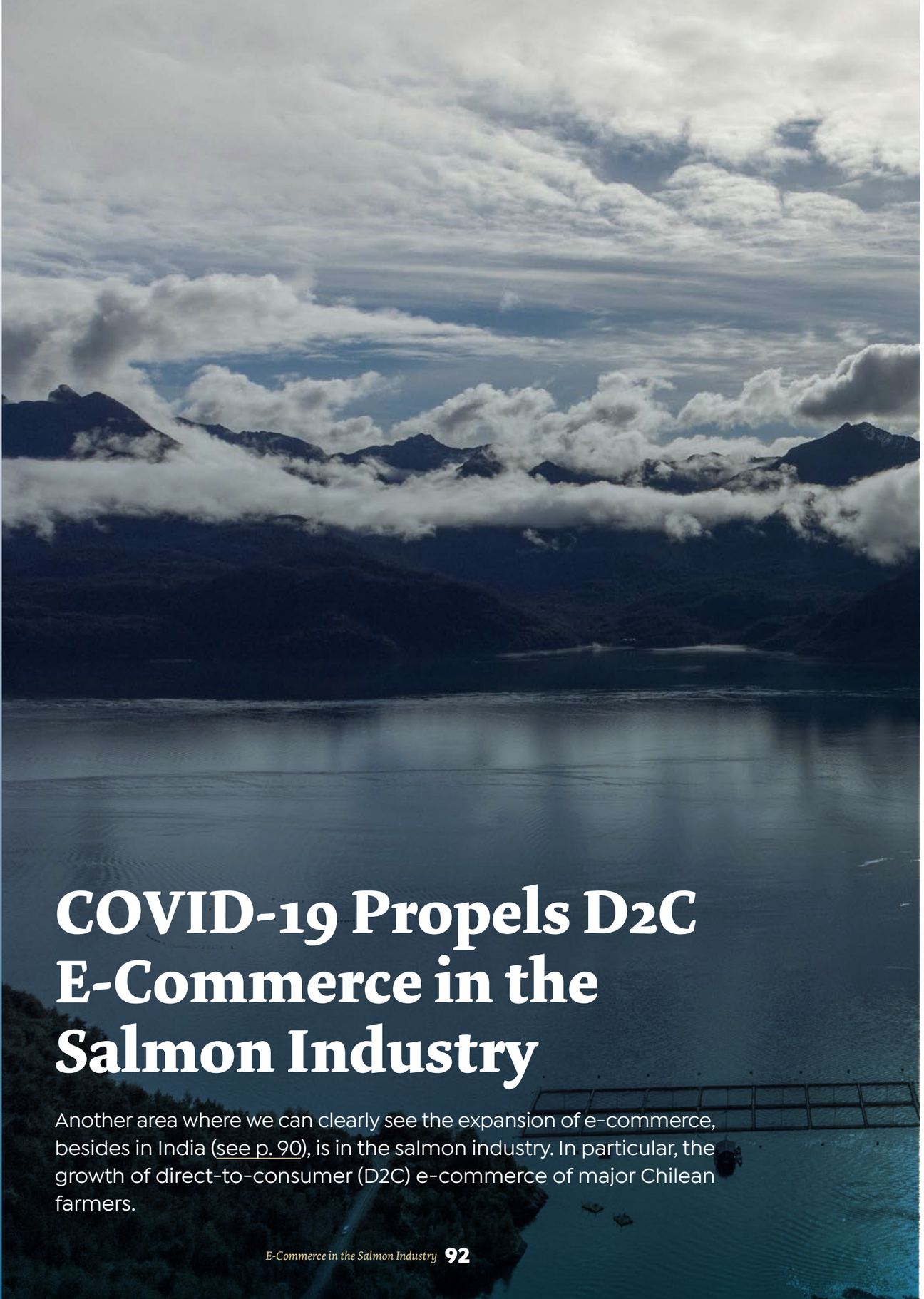
An early-stage VC fund investing in AgTech, food, and healthcare startups with transformative technologies for the next billion Indians.

HQ	Mumbai, India
Geographical scope	India
Sectoral focus	AgTech, food, and healthcare
Investor type	Seed and early-stage venture capital
# of companies in portfolio	21
# of companies in aquaculture	1
Companies in digital aquatech	Captain Fresh, since 2021

Ritu Verma
Co-Founder and Managing Partner

"To keep fish part of the staple diet in many parts of India and make it accessible to more people, aquaculture needs to expand. Not only does that mean innovations in aquaculture, but it also means ensuring that the farm-to-fork journey is highly efficient.

Digital aquatech streamlines supply chains and brings transparency, and more efficiently connects production to consumption centers. It also allows for more seamless financing. We'd been looking at the space for a while and then ran into Utham Gowda—Founder and CEO of Captain Fresh—who was solving what we believed to be the critical piece of the puzzle. In addition, we were excited to meet an entrepreneur who had gotten his feet wet in the industry and was a walking, talking encyclopedia of everything fishy! Seeing the demand for the tech and the related opportunities to make changes has been an exciting ride. At Ankur we can't wait to do more, and we believe that this is just the tip of the iceberg!"



COVID-19 Propels D2C E-Commerce in the Salmon Industry

Another area where we can clearly see the expansion of e-commerce, besides in India (see p. 90), is in the salmon industry. In particular, the growth of direct-to-consumer (D2C) e-commerce of major Chilean farmers.

> "We want to make salmon consumption easy for consumers and that's why we're prioritizing the offer of free delivery in Chile."
> *Bruno Stingo, Sales Manager for Mowi in Chile*

By: Matt Craze

Residents of Puerto Montt and Puerto Varas, two key cities in the $5bn Chilean salmon industry, have salmon filets on tap. From the online store Cocinasalmon.cl, one can choose between scores of varieties, ranging from Atlantic salmon and coho salmon to sea trout, with free delivery as an added benefit. I chose a 5 kg box of premium salmon, which comes in at about $75. My order, placed in the early evening, was delivered—free of charge—to my doorstep the next morning.

The company behind Cocinasalmon.cl is Mowi, the world's largest salmon farming company. Besides Chile, Mowi has been testing various e-commerce delivery channels in parts of Europe and North America to keep abreast of rapidly shifting consumer trends. Mowi started Cocinasalmon.cl in March 2021, in Puerto Montt and Puerto Varas, which serve the Chilean salmon industry in terms of labor, infrastructure, and logistics, and in capital Santiago, some 1,000 km to the north. The results so far have been "highly satisfactory" and free delivery will be expanded to another 9 cities in Chile, Stingo said.

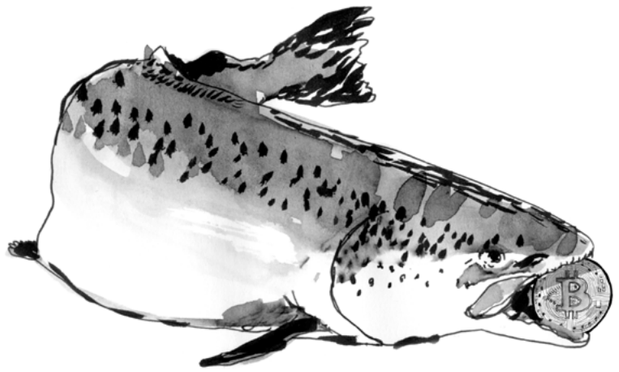
De-Commoditizing Salmon

The pandemic put Mowi's long-stated ambition to "de-commoditize the salmon industry" firmly on track. In the highly commoditized salmon industry, more than 90% of all products are sold through retailer brands, or unbranded to the food service industry. There are some exceptions to this trend, such as New Zealand King Salmon, which sells a premium farmed King salmon to high-end restaurants.

Mowi had already been working to self-brand its products, using Poland as a testing ground. Mowi-branded products are now in place in France and the UK, and sales in Asian markets are surging as well. The company targets a turnover of more than €1bn for its branded salmon products in the long term.

E-commerce is becoming increasingly important to Mowi's strategy, especially as more consumers have become comfortable with purchasing food online. Mowi has e-commerce channels in place to sell products in Chile, France, the UK, and the US.

The cataclysmic drop in demand from food service channels that followed COVID-19 restaurant closures forced salmon companies to accelerate these D2C strategies. While doing so, salmon companies increased their margins both by upping average sales prices and by taking margins from the retailers and distributors who would otherwise have sold the fish.



Other Salmon Farmers Quickly Followed Mowi's Strategy in Chile

Mowi's strategy in Chile was quickly followed by Cooke Aquaculture, which started offering online delivery services in Santiago from its Chilean farms. Several other Chilean farming companies started their own platforms later in 2021, including Australis Seafoods, Blumar, Salmones Camanchaca, and others. BluGlacier, a US company that markets the salmon of Chilean producers Blumar and Ventisqueros, even started accepting cryptocurrency payments for online delivery of its Oshen premium brand, including Bitcoin, BitPay, and Dogecoin.

The push to e-commerce wasn't just limited to Chile. Norwegian farmers have also been experimenting with online channels for some time. What's more, with the immediate loss of air passenger traffic, the logistical cost dynamics for salmon grown in Australia and New Zealand also changed overnight. Sanford, one of New Zealand's leading salmon farmers, fast-tracked a B2C strategy to boost deliveries from farm to household within New Zealand, faced with the sudden collapse of its main customer, the Chinese market.

Everything Points to Online Delivery Growing in Global Significance

During the COVID-19 outbreak, China's online food delivery industry surged by 28% to $51.5bn in 2020, and should have hit $57bn in 2021, according to Statista. The US delivery market reached $28.4bn in 2020, according to the same source. The newfound importance of e-commerce is something salmon farmers can't ignore.

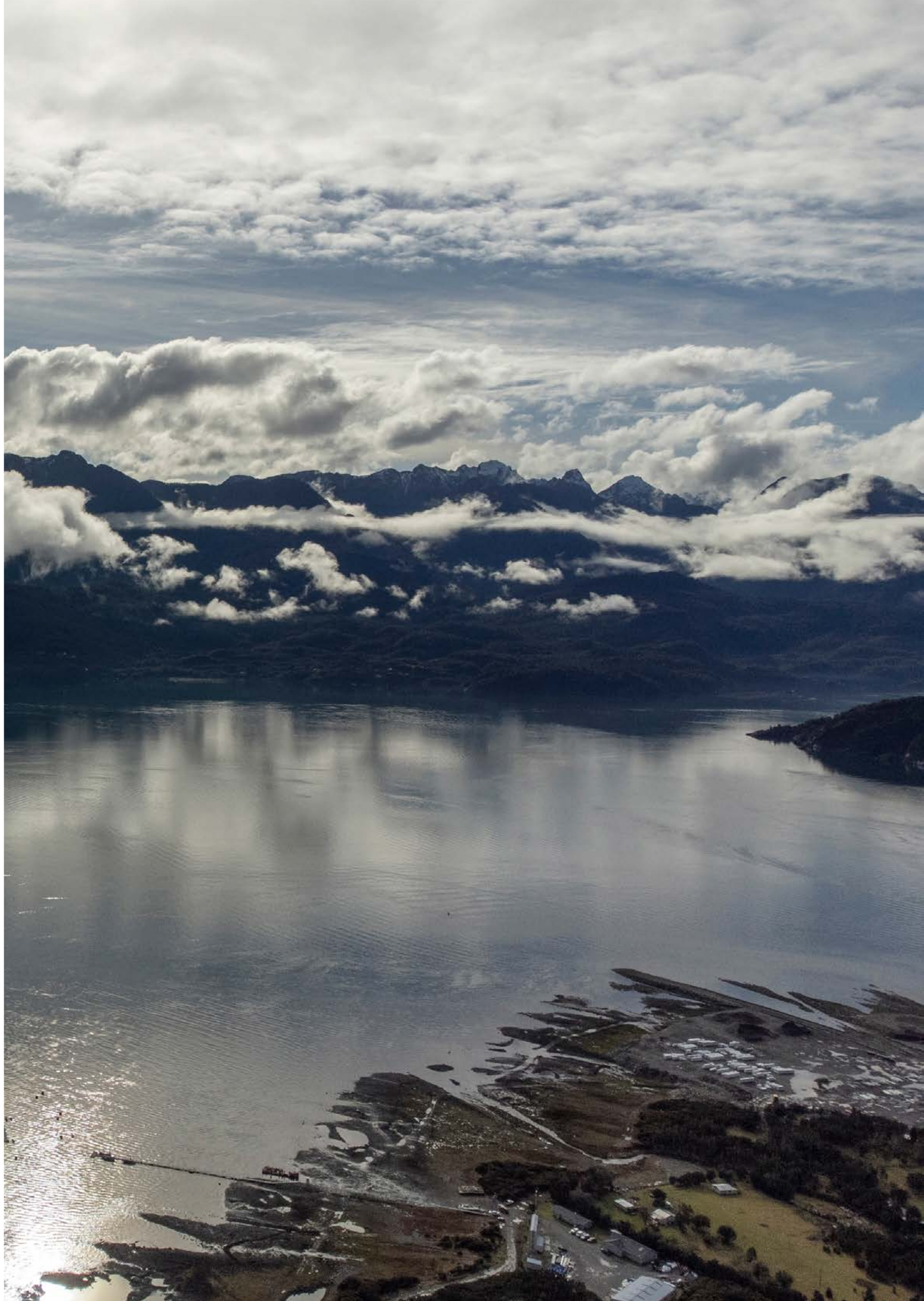
Companies have had to go through accelerated tech developments during the pandemic, adopting digital strategies on the fly, according to management consultancy firm McKinsey: "New business building is ever more important, and those that have embraced new channels tend to outperform those that don't."

Greater Emphasis on D2C May Drive Digital Traceability and Accountability Efforts, and Enhance Sustainability Performance

A greater emphasis on D2C may, indirectly, force salmon farmers to further enhance their sustainability performance and invest in the traceability of their products. According to the Norwegian Seafood Export Council, D2C marketing places a lot more emphasis on farmers to show consumers their farming practices and the inner workings of their farm.

Various salmon companies have announced to be working on implementing digital traceability solutions (see p. 84). These solutions enable individual salmon companies or groups of producers to collect and store data in a reliable and credible way and present that to consumers who can then scan a QR code on the package and read about a product's origin. For companies operating in Chile's spectacular fjords of Magallanes, e-commerce allows them to cast light on the pristine areas where salmon is farmed.

"More than anything, it's an opportunity to show what we already do," another Chilean industry executive said. "People don't understand exactly what's behind what we do, and they're often amazed when they find out more about our production process. As an industry, we've not done a good job at this in the past."



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