Bio Market Insights

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BLUE BIOECONOMY SPECIAL

THE COMPANIES AND TECH PIONEERING A TRILLION DOLLAR SECTOR

- TOP 6 BLUE GROWTH SECTORS BY BRAID THEORY CTO JIM COOPER
- FUTURE BIOTECH FROM UNICELLULAR ALGAE
- HOW A CARIBBEAN-BASED BIOREFINERY IS PROFITING FROM OCEAN CLEAN-UP
- MANTIS SHRIMP CAN PROTECT YOUR TECH: THE BIOMIMETIC DESIGN REVOLUTION

CONTENT

This issue focuses on innovation and emerging sectors in the blue bioeconomy

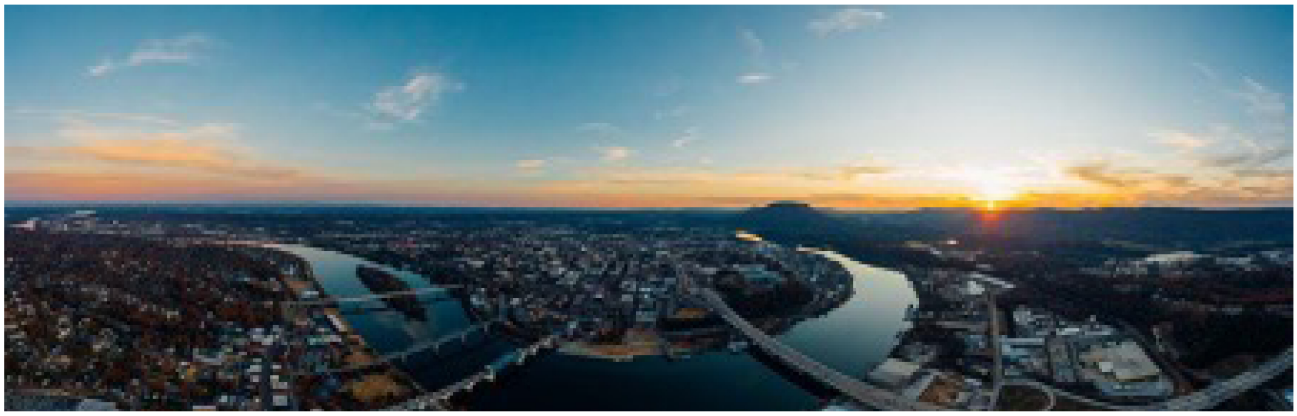
Editor's Intro and contents

Over the coming century, aquaculture and mariculture are expected to rival land-based farming in economic value. New forms of energy, biotech, food sources, feedstocks, and biomaterials are set to radically alter the way we relate to our oceans and waterways. This issue showcases the emerging dynamism of the blue bioeconomy.

Our feature articles explore the outer edges of innovation in sustainable aquatic farming and biotech. On page 11, we describe how a family of single-celled algae found everywhere from puddles to polar oceans could enhance our technology and fuel our vehicles. Page 6 profiles biomimetics companies that are finding natural design and engineering solutions beneath the waves. Our industry report on page 13 details the companies taking big data and robotics to aquatic farming. Data technology also features in Braid Theory CTO Jim Cooper's list of top blue growth areas on page 4.

The growth of the blue bioeconomy is a global phenomenon. Our content seeks to reflect this. We track developments across four continents through industry sources in North Africa, North America, China, and Europe. In our leader's interview, we spoke to Jason of C-Combinator, a Caribbean-based seaweed company balancing carbon capture with profit. For our contributor article, our Tunisian correspondent reports on how aquaculture is making the sustainability transition in his country.

The ascent of the blue economy opens unparalleled business opportunities. Yet, the sector also carries heavy responsibilities. Seven decades ago, global staple yields skyrocketed through intensive synthetic fertiliser use and monocropping. This leap in bioproduction is known as the green revolution — except it was anything but. Our post-war drive for maximum yields had catastrophic environmental consequences that are still unravelling.



OCEAN OUTLOOK: BLUE ECONOMY GROWTH AREAS TO WATCH

Jim Cooper, CTO and Managing Partner at accelerator Braid Theory, gives an insider's view on investment opportunities in the ocean economy.

A relatively nascent but growing area of technology, nestled between deep-tech and various industrial sectors, is bluetech—ocean-related technologies. In 2016, estimates indicated growth in the 200% range by 2020, but by early-2020 it became clear that investment was nearer 420% growth year-on-year since 2016.

Bluetech and its connected industries in the Blue Economy represents a relatively greenfield and blue-sky opportunity for investors and industry. Yet few have the domain expertise to understand all its moving parts.

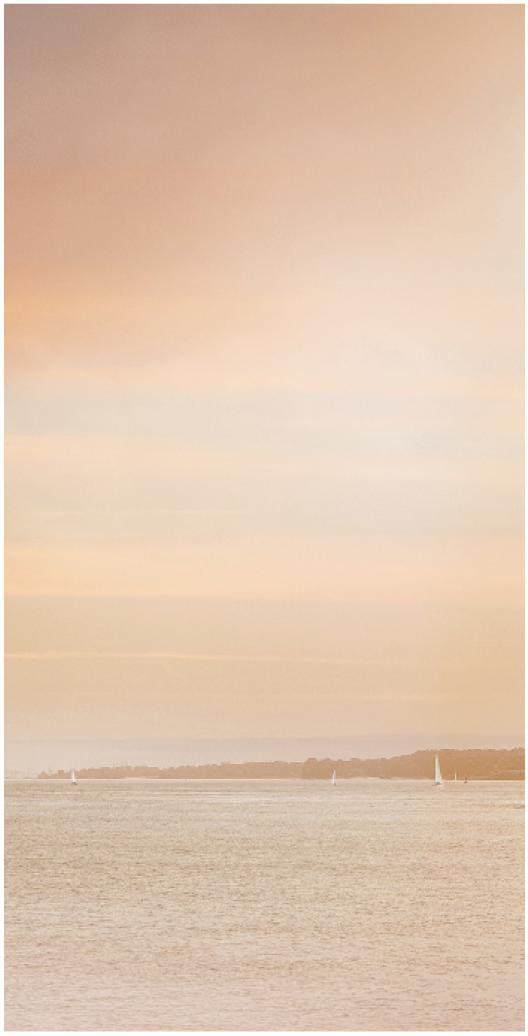
It's better to describe the Blue Economy and Bluetech in reverse order. Bluetech is applied to solve problems in the Blue Economy: bottlenecks, issues around regulatory affairs, climate change and as sources of food and energy. By contrast, those industries that comprise the Blue Economy include everything from aquaculture and fisheries, to shipping and logistics, ocean-based energy systems, coastal resilience, and even defence.

Over the past decade, I have worked with ocean-related incubators and accelerators to commercialise emerging technologies. As we have seen the growth in the broader Blue Economy sector, several areas stick out which are ripe for investment and a coming growth trajectory. Here is an overview of areas I've seen growing at astonishing rates.

Synthetic Biology

Synbio is 'building-with-biology' by creating new products from living organisms, or new tools to capture a part of that genetic engineering. Biofuels, bioplastics, value-added food ingredients, circular economy, alternative proteins, novel chemicals, biomanufacturing and biocircuitry, are all emerging and creating unicorns in the process.

Circular Economy



Circular economy is turning waste products into utility. These could be old fishing gear into nylon–based clothing, digested seafood waste turned into biofuels, and a host of other applications.

Kelp

Macroalgae can be turned into a myriad of products including value–added food ingredients, food prod–ucts from kelp (like seaweed snacks), biopolymers, tuning the kelp strains to produce more lipids, polysaccharides and optimising lighting for yield.

Shipping and logistics de–carbonisation

Shipping today is a complex web of transnational agreements, ports, shipping lines and intermodal freight systems, which relies heavily on petroleum or coal. Logistics is the engine of trade, and efforts are being made to reduce or eliminate carbon, or allow for offsets. This movement began many years prior to COP26, when shippers were increasingly being restricted by port visits and bunkering as well as the cost of fuel. New engineering is driving the adoption of decarbonisation, and "net–zero' goals.

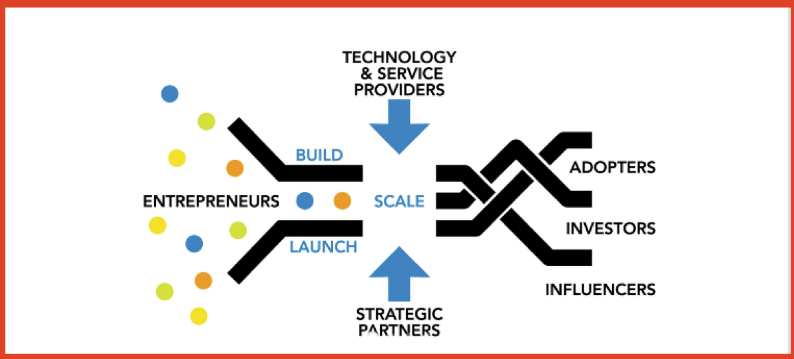
Coastal Resilience and Coral Restoration

Sea–level rise is coming, and, in fact, is already here. Storm surges, coastal erosion, and subsidence will cost coastal communities, both directly and to insure property in low–lying areas or areas subject to climate change. The situation is much worse for coral which is dying off due to factors related to climate change, including invasive species, acidification, higher tempera–tures, disease, pests, and human activity, like the destruction of mangroves or run–off. Several startups are confronting coral loss, especially where tropical communities are seeing loss of revenue from tourism. Tourists love to see the reef landscape, but where will they go when the reefs are stripped of life? Other companies are building concrete–related products to strength–en tide pools and revetment walls.

Enabling technologies

Finally, we cannot do anything in the Blue Economy without good quality data. This is acquired from a network of sensors, satellites, human inputs, piles of documents and forms, all linked by another network layer of dash–boards, apps, algorithms, AI and machine learning, which packages the information, to make it useful for those in the field. This data is used for everything from determining poisonous algal blooms for aquaculture, to LiDAR which measures the water column in oceanography and bathymetry.

There is an ocean of opportunity in today's Blue Economy. We are only lim–ited by our thinking to solve the challenging problems of our day—whether that is port congestion, or ocean plastic pollution. Facing these challenges head on, are a dedicated group of startups and scale up companies, which form a vanguard for our oceans. It is their ingenuity and entrepreneurship that are giving us a vision of what a positive tomorrow may look like.



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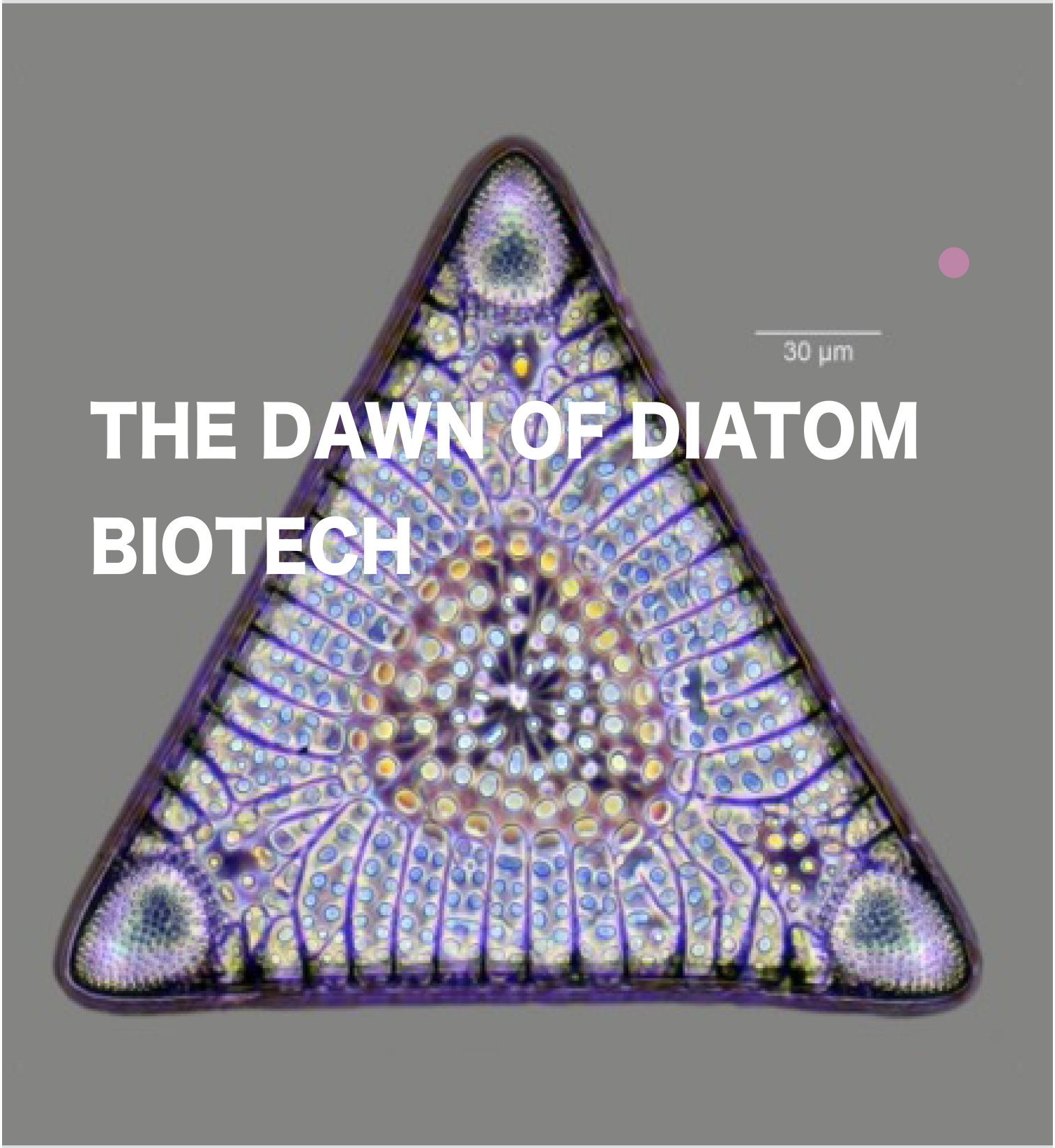


THE DAWN OF DIATOM BIOTECH

Diatoms are single–celled algae that hold applications in almost every industrial sector. We cover two companies at the cutting edge of diatom biotech.

Glass powerhouses

Diatoms are the most beautiful organisms on earth. Under dark–light microscopy, their outer shells (called frustules) resemble crystalline sculptures whose surfaces refract light into jewel colours. Each of the 100, 000 diatom species has a unique frustule shape, offering a masterclass in geometry. Some are pillboxes or stars, others Christmas crackers and ribbons. Inside, they are highly structured silica dioxide labyrinths. Pocked by chambers and pores, their surface areas can measure up to 200 metres squared per gram. This nano–scale origami is very difficult to recreate artificially.

The physical properties that make diatom frustules so visually arresting are attracting serious attention from material scientists. Their intricate structures hold proven uses as solar panel components, mediums for drug delivery devices, material for electrodes and energy storage devices, and biological wastewater filters. Jaw–Kai Wang, founder of a diatom bioengineering company, was drawn to them for two reasons. “First, the frustule is the only naturally produced nano–material. Secondly, its production is environmentally friendly. It is the only engineering material that can claim such distinction.”

The value of diatoms doesn’t end at their outer shells. The frustule envelops a tiny single–celled body. Here, we find lipids — an essential feedstock for biofuels. Some diatom species are richer in these fatty substances than other microalgae currently being developed for energy purposes. On top of this, the diatom requires few inputs. Its diet consists of carbon dioxide and water – even toxic wastewater will do.

An overlooked bioresource

That such high–value products could come from such a hardy and ubiquitous organism raises the tantalising prospect of a new bio–industry. Yet despite their virtues, diatoms have received little press or industry attention.

The only major industry around diatoms is currently the trade in diatomaceous earth – immense, subterranean piles of primordial diatom carcasses dug up as a mining byproduct. High–tech, high–value applications that exploit its nanostructures and lipids are rare. The investment limelight has fallen on their larger cousins, like kelp and sargassum.

Much of this neglect owes to their size. For a long time, even microbiologists were vague about their biology. Our psychological bias towards land–based raw materials has played a part. Microbial geneticist Thomas Mock explains: “Humans are land–based right? Therefore, there is much more knowledge about what you see on a daily basis. Algae that are currently used in biotech the most are all fresh–water species. This just reflects how we as a human society solve problems by picking the things that are closest to us.”

As scientific knowledge of diatom biology has grown, so too has the research on their applications. Few companies have taken the bait but there are some outliers. One of them is Swedish Algae Factory.

Swedish Algae Factory: Diatom Pioneers

Founded in 2014, Swedish Algae Factory is the world’s only company to have scaled diatom cultivation. They are also the only company to market frustules for their material properties. Currently, their biggest customer is the skincare industry. Algica, a trademark product, offers an environmentally friendly alternative to the chemicals and microplastics commonly used in SPF, moisturiser, cleanser, rheology modifier, and anti–pollutant skin products.

Swedish Algae Factory shows how there is little to separate scientific expertise from commercial feasibility in the diatom biotechnology sector. Its founder Angela Wulff is a marine biologist by training and her business idea came to her while observing diatoms in the Antarctic.

Wulff’s products work at the limits of biological research. In 2018, she co–authored a Nature paper on how the pore patterns on frustules scatter UV rays. Wulff and her colleagues propose that UV protection is the main evolutionary function of their elaborate makeup. Certainly, the frustules operate at suitably minuscule scales. The wavelength of UV radiation ranges between 10 to 400 µm (micrometres). Some frustules measure 5µm at its widest point with pore diameters as small as 0.15 µm. The diameter of a human hair is around 50 µm.

Now, Swedish Algae Factory is setting its sights on solar power. In January 2020, it announced a method that boosts solar panel production. When frustules are applied in a thin coat to panel glass, they boost their energy–generating efficiency by 4 percent in silicon–based panels and 60 percent in dye–sensitised ones. This application relies on the same properties that make frustules such effective UV shields. The pores act as countless tiny lenses that concentrate sunlight. The solar industry has long sought nanostructures fit for this purpose. Manufacturing them would be prohibitively challenging but diatoms offer a ready–made natural solution.

Aside from biological knowledge, commercial diatom manufacture also requires engineering acumen. Cost–effective products require a multi–dimensional value chain: companies

must install a manufacturing process that exploits many diatom applications simultaneously. SAF has cracked this. On top of offering products with multiple uses, their cultivation system doubles as a wastewater treatment method. Diatoms are grown in effluent wastewater emitted by a recirculating aquaculture system. Using this method, SAF is producing 30 kg of diatoms a year. Next, they are aiming for 1 tonne. By 2024, they want three production units yielding 10 tonnes of diatoms per year.

Yet, however impressive these figures, they still fall short of the amounts needed for cost-effective 'dia-fuel'. Larger scale diatom cultivation comes with unique problems. Although hardy and resource-efficient, diatoms face microscopic predators and diseases that cultivators must combat without chemicals that harm the organisms or toxify their products. This is something that Shenzhen Jawkai Bioengineering, a Chinese diatom R&D company, has been chipping away at.

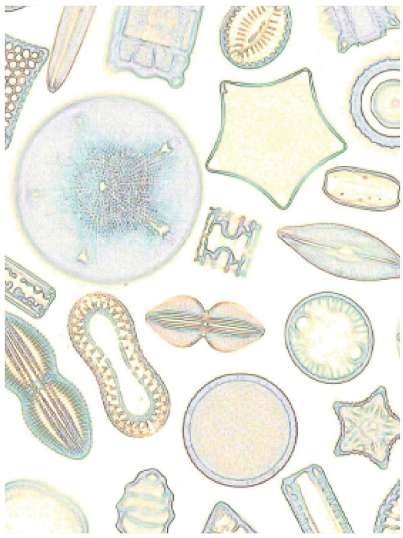
A world leader in diafuel

Shenzhen Jawkai Bioengineering was set up by fishery engineer Jaw-Kai Wang. Its ambition is to develop commercially viable diatom biofuels. Already, it has developed an open-air diatom culture system that holds EU, Chinese, and American patents. Using selected diatom strains from the Shenzhen coast, it achieved a world-first in 2017 by producing diatoms at a rate of 120 dry tons per hectare per year. Their groundbreaking trial takes advantage of the diatom's rapid reproduction with daily harvests.

"We are the only company that can produce near-pure diatoms without using herbicide or any artificial means of control," Wang told Bio Market Insights. They have now pulled off five years of continuous outdoor production at a commercial scale.

The million-dollar question is how much oil we can get from these harvests. Wang's diatoms have a lipid content of between 15–20 percent but this could go higher. One way to boost lipids in diatoms is to starve them. However, hungry diatoms grow more slowly. Coaxing more lipid formation in microalgae without limiting growth is a major problem across the entire biofuel industry.

Wang has a radical answer to this. He thinks biofuel producers should abandon their focus on lipids and instead exploit diatom's carbon content. This is an elegant solution to the lipid-versus-growth conundrum – carbon production doesn't compete with reproduction rates. A pivot to carbon would leave producers free to worry about the growth rate alone. Carbon-based biofuel requires a more complicated conversion process, but Wang thinks



this cost can be minimised. Industry interest in carbon over lipids could also catapult the diatoms' fortunes. Their main advantage over other microalga is their superior growth rate.

For Thomas Mock, gene editing can achieve more lipids alongside high growth. Already, researchers have genetically modified other microalgae to prime them for maximum fuel production. Diatoms could be subjected to the same methods as their diversity offers geneticists a chocolate box of potentially useful traits. "No other algal group has so many different species".

Diatom dreams

Swedish Algae Factory and Shenzhen Jawkai prove diatom commercialisation is possible. Yet much remains to be done. Few appreciate the scale of the task ahead more than Jaw-Kai Wang. "We need to develop additional applications so that the markets for frustule can be counted in terms of millions of tonnes. This is the only way we can produce biofuel in large quantities as a byproduct."

There is a predictable obstacle in the way of all this. Scaling such an embryonic and technical industry requires the kind of funding few private investors would be willing to wager. However, seaweed biotech once found itself in the same situation. By the 1940s, we already had an extensive scientific literature on their biochemical applications. Yet four decades later, nobody in the West had scaled harvests in a way that made seaweed competitive with other feedstocks. By the 1980s, European and American seaweed cultivation had floundered on experimental field trials and a string of failed startups. This changed very suddenly in the 2000s.

Some places are more favorable to high-risk innovation than others. Swedish Algae Factory managed to pioneer in the industry thanks to Sweden's a state-supported incubator system that provides early-stage support for startups. According to the European Commission, the country is the EU leader in innovation. On the other side of the world, Jaw-Kai Bioengineering profits from Chinese government support.

The real question is not whether the diatom industry is economically feasible, but for how much longer we can afford not to explore technically viable alternatives to our carbon fossil complex. The science is clear: diatoms could offer a way out. Larger algae were also once similarly overlooked but they are now spawning countless sustainability enterprises. Perhaps a similar public relations turn-around could happen for the diatoms. Their aesthetic appeal wouldn't be a bad place to start.

5 MINS WITH...
C-COMBINATOR

C-Combinator is a Caribbean-based biorefinery turning Sargassum into a range of high-value products. A year ago, we interviewed them on their innovative project combining environmental clean-up with profit. Here, we speak to SVP of Innovation Jason Cole for a follow-up on their work.

Wide Sargasso C

In the 1966 classic novel Wide Sargasso Sea by Jean Rhys, the Sargasso Sea is a sprawling metaphor for dislocation and entrapment. Rhys chose her symbol judiciously. Devoid of wind and currents, this infamous ocean gyre off the Caribbean coast has long been known as a graveyard of ships. Its otherworldly reputation also rests on the seaweed that floats upon its surface. Clotted mats of the brown algae Sargassum span thousands of square miles.

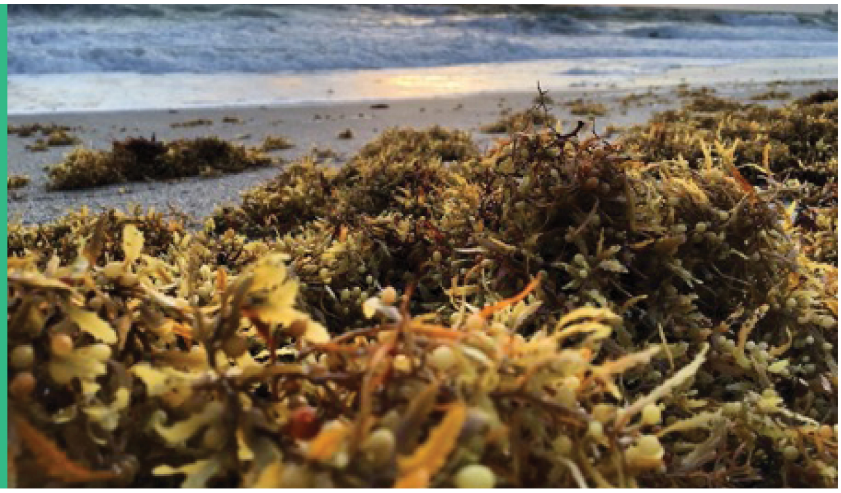
Recently, Sargassum has more than lived up to its fearsome reputation. Ten years ago, a completely separate bloom from the Sargasso Sea started appearing in the Caribbean and mid Atlantic Ocean – stretching from West Africa to the Gulf of Mexico. This bloom, called the Great Atlantic Sargassum Belt, has led to thousands of tonnes of the brown algae washing up onto beaches across the Caribbean beaches. The decomposing mass releases putrid chemicals that kill coral, fish, and the local tourism industry

C-Combinator saw a business opportunity in this. The company began collecting it as feedstock for their patented processing technology that turns macroalgae into high-value, carbon-neutral products. "Our goal is to manage the Sargassum bloom responsibly, and to avoid the environmental impacts it has had in the Caribbean." Instead of rotting away, the Sargassum becomes bio-stimulants for cultivation and ecosystem restoration, emulsifiers for pharmaceuticals and cosmetics, and bio-leathers for fashion, apparel, and interior design.

The products

Jason gives us a run-down on C-Combinator's current and upcoming algae products. "Our plant-based emulsifiers are in trials with select global partners in the cosmetics industry. They perform as well and is priced similarly to existing emulsifiers that have plastics, petro-chemicals, or other environmentally challenging ingredients. It's the first seaweed emulsifier so its natural characteristics are exciting. Our plant-based leather is in initial development and we hope to have it in the hands of designers within 3-6 months. This also has no fossil fuels, no plastics, and no harmful chemicals while being strong and workable from a sewing and quality feel perspective."

Product demand is strong, a trend set to continue. "Market demand for sustainable inputs is coming from a wide range of industries – cosmetics, chemical industries, fashion, energy, and agriculture are the most interested. The challenge for the industry will be to scale both sides of the equation." Of their many offerings, Jason is most excited about C-Combinator's biostimulant: "Our naturally-extracted biostimulants are already on the market, with significant pre-orders in place and final certifications nearly complete. It performs extremely well, with yield increases of



up to 40% and good drought resistance in a number of crops. We think this can have a major impact for local farmers, improving farm finances and decreasing pressure on tropical forests.. ”

Market edge

Macroalgae biomass isn’t a new industry. A sophisticated soda–seaweed industrial complex developed in Europe for hundreds of years, reaching its zenith in the early 1800 before synthetic alternatives were found. For millennia, macroalgae have been used as a natural fertiliser. What makes the current industry unique are the products being made and the scale of manufacture. Feed, food supplements, nutraceuticals, pharmaceuticals, and third–generation biofuels are now hitting the market. In 2016, global production hit around 32 megatons, double the figure ten years earlier.

In this booming algae biomass sector, C–Combinator stands out from the competition in several ways. The global algal biomass industry overwhelmingly draws on cultivated seaweed. Wild seaweed like C–Combinator’s Sargassum is responsible for only a minuscule fraction. “Sargassum is severely underexplored compared to cold–water seaweeds like Kelp. We are the first company to figure out how to make high value products from Sargassum through our proprietary and patented processes.”

C–Combinator also bucks industry trends through its “cascading” manufacturing model. Jason explains what this means: “each step or sequence creates a valuable product. So, besides our current product line, we are also developing additional products in biofuels, chemical inputs and agriculture. Our cascading biorefinery models means our whole process is sequentially designed to get the most value from the seaweed possible, in both monetary and environmental aspects, while minimising costs and waste.”

The cascading model ensures seaweed parts with lower market value are not simply discarded, as would normally be the case. C–Combinator appreciates that monetary value does not always reflect a natural product’s ecological value. “We use every part of the seaweed to create three products, all with a differential cost advantage. Some products create high profit margins, while others maximize carbon capture or displace emissions. We’re ultra–focused on a truly sustainable company, where long–term environmental restoration is sustained by a market–redefining manufacturing model.”

This does not mean that C–Combinator sacrifices profit. “By using a cascading biorefinery approach, we can create more value per ton of seaweed than others focused on a single product. We utilise more of the available biomass, reducing waste and increasing the incentive to remediate Sargassum inundations of shores. We carefully design our products to minimise environmental impact, which also enables us to attract customers focused on sustainability — in fact, we’re well into the process to be carbon offset certified. And finally, by focusing on a circular economy model, where Sargassum collected regionally can have significant local impact as an industrial input or environmental remediator.”

Remarkably, C–Combinator has achieved all this without taking the conventional financing routes. “We have been funded, and will continue to be funded, by values–aligned venture investors who are both institutional and profit focused, but who believe – as we do – that companies can profit by doing good for the world.”

Into the future

We asked C–Combinator what progress has been made since our last interview with them in 2020. “We’ve come a long way with our product development. Our biostimulants team has done amazing work developing a new product in a challenging field. Our research scientists have developed a new method for extracting useful products from Sargassum, and we’ve improved our understanding of what makes Sargassum unique compared to other commercial algae. Some lessons learned: don’t be afraid to start again with product and process design, everything takes longer than you want it to, and balancing biomass supply with product demand is a key challenge.”

Despite the Great Atlantic Sargassum Belt’s morbid reputation, C–Combinator is injecting life into the local economy and participating in the global sustainability transition. With all these achievements under their belt, what next for C–Combinator? “In 5 years, we will have expanded our offerings in agriculture, cosmetics and textiles, as well as new products in areas such as human health, packaging. and energy. We aim to have regional collection projects for areas affected by sargassum that integrates sustainable products, food, and energy into regional solutions that turn the sargassum influx into a regional advantage. Longer term, we are working with partners on larger scale supply chain solutions that create globally significant biomaterial, carbon, and human health solutions.”

BIOMIMETIC TECH HARNESSES NATURE'S INVENTIONS

Analysts predict that biomimetic products and services will be worth $1 trillion in 2025 globally. We look at three companies mining the oceans for natural mechanisms that could become future tech.

Fish, plants, and precious minerals: the economic value of the oceans has traditionally resided in its physical harvests. Now, companies are looking to marine biophysical processes for new sources of wealth. From self-replenishing ecosystems to biological adaptations, the sea abounds in elegant solutions for design and engineering. The task of deciphering them falls to biomimetics — a hybrid between engineering and biology that borrows from nature to improve technology.

Natural defences

Biomimetics is founded on the assumption that nature has worked longer and harder on certain engineering problems than we have. Under the pressure cooker of natural selection, only those organisms with the best strategies for obtaining energy, escaping predation, and resisting disease will survive. One company taking this principle seriously is Helicoid Industries in California.

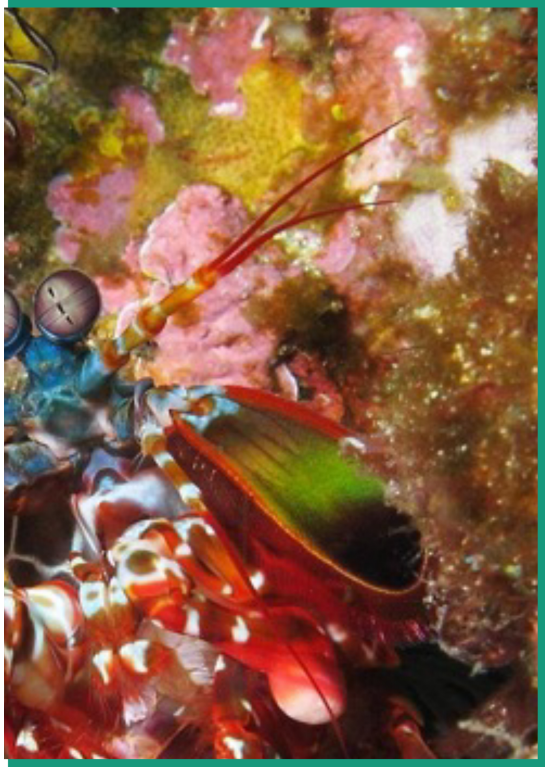
Helicoid Industries designs protective materials for industries as diverse as sportswear and aerospace engineering. Their clients demand materials that can weather high-intensity physical stress. Evaluating the performance of protective materials uses three criteria: toughness, strength, and stiffness. However, methods for engineering all three simultaneously have long eluded material science.

"In engineering, we usually design for stiffness and strength," explains Lorenzo, director of research and development for Helicoid Industries. Strength refers to the maximum load a material can carry before breaking. Stiffness refers to a material's ability to resist deformation under loads. However, these two features usually come at the expense of toughness – the maximum energy something can absorb before breaking. A strong, stiff material that cannot absorb shock-waves from high-speed impacts is useless for a motorcycle helmet or a turbine blade.

Helicoid Industries turned to the mantis shrimp for solutions. Their shatterproof clubs strike prey at speeds of 23 metres per second. These street-fighting crustaceans revealed something interesting. Balancing toughness against strength and stiffness does not necessarily depend upon inventing new chemical constituents. *How* a substance is arranged counts for more than *what* it is made from.

The claws of species like the mantis shrimp and lobster consist of thin, consecutive layers stacked on top of each other. Each layer twists by a tiny angle. The best analogue is a spiral staircase – what scientists refer to as a helicoid. This shape recurs through the animal kingdom, revealing another biomimetic principle. Nature is inherently lazy, tending to choose the easiest way to solve problems. Rather than generating new chemical structures for each high-impact scenario, evolution has selected for a transferrable shape that enhances animal protection regardless of the material that makes up their bodies.

Nature's preference for re-using successful blueprints is evident in Helicoid Industries' business model. The company embeds the patented helicoid structure into various preformed materials from flax to carbon fibre. Clients can adopt the helicoid technology using their own raw materials through an IP licensing model or order off-the-shelf pre-formed helicoid material that they can mould into products for their own pur



lighter and use less material, making energy savings.

The helicoid architecture enhances impact resilience in most fibre or inforced composites. This means it could potentially make sustainable bio-composite materials more competitive. Although bio-materials have attracted interest as eco-friendly alternatives to synthetics, their physical properties are still obstacles to wider use. "Their main problem is a relatively low performance over cost ratio compared to materials used for high-volume high-performance applications, such as glass fiber which is one of the most common composites used in automotive and wind rotor blades."

Arranging natural materials into a helicoid structure solves this. "We have demonstrated that by arranging fibers in a helicoid architecture, we can replace more than 50% in mass of glass fiber with natural fiber (e.g. flax) and at the same time achieve better impact resistance than a 100% glass fiber conventional composite. This allows us to increase usage of natural fiber composites in high volume applications traditionally made of glass fiber, hence greatly reducing the carbon footprint of these materials."

Concrete solutions

Biomimetic inspiration doesn't just come from organisms. Tech companies are also taking note of whole-ecosystem function. Every natural habitat is a finely tuned logistical triumph that would be the envy of any organisational specialist. By-products from one process become feedstock for another, ad infinitum. Every niche is filled and their opportunities exploited to the fullest.

As one of the world's few remaining wildernesses, the sea is a prime example of nature's circular efficiencies. Yet if marine ecosystems teem with organised vitality, concrete is a byword for lifeless monotony. As the world's most used construction material, its manufacture emits billions of tons of CO_2 per year. Concrete structures also steamroller habitat biodiversity – something especially evident along our coasts.

Humans inhabit shorelines by building artificial structures that reinforce the land against wave impacts. This coastal colonisation usually involves concrete, which has massive ecological costs. The interstices between land and sea usually support stunningly diverse living communities. When concrete marine infrastructures arrive, these disappear.

Israeli construction company ECOncrete is combatting concrete's carbon and ecological impacts in one. It was set up in 2012 by Dr. Ido Sella and Dr. Shimrit Perkol-Finkel, who died earlier this year. As marine biologists, they knew all about the damaging impacts of concrete. "Where concrete meets occur oceans, marine life suffers," says Maor Bezner, ECOncrete's head of product development and production.

Made using recycled materials and byproducts from the construction industry, ECOconcrete's alternative material looks and lasts like concrete. However, not only does it have a much smaller carbon footprint, it also holds ecological benefits.

When ECOncrete marine infrastructures are installed, something special happens. The line between the man-made construction and its natural environment blur. The two systems start to reinforce one another. From the perspective of sea creatures, ECOncrete material is prime real estate. Research shows that marine flora and fauna prefer it to concrete as a substrate. "Installation of ECOncrete infrastructure around the world has proved that where there is concrete based on biomimetics, there is twice the amount of biodiversity. Water quality improves 16 times and there is a seven-fold enhancement of carbon storage". In return, nature makes room for human activity. The lifeforms that accumulate on ECOncrete armour the structure against seawater corrosion, a chemical process that weakens ordinary concrete.

Water water everywhere

Habitats and organisms are the most obvious sources of natural inspiration since they are visible to the naked eye. However, biomimetic solutions can also originate in the microscopic cellular world.

Aquaommodate has created a water purification technology based on how protein cells sift out pollutants. Kidney cell membranes contain aquaporin and barrier molecules that recycle water in a circular manner. Aquaommodate builds these components into membranes used for desalinating seawater.

Other companies have used aquaporin and barrier molecules in purification systems. However, Aquaommodate has advanced a unique proprietary innovation. They strengthen aquaporins using a trick borrowed from diatoms, a tiny single-celled algae. Ocean diatoms protect their bodies with an outer shell made of silica. Aquaommodate adds this silica cocoon to aqua-

porins, increasing their robustness.

Aquammodate's purification technology began life at the Division of Applied Chemistry in Chalmers University of Technology. Professor Martin Andersson, one of the company's co-founders, led a research team here tackling global water scarcity. This social mission still drives the company and it has reaped rewards. "Investors are excited about the great potential of our solution, both in terms of the purely economic returns on investment that can be made in an increasingly attractive and highlighted growing water sector, but also in terms of the social and ecological impacts that an investment in Aquammodate can bring," says Simon Isaksson, who founded the company with Andersson.

Circular philosophies

Aquammodate's socially conscious tech indicates how biomimicry offers more than just a technical approach. In the hands of advocates like the Biomimicry Institute, it is even starting to supply an entire philosophy for the sustainable economy. This independent institute founded in 2006 by Janine Benyus consults, promotes and educates on nature-inspired design. Similar institutions exist in Germany and Japan.

Although humans share the same basic problems of species survival and resource allocation with other animals, our strategies for them over the last two centuries have come at a huge cost. While nature deploys limited resources in a balanced way, our solutions have centred around over-extraction, over-accumulation, and waste production.

Research coming out of these organisations coalesce around a shared premise: that nature is not simply an endless pool of extractive resources but a library of techniques and processes for building future economies. If our planetary crisis is rooted in anthropogenic disruption to once-seamless natural cycles, looking at nature can help us repair them.

While all this might sound esoteric, biomimetics is already big business. ECOncrete is used in more than forty marine installations in six seas and ten countries around the world. In a deal worth US$60 million, the government of New York State procured the material for Staten Island's sea defences. Looking ahead, off-shore wind power installations will bring a surge in demand for ecological marine infrastructure solutions.

Keeping nature in sight

These market successes are conferring a glittering reputation on biomimetics. Biomimetic principles also run in line with cultural currents, offering a nature-conscious philosophy that flies in the face of modernist hubris about human engineering prowess.

Industry hype can draw investment and public interest. However, it can also overshadow the importance of scientific rigour in successful biomimetic tech. Lorenzo of Helicoid Industries is adamant that science stays at the forefront: "Really to make it profitable and to be serious about biomimetics, you really need to understand the biological concept".

Biomimetics is not just a matter of lifting impressive mechanisms from biology and inserting them into the investment pipeline. For example, developers also need to understand why nature consigned certain strategies to the dustbin of evolutionary history. "You need to understand the trade-off behind [natural mechanisms] — so, why certain features have developed and why others didn't develop," explains Lorenzo of Helicoid Industries. This enables engineers to negotiate similar trade-offs in their design process, allowing them to predict the extent to which enhancing one performance metric might undermine others. Understanding the logic of evolutionary problem-solving is key to profitability. "If it's just marketing, at some point, it will stop".

Of course, biomimetics does not automatically translate into sustainability. it could just as easily optimise fossil-fuel extraction as water filtration. However, following nature's lead does hold the promise of healing the rift between economic and natural systems. Biology runs on conservational principles, meaning organisms and ecosystems strive for energy savings at all costs. The natural world is lazy and it's been working out how to get away with it for billions of years.

We should also remember that nature's optimising virtues have their limits. Evolution prefers workable strategies that require less effort over optimal but expensive ones. Humans share this tendency. Resistance to change is something that preoccupies Maor Bezner of ECOncrete. He explains how "Innovative design and technology based on biomimetic principles face the challenge of changing paradigms in the marine construction industry". Whether we can shake this inclination for short-termism and close our linear economies with practices like biomimicry remains to be seen.

DIGITAL TECH MAKES A LANDING IN AQUACULTURE

Precision aquaculture allows even the larg-est fish farms to manage health, feeding, and rearing conditions to a decimal accuracy. We give a rundown on the tech, the companies developing them, and how they can bridge the productivity gap between land-based and aquatic agriculture.

Data-driven digital tools have finally migrated into aquaculture. Precision tech is now the fastest-growing sub-sector in aquatic farming, with a global market valued at US$ 422.43 million in 2020. This is projected to reach $1,209.96 million by 2028. The regional market that will see the fastest growth between 2021 and 2026 is South America.

Currently, a few established players dominate the field: AKVA group (Norway), InnovaSea Systems (US), Steinsvik (Sca-leAQ) (Norway), Deep Trekker (Canada), Aquabyte (US), and Eruvaka Technolo-gies (India). These large companies sell conventional aquaculture technology on top of their precision tech offerings. However, smaller companies are also innovating through a narrower product range that fo-cuses on precision tools. Drone manufac-turers and underwater vehicle specialists are also jostling for a foothold in a sector set to revolutionise aquatic cultivation.

Overcoming the land bias

The precision aquaculture boom comes as no surprise. Aquaculture itself is the world's fastest-growing food production system. Mounting global demand for pro-tein and concerns to preserve wild stock means that farmed products are expected to supply almost 62% of fish for human consumption by 2030.

Upping production in aquaculture, however, will be an enormous challenge. Water-based food cultivation lags considerably behind that of agriculture. Each year, the earth's landmasses and oceans combined produce 105 gigatons of biomass. Although the land and sea contribute roughly equal amounts to this, terrestrial agriculture contributes a respectable 9.8 gigatonnes in food products while aquaculture makes up only 0.18.

The knowledge gap

Aquaculture faces a major obstacle to playing catch up with land agriculture output: we simply know much less about cultivating underwater. For two centuries, we have gained practical knowledge about disease and nutrition for land species. In aquaculture, these factors are harder to observe and control. This is especially the case in mariculture where changeable ocean currents and weather conditions hamper reliable predictions. These criti-cal variables can make or break a farm's revenue stream.

The precision aquaculture industry offers hardware and software for reducing these uncertainties. Hardware components of precision systems include robots, remote sensors, smart feeding apparatuses, and climate control systems.

Sensors are the most important of the hardware offerings. From underwater video monitors to hydroacoustic technology and aerial drone imagery, they are the beating heart of any precision operation. Whatever their form, sensors collect continuous data on fish and their environments that would be near-impossible to obtain manually.

Counting, sorting, predicting

The software side is where precision aqua-culture really adds value. These include digital programmes that store, assemble, and analyse sensor data. The internet of things also holds major applications – for example, linking sensors monitoring differ-ent areas and scales. Integrating disparate data streams in this way affords farmers a holistic view of their operations.

Canada is the leading hub of R&D in precision aquaculture software. Dalhou-sie University located in Halifax is the headquarters of Deepsea, an ambitious ocean economy data project. They have harvested data from hundreds of real-time underwater wireless acoustic sensors at multiple Canadian fish farms run by indus-try behemoths Cooke and InnovaSea. Every day, these sensors take 100,000 measure-ments daily from 11 million data points on temperature and tilt, salinity, dissolved oxygen, blue green Algae levels, chlorophyll and turbidity. IBM is a major partner in the project. DeepSense's software is built around their Power Systems data infra-structure.

Similar research is underway in Norway. Here again, IBM is bringing its computa-tional clout to bear on one of the biggest problems in aquaculture management: lice management. Under the Seafood Innova-tion Cluster programme, the software giant has collaborated with industry stakeholders on a data platform called AquaCloud. Using lice-count and environmental data from 2000 salmon cages along the Norwegian coast, it predicts sea-lice outbreaks two weeks in advance. Currently, the early-warning system has a 70 percent accuracy rate.

AI systems that can count underwater with speed and accuracy would have numerous aquaculture applications. Aquaculture feed company Derwent Group is collaborating with Lucentia Lab in Spain on an AI device that takes automatic headcounts in fish cages. Knowing exact population numbers would prevent costly over-feeding, a prac-tice that pollutes water and attracts preda-tors. In April 2021, the project completed an initial proof-of-concept. Ultimately, the partners are aiming for 90 percent count accuracy.

Precision aquaculture software is not just optimising existing farming techniques. Cermaq's flagship product iFarm signals a paradigm shift in stock health man-

agement, one that would be unthinkable without the data-crunching power of digital processing. The iFarm system centres on a sensor chamber that recognises individual salmon based on their bodies' unique dot patterns. When fish swim through the chamber, a computer evaluates their weight, lice count, wounds, and other signs of illness.

Until now, aquatic livestock has been treated as single, massified populations. However, from an economic and epidemiological perspective, sorting fish individually makes sense. It nips disease and parasite outbreaks in the bud before they damage large swathes of stock. Farmers would no longer rely on wasteful mass treatment and disposal methods guided by rule-of-thumb intuition.

Smart farming

The systems described above are essentially descriptive. They give farmers an accurate picture of the underwater world their livestock inhabit. Now, the challenge is to create software that can participate in the day-to-day decision-making of farm management.

In Canada, DeepSense is developing machine learning software that turns sensor information into a menu of evidence-based management strategies. Farmers simply select which of these to implement. DeepSense's decision platform will be able to generate optimal regimens for feeding and lice management using fish biomass and activity data,

UK company Observe Technology is embarking on a similar project. Their data analysis software notifies farmers when to increase or decrease feeding. Over time, the software learns which factors influence productivity most in both individual cages and across the farm. Observe Technology has already sold its AI software to farms around the world. In February 2021, AKVA Group – a major player in digital aquaculture – acquired 33.7% shares in the company.

The labour productivity gap

Another factor behind the land-water production gap is that aquaculture tends to be more labour-intensive. Traditionally, cheaper labour costs have underpinned Asian dominance of the global aquaculture market.

Again, precision aquaculture offers solutions. Drones or automated bots could feed, track, and manage fish in ways that are responsive to environmental changes and stock health. Although completely unmanned farms remain only a theoretical possibility, the intersection between robotic hardware and AI could well accelerate the sector's transition to becoming a low-labour, high-skill sector.

Automated AI management systems are being developed around the world. Some have been implemented at a small scale. For example, Norwegian company Fishery Equipment Enterprise has developed an automated smart monitoring and feeding system. An online monitoring system tracks water pH, dissolved oxygen, and temperature in real time. This data is fed to the feeding system that automatically dispenses the correct amount of bait.

A 'Feeding Robot' developed by Finland's Arvo-Tec company can remotely control feeding and water quality through a web interface. The system takes water temperature, oxygen content, biomass, and other parameters into account in deciding how much to dispense.

The life aquatic

Machine learning and remote sensors are already used in land agriculture, finance, and manufacturing. Aquaculture may have been slower on the uptake but this has not been without its advantages. These technologies are not fundamentally new, having been trialled in similarly complex optimising scenarios. Moreover, most people in the developed world are veterans of app interfaces for algorithmic technologies.

However, aquaculture does make specific demands on its digital tech. The major differences are the biological and ecological datasets specific to the sector. Hardware and software design must integrate knowledge about fish behaviour, physiology, and ecological interactions.

The importance of animal-machine interaction in precision aquaculture is well-understood by Norwegian researcher Eleni Kelasidi. She is a senior researcher at the independent research institute SINTEF Ocean where she develops unmanned underwater robots for aquaculture management. Her machines are designed to respond intelligently to fish movements and behaviour. This cutting-edge research will support next-generation precision tech that pairs machine learning software to autonomous robots. Getting biological and mechanical systems to work in concert is vital for creating devices that can perform essential tasks with minimal human supervision.

Second, aquaculture hardware must be fully adapted to their underwater environment. This means resistance to prolonged submersion, including in seawater. Since the sensors must collect data for long periods in areas that are difficult for human divers to access, devices must be low-maintenance, reliable, and energy-efficient.

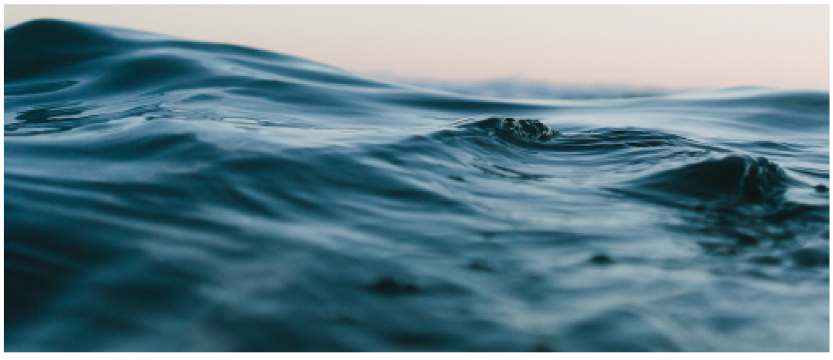
Certainly, the most effective way of adapting digital tech for aquaculture applications is the university-industry pipeline on the DeepSense model. Its multi-industry partnerships ensure innovations rapidly move into realistic field trials on large established commercial farms — the real test for any emerging agritech. This fluid interchange between labs and industry allows systems to be refined more quickly into marketable products.

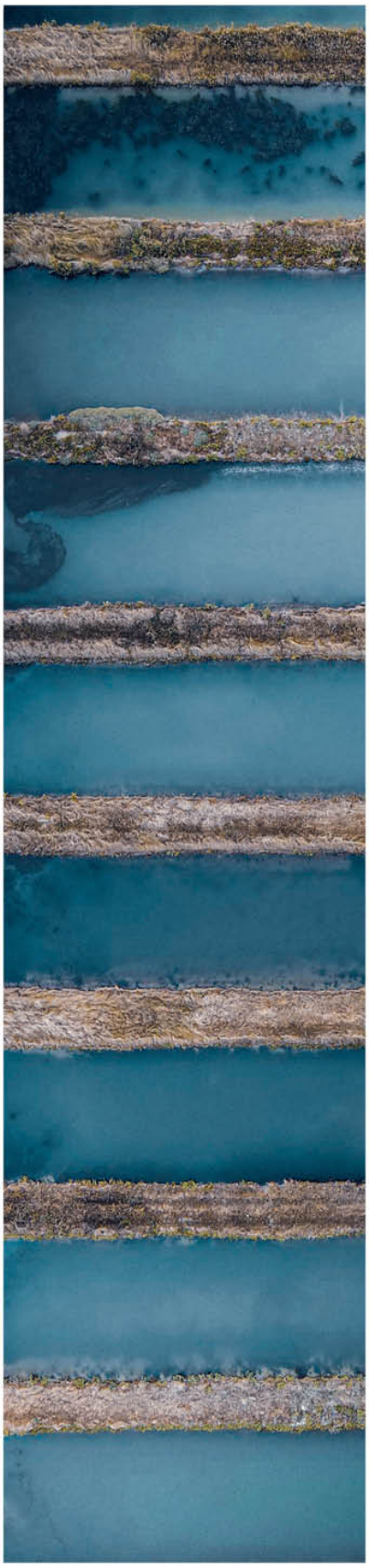
Principled precision: Can the blue economy go green?

Big data encourages a systems approach to farming. It fosters appreciation for how numerous interconnected factors affect productivity and how minute adjustments to management can result in large savings across the board.

There is no doubt that precision aquaculture will become a permanent feature of the blue bioeconomy. But whether its driving principle of systems thinking will extend beyond individual enterprises to the industry as a whole remains in question.

Technologies are only ever as sustainable as the infrastructural ecosystems they sit within. For the production gap between land and water-based agriculture to be closed responsibly, precision aquaculture must look hard at the entire lifecycle of its tech. This includes the materials and processes used in their manufacture as well as how their devices get decommissioned. Farms must also pivot towards renewable energy sources. Only a collaborative effort between adjacent industries across the supply chain will turn precision tools into the basis of a truly secure food system.





SUSTAINABLE AQUACULTURE IN TUNISIA

Aquaculture student Mohamed Jaidene reports on how Tunisian aquaculture is making the sustainability transition with an eye on development.

Green horizons

Aquaculture is Tunisia's fastest-growing agricultural industry. Production skyrocketed from 2855 tonnes in 2006 to 22, 723 in 2019. New projects and facilities are being established every day.

While the sector is boosting the economy, efforts to ramp up the sector have had environmental costs. One unsustainable yet highly profitable practice has been the monoculture in predator species. Fish at the top of the food chain like sea bream (Sparus aurata) and sea bass (Dicentrarchus labrax) devour resources while generating massive amounts of waste.

Growing environmental awareness among Tunisians has meant that the industry is starting to move towards alternative aquatic harvests. Here, we look at some enterprises that are making Tunisian aquaculture sustainable.

Algae farming by Selt Marine

A remarkable aquaculture project has taken shape in a lake in northern Tunisia. Here, farmers harvest red algae (Gracilaria verrucosa) that they have cultivated themselves. This is an algae farm owned by Selt Marine. After waiting 20 years for authorization, it became the first and only company in Tunisia to cultivate algae on an industrial scale.

Their main applications are as food texturizers and thickeners such as agar-agar.

Traditionally, these essential products were made from animal-based gelatin. Now, demand for vegan alternatives is growing - particularly those derived from algae. Red algae is also making inroads in the beauty and pharmaceutical industries.

Selt Marine, a food texturizer company, is the leading algae farming project in the Mediterranean. Its main activity is the production of food texturizers and thickeners from red algae. However, they have also succeeded in producing and commercializing the first vegetarian nuggets in North Africa. The nuggets are made entirely of marine algae and have the same flavor and texture as animal-based nuggets.

Food isn't the only product that comes out of aquaculture. It is a vital source of new, sustainable biomaterials. Selt Marine's research department is also working on biodegradable bottles and noodles made from algae.

Economically, their business model has been a success. The company is already planning to expand its cultivated area to 80 hectares with an expected harvest of 7000 tons as declared by its CEO Mounir Bouklout.

Algae farming is the most environmentally friendly method of aquatic biomass production. is the only aquaculture activity with almost no carbon footprint. Culturing the seaweed and harvesting the biomass are the only moments in the algae's life

is ready. Ten kilos of algae is produced from every kilo of starting culture. 10% of the harvested biomass is set aside for kickstarting a new culture cycle.

Spirulina

Algae isn't the only sustainable species being cultivated in Tunisia. We have seen a boom in the Cyanobacteria culture, particularly the Arthrospira genus. It is used as a dietary supplement due to its high protein and polyunsaturated fatty acids content and is a common ingredient for the beauty and pharmaceutical sectors.

This species culture requires little land for cultivation and low energy inputs while the sector relies primarily on renewable resources. It is still produced on a traditional scale since we still believe that perfection comes from artisanal work rather than machines. Currently, there are approximately eight spirulina farms around Tunisia with some of these located in Sidi Bouzid, Mahdia, Nabeul, Gabes, etc. In 2017, total production came to 6.5 tonnes of dry product.

Aquaponics

Aquaponics is also gaining traction in the market. "Tunisie Aquaponie" is one of its newest and most enthusiastic proponents. Founded in 2018 and now drawing a revenue of around $725, 870, the company installs aquaponics systems in urban residences and businesses. It also organises training and events around sustainable rearing practices in cities around the Mediterranean.

Aquaponics is one of the most sustainable food production techniques - a hybrid of agriculture and fish farming that sees freshwater fish being cultivated alongside plants. In recent years, we have seen massive government investment in this as it provides two major sources of nutrients at the same time. The method also economises on resources, particularly water – an important consideration in Tunisia, which tops the region for water scarcity ratings.

The Nile tilapia (Oreochromis niloticus) is the main species used. It has a good conversion ratio, it is a herbivore, and it is fast growing. Essentially, the tilapia produces more for less, and could claim the title of having the lowest carbon footprint among farmed fish species.

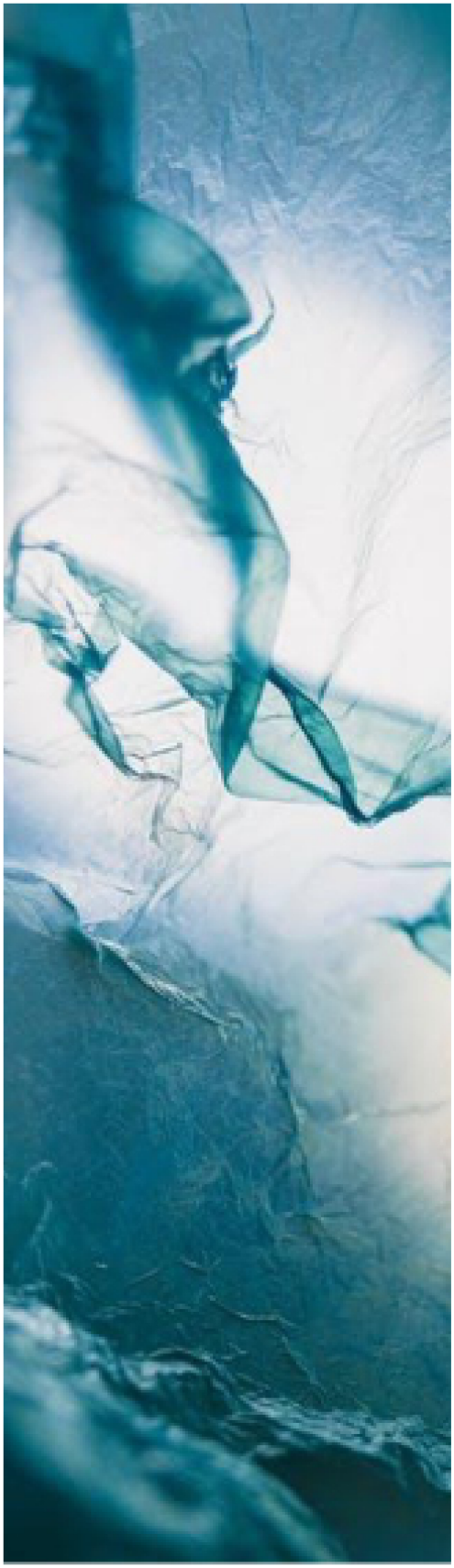
An international partner in sustainable aquaculture

Many international programs are pushing for sustainable aquaculture development in Tunisia. One example is the United Nations Development Organization's (UNIDO) project. It aims to apply more resource-efficient and circular production practices in Tunisia's aquaculture value chain. This is part of the SwitchMed Blue Economy component which encourages ecologically and socially beneficial economic activities in coastal regions. The project was launched at an event featuring representatives from the Tunisian government, the European Union's Delegation, and 25 companies from Tunisia's aquaculture industry.

Tunisia is also forming international agreements to promote sustainability in the aquaculture sector. The largest and most detailed is the €900, 000 Celavie cooperation project between Tunisia and Italy, funded by the European Union. It specifically aims to construct a dependable aquaculture system in Sicilian and Tunisian territories through aquaponics.

The private sector and SDG

Tunisia is a small developing country. Balancing sustainability with development is a challenge it shares with other nations attempting to modernise at the beginning of the twentieth-century. The post-2011 democratic reforms have gone a long way to fostering a business environment where private initiatives can help meet these goals. Before this time, economic projects were the exclusive preserve of the presidential family. Now, the entrepreneurial ecosystem has diversified beyond imagining. Thanks to these changes, green aquaculture could well shape Tunisia into a model regional economy.



5 BLUE ECONOMY START-UPS MAKING WAVES

The value of the global ocean economy is expected to double to $3 trillion over the next decade, according to Forbes. The transition to a sustainable blue economy has innovation at its core. Who better to come up with these innovations and explorations than entrepreneurs and startups? Here, we give the spotlight to a selection of 5 startups to be on the lookout for.

C-COMBINATOR: One of the few global companies exploring the benefits of seaweed, C-Combinator's innovative bio-manufacturing, with a system-level approach, turns seaweed into sustainable solutions. Their scalable systems are capable of supplying to a global economy while having a measurable positive environmental impact. So far, their products include vegan leather and the SeaBalance line of broad-spectrum emulsifiers.

DESOLENATOR: A Dutch startup tackling the drinking water crisis by building water independence. The UN has estimated that by 2030, half the world's population will live in water-stressed areas, stressing the urgency of the current water challenges. Using 100% solar power, Desolenator can purify all water sources into safe, drinkable water. Using this technology to give access to clean water also decreases the need for highly priced water.

MINESTO: This Swedish startup is looking to unlock the potential of ocean energy, one of the least explored forms of renewable energy. They harvest energy from ocean currents and tidal streams. Using an underwater 'flying' power plant, "the turbine is pushed through the water in an eight-shaped trajectory, reaching a water flow several times higher than the actual stream speed and thereby diffusing power to a generator". Minesto is currently working with Faroe Islands in their ambitious plans for 100% clean energy by 2030.

OCEANIC LABS: Based in Cambridge, MA, Ocean Labs is an ocean technology skunkworks dedicated to creating scalable tools for ocean monitoring and conservation. This startup brings together the "risk-averse" culture of traditional ocean engineering with the "risk-tolerant" practices of modern rapid prototyping and at-scale manufacturing to tackle key bottlenecks in marine instrumentation at an industrial scale.

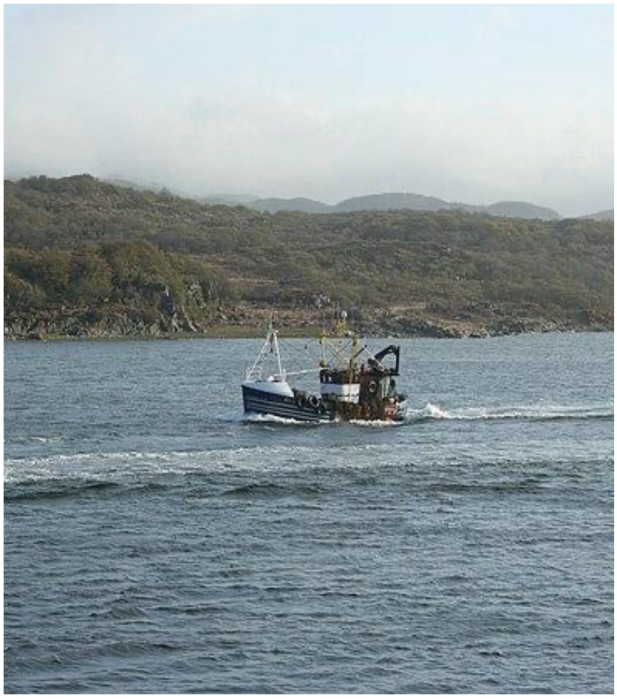
THE OCEAN CLEANUP: Another Dutch startup, Ocean Cleanup aims to restore ecosystems within the blue economy and rid bodies of water of harmful plastic waste. They create floating systems of artificial coastlines, where there are none, to concentrate the plastic. These systems are designed to capture plastics ranging from small pieces to large debris. With the help of computational modeling, they predict where the hotspots of waste are and place the cleanup systems in these areas. The Ocean Cleanup aims to remove 90% of ocean plastic by 2040.

With new innovations being introduced and technologies being developed every day, we have no doubts that 2022 will mark a great year for the blue economy.

NEWS STORIES

INTERNATIONAL PARTNERSHIP TO DEVELOP PRECISION AQUACULTURE IN SCOTLAND

A €1.3 million international consortium project based in Northwest Scotland will develop new software for aquaculture data collection and analysis from remote sensors. Partners include salmon producer Loch Duart and Scotland's Sustainable Aquaculture Innovation Centre (SAIC), and Japanese tech company Uhuru. The software will integrate data streams from multiple technologies and farms to improve sea lice management, efficiency, and sustainability.



UK AND GERMANY TOP OCEAN SUSTAINABILITY RANKING

An MIT study ranked the progress of 66 countries in ocean sustainability. UK and Germany came first with four Nordic countries in the top ten. Countries that scored highly all have well-developed blue technology innovation ecosystems. China came 17th, a position reflecting both its high blue technology investment and its poor marine conservation efforts. Countries that came lowest are those struggling to reconcile development goals with sustainability, such as Tanzania, Colombia, Egypt, and Vietnam.

LANDMARK INTERNATIONAL STANDARD FOR ESG REPORTING EMERGES FROM COP26

A new international standard for corporate ESG disclosures was announced on November the 3rd at COP26. It sits within the International Financial Reporting Foundation (IFRF). The International Sustainability Standards Board (ISSB) will absorb the existing International Financial Reporting Standards Foundation (IFRS) and the Climate Disclosure Standards Board and Value Reporting Foundation (VRF). This consolidation will be complete by June 2022. The ISSB aims to offer a consistent set of standards on how companies should compile their ESG disclosures. By offering a consolidated set of rules, the ISSB promises to simplify the fragmented institutional frameworks that currently guide how companies report ESG.

CHINESE REGIONS INVEST IN BLUE ECONOMY

The city of Shenzhen and the provinces of Liaoning and Shandong in China have announced new investment programmes for marine industries. Shenzhen intends to invest 10 million yuan (US$1.6 million) and other resources in marine projects and companies. Last month, Liaoning province in China's northeast also said it would offer up to 8 million yuan for its blue economy. Shandong plans to establish a modern marine industrial system and focus on developing emerging industries such as marine equipment manufacturing, marine medicine, biological products and seawater desalination.

$8 MILLION FOR SUSTAINABLE SEAFOOD IN NORWAY

On December 10th, the Norwegian ministry of fisheries and marine affairs committed a total of $7.6 million to 11 blue bioeconomy companies over the next three years. The award recognised companies making notable R&D contributions in the areas of sustainable aquaculture and fisheries growth. Awardees include Under Restaurant for its live seafood storage tech, Forsoljenta for small king crab cage rearing techniques, and fish feed company EWOS for researching the effects of omega-3 in rainbow trout feed.

SEAFOOD WATCH PROGRAM PLACES GLOBAL SALMON FARMS ON RED ALERT

The Seafood Watch program released its latest ratings for farmed salmon on December 6th 2021. The organisation rates global seafood production regions on a scale of red (avoid), yellow (good alternative), to green (best choice). Two-thirds of regions producing farmed salmon have been rated red for chemical use, disease, and salmon escapes. Nova Scotia, dominated by major aquaculture company Cooke Seafood, improved its rating from red to yellow. Several Norwegian regions and Scotland's Orkney Islands also received a yellow rating. No region achieved green.

€150 MILLION SUSTAINABLE BLUE ECONOMY FUND ATTRACTS INTERNATIONAL BACKERS

London-based fund manager Ocean 14 Capital aims to raise €150 million ($170.5 million) to invest in growing technology companies working with sustainable fish, aquaculture and alternative protein. It has secured €60 million so far. Ocean 14 will also invest in ocean health and conservation. The European Investment Fund committed €35 million while Chr. Augustinus Fabrikker is giving €15 million. Lukas Walton's Builders Initiative and Australia's Minderoo Foundation are committing €10 million each.