AQUACULTURE

The future of aquaculture is now

Lisl Robertson Lain and Marié E. Smith report on the ASTRAL project and the sustainable development of Atlantic aquaculture in South Africa.

Aquaculture in South Africa is really taking off, with around 230 farms countrywide, cultivating a wide variety of fish and shellfish species. Most of these are freshwater farms, and it is the freshwater sector that is indeed growing the fastest, with species like tilapia and trout in increasing demand. However, in terms of tons of produce, the marine sector is much larger and represents double the output of freshwater farms, despite coming from less than 10% of the total number of farms. In 2018, marine aquaculture represented over 86% of the value of the industry as a whole.

Given the size of these marine operations, it is increasingly important that the industry is developed in an ecologically safe and sustainable way. One of the ways to reduce environmental risks and maximise production is by employing an integrated multi-trophic (IMT) farming approach. This is the concept of cultivating animals and/or plants at different positions or levels in the food web, ideally those with a complementary function in the farm's overall ecosystem. For example, the waste of one species can be used as fertiliser or feed for another.

This is particularly relevant for aquaculture, where the target species are very sensitive to their environment, depending on nutrients in consistent supply while simultaneously requiring good water quality untainted by waste products and the growth of unwanted organisms. When managed well, integrated systems like this can reduce eutrophication from nutrient oversupply in farming systems, and can accelerate growth without detrimental side effects.

IMT farming can also provide valuable diversification of the business in terms of produce. An important potential benefit of investing in such systems is that advancing thinking towards recirculation of nutrients and energy in aquaculture (and in farming in general) can ultimately benefit under-resourced and small-scale farmers as well as large commercial operations.

The potential of aquaculture's contribution towards food security and economic benefit is increasingly recognised at an international level. Since 2014, the Horizon 2020 EU Research and Innovation programme has made available nearly €80 billion in funding with an emphasis on excellent science, industrial leadership and tackling societal challenges. One of the funding actions, the All Atlantic Ocean Research Alliance Flagship, aims to better understand and sustainably manage the Atlantic Ocean as a whole, with initiatives specifically focusing on aquaculture production; the four-year All Atlantic Ocean Sustainable, ProfiTable and Resilient AquacuLture(ASTRAL) project, which kicked off in September 2020, supports the development of this industry in a sustainable way, ensuring a strong climate-ocean-food value chain.

Sixteen partner organisations along and across the Atlantic ocean, three of which are from South Africa, are working together in acknowledgement of the need for this sector to be developed sensitively under good governance towards equitable and sustainable community benefit. With a targeted focus on IMT aquaculture (IMTA) farming, the project encompasses economic, social and environmental elements ranging from farming best practices to human capital development to business support to climatic and ecosystem risk assessment.

Above all, the project serves to provide a collaborative system for understanding Atlantic ecosystems and ensuring a sustainable harnessing of Atlantic Ocean resources. This effort is supported by the framework of the newly initiated Atlantic Aquaculture Alliance to enhance cooperation among all Atlantic countries and ensure the longevity of value created, after the project has ended.

The ASTRAL project oversees a wide range of tools and systems under development to facilitate the optimisation of such an approach: new sensors for environmental monitoring and hazard identification, new techniques for species combinations, as well as comprehensive investigations on regional climatic and environmental risks (including harmful algal blooms, which represent a major risk for systems open, or partially open, to the ocean).

ASTRAL partners encompass specialists in technology and IT development, marine science and biology, engineering and

a variety of other fields from companies and organisations across three continents. South Africa's Council for Scientific and Industrial Research's Coastal Systems and Earth Observation Research Group will be contributing satellite-based monitoring capability and climate-related research, together with support for targeted technology development and the planning of sensor validation activities for the project. But the project's four aquaculture farms, termed the "IMTA labs", is where the magic happens.

Viking Aquaculture

An aerial view of Buffeljags abalone farm

The ASTRAL IMTA labs represent the collaboration of commercial farms and research institutes in South Africa, Brazil, Ireland and the UK, and feature a variety of closed system, land-based flow-through, and open ocean systems in which new techniques and technologies can be tested. The South African IMTA lab is led by specialist marine animal and plant biologists from the University of Cape Town (UCT) and the Department of Forestry, Fisheries and Environment (DFFE), with a marine research lab at DFFE in Seapoint and practical implementation on site at Viking Aquaculture's Buffeljags abalone farm on the South Coast of the Western Cape.

At Buffeljags, commercial-scale multi-trophic farming is well underway. The abalone are grown on land in large 'raceway' tanks. Seawater flows constantly through the system, with half of it coming in fresh from the adjacent ocean, while half is recirculated within the system. Alongside the abalone raceways are large paddle raceways where ulva (a seaweed also called 'sea lettuce') is grown. The Ulva tanks receive abalone effluent containing high levels of nitrogen (excreted by abalone as ammonia). As the ulva grows, it takes up the nitrogen from this water, promoting healthy seaweed growth and enabling the water to be re-circulated back into the abalone tanks together with some fresh seawater intake. But the ulva serves another purpose too – it is feed for the abalone. In this way, an integrated multi-trophic interaction of nutrients, water, plants and animals has been established.

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There is a strong emphasis within ASTRAL on research and the creation of new production methods and value chains in aquaculture. The introduction of sea urchins to the Buffeljags farming ecosystem is a primary focus of the South African IMTA Lab research, and represents a new innovation towards an increasingly complex system. Sea urchins also eat ulva, and ulva may also benefit from urchin effluent. The economic advantage of incorporating urchins into the system is clear: abalone reach commercial maturity around 4 to 5 years, while urchins grow rapidly and are ready for consumption at 9-10 months. This research speaks directly to ASTRAL's objectives of increasing

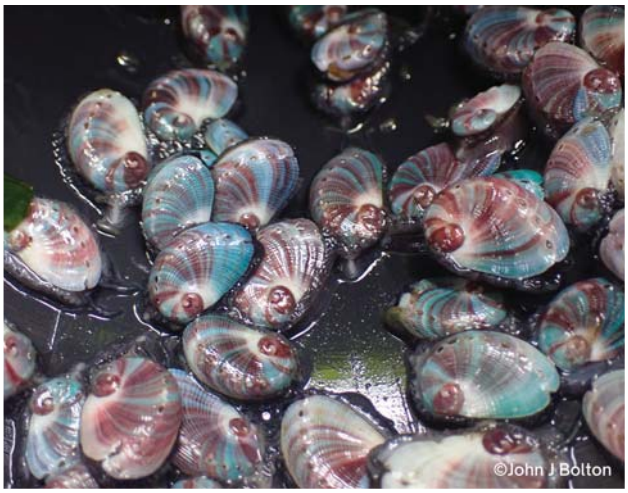
Viking Aquaculture

The Buffeljags abalone IMTA system, with ulva (seaweed) raceways in the center and the abalone tanks on the sides

Lisl Robertson Lain

The white-spined sea urchin, Tripneustes gratilla, cultured at the Buffeljags aquaculture facility as part of the ASTRAL project

John Bolton



The abalone species grown at the Buffeljags aquaculture facility, Haliotis midae

resilience and profitability in aquaculture, concentrating the focus on multi-trophic farming as a means to reducing waste, increasing the sustainability of farming ecosystems, and increasing business stability by diversifying farm revenue. One of ASTRAL's tabled outputs is a ***Species for the Future*** catalogue, which will provide comprehensive descriptions of the best species to be cultivated regionally within the partner countries, assessed in terms of their nutritious value, profitability and sustainability. The catalogue will also include details on business models and production estimations.

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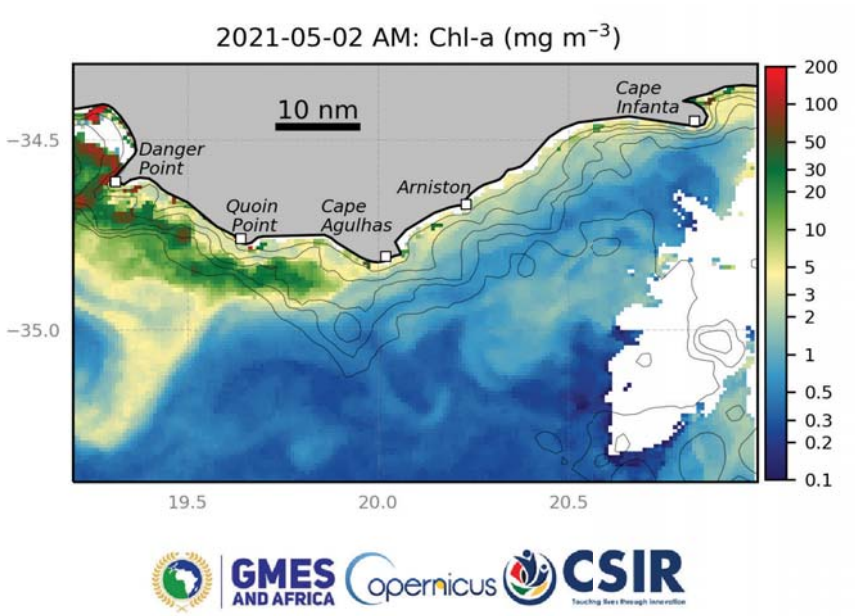
It is a central tenet of ASTRAL that the public availability of such documents will inform and encourage the sustainable development of the aquaculture industry, and there is a long list of public documents and reports that will be made available as the work of the project progresses. These include practical manuals for animal husbandry, health and welfare, guides to environmental monitoring technology, as well as reports on climate trends and change informing risk profiles.

ASTRAL is mindful to contextualise the development of the industry with the understanding that climate variability and a changing environment present great risks to aquaculture farming. The project addresses three main environmental risks: the presence of microplastics as an increasingly ubiquitous pollutant, and the frequency of occurrence of pathogens and harmful algal blooms (HABs) – particularly in terms of climate change.

CSIR



A satellite image from the Sentinel 3 OLCI sensor of the Western Cape's south coast, showing the surface ocean chlorophyll a concentration (as a proxy for phytoplankton biomass). A phytoplankton bloom is visible in the western part of the image.

HABs can take on many forms, ranging from low concentrations of toxin producing algal species, to extreme cases of high biomass blooms that risk collapse, decay and hypoxia. Although toxin producing phytoplankton are found endemically along the entire southern African coastal region, they generally occur in very small numbers of no real concern. Below a certain concentration, most phytoplankton present no threat to animal or human health and form an important part of the marine food web.

However, particular atmospheric and oceanographic circumstances can result in environmental conditions that favour specific algal species, providing the ideal growing conditions that allow them to 'bloom'. These blooms, often referred to as "red tides", typically discolour the surface of the water depending on the type of species present and the type and concentration of photosynthetic pigments they contain. When they cover a large enough area of the ocean's surface they can even be detected by satellite imagery.

Aquaculture farms keep a close eye on what is happening in the water in order to mitigate HAB-related risk: frequent water samples are taken at the intake pipes in order to identify and count the phytoplankton species, while satellite imagery are used to monitor the regional near-shore coastal zone for blooms and potentially exacerbating environmental conditions (e.g. warmer sea surface temperatures).

Abalone are particularly vulnerable to the presence of yessotoxins, produced by certain algal species found in the region. Yessotoxins cause inflammation of the external soft fleshy surfaces and gills of abalone, potentially causing secondary infections and deterioration of animal health. A variety of contingencies exist that can be implemented if a potentially harmful bloom is detected, ranging from slowing the pumps, decreasing the animals feed, and temporarily increasing the proportion of recirculated water on the farm.

ASTRAL seeks to provide integrated information systems to support this kind of decision-making, together with recommendations on optimal monitoring strategies to minimise risk and maximise mitigation opportunities. Sensors aimed specifically at the identification and quantification of pathogens, microplastics, and phytoplankton particles will be integrated into a farm-wide Internet of Things network together with other valuable physico-chemical environmental monitoring information (water pH, temperature, salinity, and so on) – all accessible via a data analytics platform enabling real-time data visualisation as well as record-keeping.

Given identified thresholds for microplastics or pathogen detection, and for physico-chemical parameters such as pH or salinity, alerts can be programmed to facilitate the identification of problems but also to mitigate them. The system will go further, though, with Artificial Intelligence (AI) processing information brought to the platform from multiple sources – looking at parameters inputted from sensors at the farm in the context of the biogeochemistry and weather/climate of the wider region, in order to make a comprehensive assessment of current anomalies or impending threat.

On-site testing of the new monitoring systems will inform a comprehensive feedback report with recommendations for optimising environmental monitoring strategies at the different types of IMTA farms across the Atlantic. Close monitoring is essential not only for external risks washing in with seawater, but also to ensure the healthy functioning of recirculation systems. The circularity approach, as it is called, is encouraged as a path towards zero waste in the IMTA labs – a goal requiring intensive research and sensitive implementation in order to achieve balance in the very delicate IMTA ecosystems. Business models as developed and recommended by ASTRAL will all be created with climate change mitigation, nutrient recycling, waste profiles and environmental sustainability at the forefront.

The potential for South African aquaculture to benefit from ASTRAL's outputs and develop farming businesses in innovative, environmentally secure ways, with the support and guidance of international partners, is a valuable opportunity. A number of training courses and educational materials will be made available, and the interested public is encouraged to take part in the conversation.

Further information is available at https://www.astral-project.eu/.

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Cultivation of abalone in South Africa

Abalone has been cultivated in South Africa since the late 1980's and is the most successful and valuable commercial aquaculture product in the country. The value of the abalone industry was estimated to be R837 221 000 in 2018, with a contribution of R114 123 543.00 to the export market. South African abalone is well regarded, with the current industry producing between 1270 and 1700 tons a year between 2013 and 2018.