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EDITORIAL

ALL ABOARD FOR BETTER MARINE STEWARDSHIP THROUGH RESEARCH AND INNOVATION

Human society depends on the seas for a multitude of products and services. They provide a source of food and energy, facilitate transportation of goods and people, and also offer recreation opportunities. However, along with marine exploitation comes the imperative for sustainable approaches, which must strike a balance between socio-economic advantage and environmental protection. With almost three quarters of the planet covered in water, the stakes are high.

When we speak of the maritime environment, we often do so in language which conjures up notions of a strange and somewhat unknown environment, where much is hidden. This has led some to claim that the seas – not space – represents the last true frontier. When it comes to efforts such as determining the prevalence and impact of maritime pollution or the search for novel lifeforms, it is clear that much does indeed remain unexplored.

Coordinated efforts for resource management

The EU's approach to maritime activities is centred on the inter-connectedness of marine-based human activities. Integral to this approach is a sensitivity of the fact that changes to one aspect of the system can affect others. Additionally, various authorities have been encouraged to cooperate, for example with the sharing of data across policy areas, which can result in more holistic risk assessments and solutions.

Alongside joined-up working, the key to success will be the availability of timely data, afforded by cutting-edge bio-sensors and automation advances, which can offer early-warning protocols. In tandem, there is a need to put into practice sustainability resource management principles, with approaches such as the recirculation or repurposing of materials.

A better understanding of environmental processes, biodiversity, the impacts of human activities (land-based and marine) and of climate change, including sea-level rise, as well as the socio-economic impacts of marine protection, requires a multi-disciplinary approach. As such, EU programmes such as FP7 and Horizon 2020 have been providing the necessary funding to exciting research initiatives across Europe.

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Effect of vegetarian feeds on farmed fish

Fish caught at sea are used as feed for Europe's growing aquaculture sector. An EU-funded initiative addressed this unsustainable use of marine resources by examining the effect of plant-based nutrition on farmed fish.

In Europe, most farmed species of fish are carnivorous; their feed contains fish meal (FM) and fish oil (FO) derived from wild stocks caught at sea. However, demand for this 'raw material' is now increasing from the expanding aquaculture sector and the human health sector that uses FO in food supplements. There is a growing need for sustainable alternative ingredients, such as plant-based feeds to reduce pressure on marine resources.

Biologists from the ARRAINA (Advanced research initiatives for nutrition and aquaculture) project investigated the nutrient requirements of the five most commonly farmed fish species in Europe: Atlantic salmon, Rainbow trout, European seabass, Gilthead seabream and Common carp. This information was used to develop sustainable plant-based aquaculture feeds tailored to the requirements of each species, but containing lower levels of FM and FO.

'The aim was to provide flexibility in the use of cost-efficient and environmentally friendly ingredients in the formulation of feeds in order to produce seafood of high nutritional value and quality', explains Dr Sadasivam Kaushik, the coordinator of ARRAINA. He adds, 'Beneficiaries will include all those linked with the European fish farming sector, from suppliers of feedstuffs to feed producers and farmers.'


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Biomarkers measure effects

Project partners developed tools based on relevant biomarkers to measure and predict the effects of alternative feeds on fish metabolism and to identify the nutritional requirements for each species over the whole life cycle. Researchers measured the long-term effects of changes in dietary formulations on fish performance, including threshold effects, nutritional intervention in early life stages and the impact of maternal diet on larvae.

According to Dr Kaushik, 'Developing exploitable predictive biomarkers to assess the effects of nutrients was a key result. Furthermore, novel data was obtained on nutrient requirements, especially in the context of using feeds rich in plant protein and oil sources.'

Scientists established new ways to deliver specific micronutrients to modify egg composition or enhance the growth performance of fish-larvae, thereby improving the efficiency of the production process. They could significantly reduce the levels of FM and FO in the feeds of the five species studied without adversely affecting key performance indicators or nutrient utilisation.

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Greater productivity and improved performance

The use of nutritional programming to improve alternative diets in the selected fish species was also investigated. Nutritional programming is based on the idea that differences in nutrition during critical periods in early life can programme an organism's development, metabolism and health for the future.

In addition, a web-based tool that assesses the possible nutrient loadings into the environment was created and made available to all stakeholders. Project partners also designed and delivered training courses in fish nutrition to increase research capacities and expertise, particularly in countries of the enlarged EU.

By developing applied tools and solutions of technological interest in collaboration with small and medium-sized enterprises (SMEs), ARRAINA generated new knowledge and strengthened the links between the scientific community and the EU feed industry. This will contribute to the increased productivity and performance of the aquaculture sector, leading to competitive advantage to the whole sector at a global level.

Project	**Advanced Research Initiatives for Nutrition & Aquaculture**
Coordinated by	Institut National de la Recherche Agronomique, France
Funded under	FP7-KBBE
Project website	http://www.arraina.eu/

Assessing trawling impact to better protect seabeds

EU-funded researchers have carried out an in-depth analysis of how trawling can impact life on the sea floor. This has provided a clearer picture of the balance that must be struck between profitable exploitation of the seas and environmental protection.

Analysis, carried out through the EU-funded BENTHIS project, has shown that the damage caused by trawling is directly related to the penetration depth of equipment. The findings will help inform the fishing industry about its potential impact, the habitats most affected and fishing gear that cause the most damage. Using this assessment framework means that environmental impact can be predicted without the need for trial tests.

This methodology is now available for use by relevant authorities. Project findings on the impact of trawling will also now inform the development of EU Marine Strategy Framework Directive (MSFD) indicators on sea floor integrity.

'This means that we have the chance to further develop these methods and improve them,' says BENTHIS project coordinator Professor Adriaan Rijnsdorp from Wageningen Marine Research in the Netherlands. 'Ultimately, this project will help contribute towards the profitable exploitation of the sea at minimal ecological cost.'

Life on the seafloor

The seafloor provides a habitat for an enormous diversity of life, in particular invertebrate species. These incredible organisms can alter the seafloor, for instance by building coral-like structures, or digging into the sediment.

'This community of organisms found on or in the sea bed, known as benthos, also plays an important role in the transport of carbon from the water into the sediment, and for the release of nutrients into the water column,' explains Professor Rijnsdorp. 'Benthic invertebrates are also an important food source for many of our commercially exploited fish, shellfish and crustaceans.'

However, benthic ecosystems are increasingly affected by human activities such as fishing, sand and gravel extraction, oil and gas exploitation, shipping and pollution. Fishing, in particular bottom trawling, occurs in many parts of the sea floor of the continental shelves.

This project will help contribute towards the profitable exploitation of the sea at minimal ecological cost.

'There is growing concern about the detrimental effects of bottom trawling, with some groups even calling for the practice to be stopped altogether,' says Professor Rijnsdorp. 'We therefore saw a need for robust science to determine exactly how serious this problem is; which areas we should be concerned about; and which fishing gear is causing damage.'

Mapping impact of trawling

The BENTHIS project therefore set out to map the pressure of bottom trawling in European seas, and to quantify the environmental impact. The pressure of trawling was assessed by using high resolution data from various fishing fleets. The impact was estimated by conducting meta-analyses of existing peer-reviewed literature and integrating previous project results.

'We also collaborated with industry in order to develop gear innovations that might mitigate trawling impact,' explains Professor Rijnsdorp. 'This has been very fruitful. Trawlers in the Mediterranean for example applied technical innovations to reduce the impact of digging, which also has fuel saving potential.'

The BENTHIS project's assessment framework on the impact of trawling can be applied across European seas. In addition to demonstrating that benthic mortality rates are directly related to the penetration depth of fishing gear, the project also identified regions of the seabed most at risk.

'We found that habitat sensitivity can be estimated from the longevity distribution of the benthic community,' explains Professor Rijnsdorp. 'Meta-analyses revealed that the recovery rate of a species is related to its longevity. This means that communities of long-lived species are more sensitive to trawling because of their slow recovery compared to short-lived communities.'

Project	**Benthic ecosystem fisheries Impact Study**
Coordinated by	Stichting Wageningen Research, the Netherlands
Funded under	FP7-KBBE
Project website	http://www.benthis.eu/en/benthis.htm

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Could a cluster of biosensors effectively monitor a wide range of ocean pollution?

Combining novel biosensors, the EU-funded BRAAVOO project has designed a device to detect toxins in the oceans. The approach developed can detect a range of molecules *in situ*, from antibiotics to heavy metals.

The oceans were once thought big enough to absorb oil spills, toxic waste, floating plastic and more, but it's now clear that pollution in the oceans is an accelerating problem. 'In developing sensors to detect polluting toxins in the marine environment, the problem now is deciding which of the thousands of compounds that end up in the seas to monitor,' says microbiologist, Professor Jan van der Meer, from the University of Lausanne, Switzerland and BRAAVOO project coordinator. 'Our project decided to target a number of recurrent pollutants for which no easy analysis was available.'

BRAAVOO has developed a unique device using biological sensors, deploying multiple technologies that make it possible to simultaneously identify antibiotics, toxins from algal blooms, endocrine-disrupting chemicals from paints, oil-derived compounds, and toxic heavy metals.

The consortium of eight academic and SME partners completed its three-year project in 2016. Each partner designed an element of the monitoring device which formed the complete automated sensor system. Three types of sensors were incorporated into the device – immunosensors that use antibodies to detect specific biological molecules, bacterial biosensors, and a system to detect toxins using the light-dependent reactions occurring in algae.

In particular, BRAAVOO combines highly specific biosensors and more general wide spectrum detectors. 'We wanted to have some biosensors which are very compound-specific, for example, targeting a single antibiotic, or a single algal toxin. However, by deploying very specific biosensors, one might miss other toxins in the water, therefore, we also included very general biosensors that react to anything that may be toxic,' explains van der Meer.

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Detecting toxicity isn't always easy because it isn't always know what to look for, but BRAAVOO took the approach of detecting the biological effects of toxicity on cells rather than only detecting chemical substances of known toxicity. For example, van der Meer says, 'Looking at evidence of bacterial stress provides a very sensitive detector of toxic compounds or combinations of compounds in the water that will cause toxicity to other living things.'

Three ingenious biological sensing methods have been utilised in BRAAVOO's device which was designed to be integrated in a marine buoy for automated analysis. Immunosensors deploy an antibody that will bind to target compounds. 'The innovation here was detecting very small changes in the size of the interacting antibody-target complex which enables miniaturisation of the assay,' says van der Meer. Bacterial sensors used freeze-dried cells that, when in contact with a chemical target, such as mercury or cadmium, cause bioluminescence. The amount of light produced is a measure for the level of chemical exposure. The third sensor used immobilised marine algae in small beads which are exposed to a sample in an incubation chamber where fluorescence can be detected.

Testing the system in real life was challenging, because, says van der Meer, 'We couldn't first control the level of contamination present in the sea.' So they used a mesocosm – a tank big enough to contain the system which was artificially


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contaminated. The device was also successfully tested off the coast of Ireland.

Whilst a prototype for commercialisation was not pursued due to limited resources, the algal detection system is now being developed by Biosensor SRL in Italy.

Project	**Biosensors, Reporters and Algal Autonomous Vessels for Ocean Operation**
Coordinated by	University of Lausanne, Switzerland
Funded under	FP7-KBBE
Project website	http://www.braavoo.org

New technology and management techniques could lift European aquaculture industry

Aquaculture is a booming industry, but growth in Europe is falling behind the rest of the world. One EU-funded project has developed new concepts and technology that could turn this around by triggering sustainable growth in European aquaculture.

Growth in European aquaculture is increasingly facing resistance from regulators and stakeholders. Now, EU scientists working for the IDREEM project (Increasing Industrial Resource Efficiency in European Mariculture) are hoping to solve this by introducing innovative sustainable techniques.

'If we can move European aquaculture to more integrated-based production systems then we can help the industry to grow in an environmentally and socially sustainable way, while ensuring its economic competitiveness,' says IDREEM Project Coordinator Adam Hughes.

One of the biggest problems the industry faces is waste. Aquaculture produces two main types of waste – small particulate waste and dissolved waste such as uneaten food or fish waste.

Under current practices, waste is simply lost to the wider environment where it is absorbed into the ecosystem. 'This can lead to the accumulation of organic matter underneath aquaculture production sites, as well as a potential over-loading of nutrients in coastal waters,' Hughes explains.

Using innovative new concepts, the project has created waste management strategies that convert waste streams into high value products. The Integrated Multitrophic Aquaculture (IMTA) system reduces net environmental emissions and increases productivity and profitability for European aquaculture businesses.

The project found that growing different species together – such as queen scallops and salmon, or sea bream and oysters – cuts waste as queen scallops and oysters eat waste from the fish.

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'This increases the productivity at the site, and diversifies the aquaculture industry, both of which contribute to the economic sustainability of the industry,' says Hughes.

IDREEM also developed advances in the design of farm layout, including making changes to anchoring grids which keep fish cages in place to make space for seaweed production. Meanwhile, modelling technology was developed to allow for a better prediction of the benefits of IMTA, maximising productivity and environmental benefits onsite.

IDREEM's technology and strategies are currently in place at several sites across Europe, while the modelling technology is also available to the aquaculture industry via the project's website. IDREEM has already produced products available on European markets including a condiment made from seaweed, and shellfish products such as queen scallops and mussels.

With this initial success now achieved, the project faces new challenges such as developing ways to certify products produced with the IMTA system. 'Although our project showed that across Europe there is willingness to pay extra for fish produced in an IMTA system, it is difficult for producers to secure this market premium without certification,' Hughes explains.

Appetite for seaweed grown in Europe was also a hurdle. Today, seaweed is a high value product imported into Europe in large quantities for uses like fine chemicals and gelling agents. There is a very limited market for European seaweed due to the current small-scale of production, but this is changing.

However, many IDREEM project partners are continuing to use the IMTA production system and some are looking at rolling it out across many sites. Meanwhile, Hughes hopes that work can continue overcoming the challenges the project identified.

Project	**Increasing Industrial Resource Efficiency in European Mariculture**
Coordinated by	Scottish Association for Marine Science, United Kingdom
Funded under	FP7-ENVIRONMENT
Project website	http://www.idreem.eu/cms/about-project/

Sustainable food production through aquaponics

EU-funded researchers have successfully implemented new technological approaches to aquaponics – aquaculture and hydroponics combined – offering cost savings for food producers, market opportunities for high-tech SMEs and environmental benefits for everyone.

While feeding a growing global population inevitably requires an increase in agricultural output, this cannot come about at any cost. In order to be sustainable over the long term, future production must ensure that water, energy and nutrients are managed efficiently, and that the principles of re-use and recirculation are respected.

The EU-funded INAPRO project has successfully implemented new technological approaches to aquaponics, with fish waste providing an organic food source for plants and evaporated water returned to fish tanks reducing the need for additional daily freshwater to less than 3 % of total volume. Due for completion at the end of 2017, the project has helped demonstrate that near emission-free production of fish and vegetables – as well as significant energy and water savings – is possible.

'In this way, the project will contribute markedly to food security for the 21st century and also help to support market access of aquaponics technology,' notes the project's scientific coordinator Dr Daniela Baganz from the Leibniz-Institute of Freshwater Ecology and Inland Fisheries in Berlin, Germany.

We see the technology pioneered in INAPRO as highly promising in producing nutritionally high valued food sustainably, without environmental threats.

Efficient production by design

In order to develop and demonstrate an efficient and viable aquaponics system, modelling approaches were first used to better understand different elements, such as the dynamic behaviour of animals and plants and the ideal design and construction of various components. A range of technologies were then assessed aimed at maximising production while minimising resource usage. These included optimised filters, systems to retrieve water via condensation, bespoke sensors, as well automation and production management software.

'From this, project partners were able to develop modular configured aquaponics solutions that are scalable and adaptable to local requirements,' says Baganz. 'During the first project period for example, we were able to test a system that went on to produce perfect fish and tomatoes.' In total, demonstration facilities were successfully constructed in Spain, Germany, Belgium and China. These helped the team to test the feasibility of various technologies at a larger scale and under different geographical and climate conditions.

'Testing and evaluation, including a live cycle assessment of technological components, is still ongoing,' says Baganz. 'We hope that these demonstrations will help to convince stakeholders of the great potential in water and carbon footprint reduction, which in turn will help to further promote innovative aquaponics.'

Tapping the advantages of aquaponics

One European sector that stands to gain from this anticipated aquaponics take-off, is food producers. 'Much less water is needed, while the environmental impact is reduced due to nutrient recycling by the plants,' says Baganz. 'This means that additional fertiliser can be cut out, which is especially significant in terms of phosphorus. Price surges have already

been observed and are likely to continue, given that phosphate is a non-renewable resource.'

The growth of aquaponics could also create a new market for system manufacturers and high-tech SMEs involving in sensors, automation and filtration. 'Developing innovative, sustainable solutions for future agricultural production strengthens Europe's global competitive advantage in high value-added products and services,' says Baganz. 'One of the project's goals has been to create new market opportunities.'

In turn, the reduced impact that aquaponics has on the environment compared to conventional agricultural production, which can cause nutrient leaching, water pollution and eutrophication, could bring wider environmental and social benefits. Local aquaponics production would mean less need for food imports, resulting in a reduction in transport-based CO_2 emissions.

'While currently a small niche market, we predict that regional and resource friendly production will become of much greater importance in the near future,' says Baganz. 'We see the technology pioneered in INAPRO as highly promising in producing nutritionally high valued food sustainably, without environmental threats.'

In this way, the project will contribute markedly to food security for the 21st century and also help to support market access of aquaponics technology.

Project	**Innovative model and demonstration based water management for resource efficiency in integrated multitrophic agriculture and aquaculture systems**
Coordinated by	Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Germany
Funded under	FP7-ENVIRONMENT
Project website	http://www.inapro-project.eu/ http://bit.ly/2xQOgtt

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Open ocean fish farming can produce healthier fish and less pollution

An Israeli SME has adapted its system to enable fish farming far out at sea. Its innovative solution harnesses ocean currents to lessen environmental impact and can submerge beneath the surface to avoid winter storms.

An EU-funded project aims to make fish farming more sustainable and cost efficient by taking it away from coastlines and out into the open ocean. OCEANFISH, due to end in April 2018, has allowed Israeli SME Gili Ocean Technologies (GOT) to adapt its existing system to withstand the harsh conditions of the open seas and to introduce several technological innovations.

Saltwater aquaculture is usually done in sheltered areas near land 'because it is easier; you do not have to fight the ocean,' says project coordinator Josef Melchner, CEO of GOT. 'But you lose the natural effect of the ocean – oxygen saturation and the flow of micro-elements such as micro algae which help fish nutrition.' Moreover, near-shore aquaculture can cause pollution due to fish feed and faeces as well as antibiotics, often used intensively to fight disease.

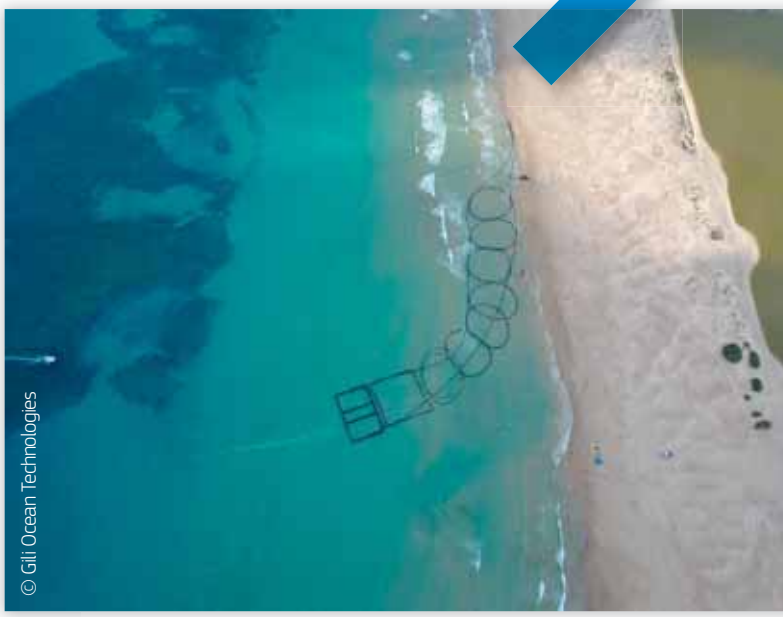
Less pollution

OCEANFISH has adapted its Subflex system to allow fish farming to take place in much deeper waters than previously possible. This will allow fish farmers to grow their fish in better quality water while significantly reducing their environmental impact.

The system is a flexible array of cages held together by ropes. It is attached to a single mooring unit which means the system can rotate with sea currents, thereby reducing wear and tear.

'The main advantage with this is that it disperses organic matter over a large area, so if you add to this the ocean current, you have a natural dispersing mechanism,' says Mr Melchner. Farming fish in better quality water makes them healthier and means that antibiotics do not need to be used as frequently.

The structure is equipped with a mechanism which allows it to quickly submerge in the event of a storm, thereby protecting fish and the assembly from harm. 'The system can withstand waves 17 metres high or more,' says Mr Melchner. The OCEANFISH team used computer simulations to calculate the buoyancy needed to keep the system hovering several metres below the surface of the water regardless of conditions above.



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The system can withstand waves 17 metres high or more.

Tracking the growth rates of farmed fish can be difficult. OCEANFISH used image processing techniques to produce a camera which shows the size and biomass of fish as well as the number of dead ones. It is now being tested in the open ocean. 'We haven't yet reached the accuracy we are aiming for – 1 % deviation – but we are not far off,' says Mr Melchner.

Small submarine

The team also came up with a new way of feeding fish which works even when the cages are submerged. This consists of a

We haven't yet reached the accuracy we are aiming for – 1 % deviation – but we are not far off.

feeding capsule much like a mini submarine, fitted with sensors and remotely operated, which allows fish to feed and keep growing no matter what the current weather conditions are. Following successful trials at sea, the final design is now ready for production.

The need to make aquaculture more cost-efficient led the team to try adding a rectangular cage to the array of traditional round ones. Adding corners gave 33 % more capacity without increasing the system's drag force. The first full-size cage is now being tested at a depth of 70–80 metres 15 km off the Israeli port of Ashdod.

GOT aims to have most of these technological developments ready for commercialisation by April 2018 and is already talking to companies around the world about the potential opportunities for new joint ventures.

Project	**Open Ocean Fish Farms**
Coordinated by	Gili Ocean Technologies, Israel
Funded under	H2020-SME, H2020-FOOD
Project website	N/A

Marine biodiscovery digs deep in the quest for new treatments

Despite containing huge potential for the harvesting of unique chemical compounds, the world's oceans remain under-explored. The EU-funded PHARMASEA project sets out to release some of these tremendous bioresources by tackling barriers to their exploitation.

With clarion calls, such as the 10 x 20 initiative from the Infectious Diseases Society of America for 10 new antibiotics by 2020, there is a widely-recognised need to source new medicines. Recent exploration and analytical advances have highlighted extreme environments, once thought insurmountable to life, as rich habitats for novel bioactive communities. Despite the ocean depths holding out much promise, realising new marine-based compounds face a number of developmental hurdles. These include challenges related to access (physical and legal), biology (knowledge of genetics and compound isolation) and exploitation (pipeline bottlenecks).

We chose deep seas and the polar regions especially, believing they generate unique biodiversity giving rise to unusually biologically active chemistry. This has proven to be an accurate hypothesis.

The EU-funded PHARMASEA project succeeded in developing a robust pipeline capable of processing marine microbial genomes from strain collections held by partners and new strain collections retrieved from extreme environments (deep, cold and hot vent habitats). The project isolated compounds with characteristics desirable for a range of market sectors including health, where the team developed products to treat infection, inflammation and central nervous system (CNS) diseases. PHARMASEA succeeded in creating compounds with demonstrable anti-epileptic and anti-Alzheimer properties.

Exploring deep ocean trenches for new microorganisms

PHARMASEA's guiding philosophy was simple, that unique and/or extreme environments will likely yield new species of microorganisms, as products of different evolutionary pathways. The project coordinator Professor Marcel Jaspars explains, 'We chose deep seas and the polar regions especially, believing they generate unique biodiversity giving rise to unusually biologically active chemistry. This has proven to be an accurate hypothesis.'

With so little of this extreme environment explored before, the team's first challenge was one of access. Working with EUROFLEETS II, the EU-funded marine research collaboration initiative and its 'PharmaDEEP' cruiser, the team managed to obtain both deep and cold samples from the South Shetland Trough, Antarctic. Recalling the processing of this sediment Professor Jaspars says, 'We used microbiology techniques to isolate single strains of microorganisms, then grew these in special conditions. Next, we used separation techniques to isolate the chemicals they produce, and assessed their novelty and diversity using a sophisticated database approach developed during PHARMASEA. Simultaneously we tested materials' biological activity and assessed their biosynthetic potential by genome scanning. Those that were positive for chemistry, bioactivity and genetics were prioritised for isolation and structural characterisation.'

To speed up the discovery of chemical novelty the team used chemometrics, datamining and computer aided structure elucidation. The PHARMASEA databases and dereplication tools were used to also help identify known compounds, pinpoint unknown compounds and accelerate the complex process of clarifying their structure. New compounds with novel mechanisms of action were also uncovered thanks to innovative assays and counter-screens.

PHARMASEA succeeded in producing five marine-derived compounds which were progressed to animal models for CNS

diseases. Two non-toxic compounds with drug-like properties derived from a marine sponge showed positive results in an Alzheimer's disease behavioural model, including reduced inflammation that may precede disease. Using a zebrafish model, three compounds have also proceeded to animal trials for the treatment of epilepsy, again shown to be drug-like and non-toxic. Of these, two compounds from a marine fungus reduced seizures significantly in the gold-standard animal model for epilepsy.

Influencing policy and enhancing economic performance

Currently, the team is running further tests on the epilepsy compounds, working towards human clinical trials. For Alzheimer's treatment, the team will patent active analogues and develop them further through an EU-US partnership. As Professor Jaspars concludes, 'In terms of the so-called "blue economy" we have shown that materials from deep and cold oceans may contain high value chemicals. By contributing to European technological know-how through these interdisciplinary advances, PHARMASEA helps ensure the region's completeness.' However, reducing bottlenecks in the biodiscovery exploitation pipeline, also requires policy solutions.

To improve marine bioresource access in different habitats and jurisdictions, while promoting the equitable sharing of benefits, PHARMASEA worked with a range of policymakers from the UN, the EU and national blocs, such as the African Union. PHARMASEA was able to provide policy options for the UN Preparatory Committee on the Sustainable Use of Marine Biodiversity in Areas Beyond National Jurisdiction, based on the project's scientific good practice expertise.

Project	**Increasing Value and Flow in the Marine Biodiscovery Pipeline**
Coordinated by	Katholieke Universiteit Leuven, Belgium
Funded under	FP7-KBBE - Specific Programme "Cooperation": Food, Agriculture and Biotechnology
Project website	http://www.pharma-sea.eu/

Think blue – the ocean and our lives

Europe's urbanised populations have little understanding of the importance of the oceans to life and the human impact on the sea. An EU-funded initiative wants to change that.

It should not take a massive oil spill for people to understand how human activities and the seas are interlinked. The public have become conscious of marine pollution from plastic bags and PCBs but there is still a big gap in understanding the oceans' impact on human health, wellbeing and society in general.

The three-year EU-funded SEACHANGE project brings together a consortium of 16 ocean-linked organisations around Europe and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) to help European citizens become more 'ocean literate'.

'Ocean literacy is about understanding the ocean's influence on people, and people's impact on the ocean,' explains project coordinator Jonathan Parr of the Marine Biological Association in the UK.

Around 70 % of the planet is water. 'It is our life support system,' he notes. But livelihoods from the sea have declined and Europeans have become more urban and, arguably, more inward-looking. 'The sea affects people inland as well,' Mr Parr says. 'Europe has a lot of seas but the population is not engaged with them because they do not think they impinge on their lives.'

The relationship between people and oceans

The ocean is important not just as a food source, but for its biodiversity, impact on health and well-being, and its influence on climate and weather patterns which affect the entire planet.

The SEACHANGE project compiled a literature review of the relationship between the ocean and human health. 'Some medical advances have come from marine organisms and we need to be aware of that,' says Mr Parr.

Studies have also shown that the oceans produce a sense of wellbeing – for instance, playing on the beach or sailing in boats is seen as both recreational and relaxing. 'Wellbeing is an area of increasing interest for policymakers and is rising up the agenda,' Mr Parr notes.

More broadly, the project reviewed European policy on ocean literacy and produced fact sheets for policymakers. 'We're trying to raise awareness that in policy you must also consider the ocean as part of it,' Mr Parr says.

Ocean literacy is about understanding the ocean's influence on people, and people's impact on the ocean.

Education and outreach

Schools and young people have been another focus of the project. The consortium produced a searchable online directory on ocean-related education and outreach resources known as the Ocean EDGE Directory. European networks of aquariums and

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science centres such as the European Network of Science Centres and Museums (ECSITE) have also developed local projects in collaboration with the project.

Work is ongoing to bring 'ocean literacy' into the curriculum in schools. This includes developing a MOOC (Massive Open Online Course) to train teachers in ocean literacy in collaboration with UNESCO. Finally, the European Marine Science Educators Association (EMSEA), a consortium member, has also developed materials and campaigns for educational purposes.

Changing behaviour

Ocean plastics are though an issue that has captured the public imagination in recent years. But the project's aim is also to change behaviour. 'Plastics have even been detected in the deep sea where man has never been before. It is one of those shocking things that makes people think, hang on, we do have an effect. Not using plastic bags or reusing them will make a difference,' explains Mr Parr.

Other examples are not using plastic drinking straws, using biodegradable or reusable cutlery and plates, and switching to eco-friendly cleaning products and cosmetics. Even conserving energy at home can reduce carbon emissions that cause ocean acidification.

'We have been asking people to pledge to make a small change for Sea Change,' says Mr Parr. Hopefully the outreach and educational efforts of the project will lead to further actions to ensure that the way we view our oceans changes not just for good but for better.

Project	Sea Change
Coordinated by	Marine Biological Association, United Kingdom
Funded under	H2020-FOOD
Project website	http://seachangeproject.eu/

Protecting our seafood from marine pollution

Researchers with the EU-funded SEA-ON-A-CHIP project have developed an early warning system that provides real-time analysis of marine waters in multi-stressor conditions.

The chemical contamination of Europe's maritime regions, which account for over 40 % of the EU's GNP, poses an immense threat to our environment, our health (via the food chain) and to related industries such as fisheries. Seafood safety is dependent on the quality of seawater. As the vast majority of aquaculture sites are located in coastal areas, they are particularly vulnerable to pollutants released to the environment by anthropogenic or natural sources and by biotoxins from harmful algae blooms. Many of these contaminants are taken up by aquatic organisms, thus entering the food chain and ultimately affecting consumer health.

Although a complex issue, one solution to mitigate the effect of marine pollution is the use of early warning systems that can provide extreme sensitivity, with exquisite selectivity. The EU-funded SEA-ON-A-CHIP project developed such a system. The result is a miniaturised, autonomous, remote and flexible immune-sensor platform based on a fully integrated array of micro/nano-electrodes and a microfluidic system in a 'lab-on-a-chip' configuration. Combined with electrochemical detection, the system provides real-time analysis of marine waters in multi-stressor conditions.

The system has proved beneficial for aquaculture facilities, where it provides rapid assessment of eight common contaminants… that affect aquaculture production and those produced by the industry that have a negative impact on the environment and human health.

A compact, autonomous solution

The SEA-ON-A-CHIP device is a compact, autonomous multianalyte immune-sensor with impedimetric transduction. Its electrochemical immunosensor is integrated into an automated microfluidics system that is connected to a sample-pre-treatment chamber. It is within this chamber that the clean-up process and pre-concentration of the compounds that are to be measured is done using immune-recognition. The information is then sent on to the sensing step, which takes place in the lab-on-a-chip electrochemical immunosensor, with the signals being communicated to a remote-control centre.

Each device can perform eight simultaneous measures in duplicates

Considering the harsh environments they work in, the devices can provide real-time autonomous measuring at least once per hour for up to one month. The end-user can also simultaneously connect as many devices as needed to the same platform, resulting in a very flexible and inexpensive system. 'Thanks to the use of microelectromechanical systems and micro-electrodes in flexible polymeric substrates, the cost of producing the devices has been significantly reduced,' explains project coordinator Damia Barcelo.

Benefiting aquaculture and beyond

According to Barcelo, the many opportunities and benefits offered by SEA-ON-A-CHIP have been showcased to potential customers, and initial feedback has been very positive. 'The system has proved beneficial for aquaculture facilities, where it provides rapid assessment of eight common contaminants from five groups of compounds that affect aquaculture production and those produced by the industry that have a negative impact on the environment and human health,' says Barcelo. He goes on to explain that, 'Although developed for the aquaculture industry, the SEA-ON-A-CHIP system is easily adaptable to other target compounds and situations, such as analysing contamination of coastal waters.'

Project	**Real time monitoring of SEA contaminants by an autonomous Lab-on-a-chip biosensor**
Coordinated by	Agencia Estatal Consejo Superior de Investigaciones Científicas, Spain
Funded under	FP7-KBBE
Project website	http://www.sea-on-a-chip.eu/V1/SOC50V4_Main.php

Cleaning up with the Sea Litter Critter

Could an automated 'critter' eat up and process litter at sea using plasma technology? One EU-funded project set to work to find out.

More than 150 million tonnes of plastic have accumulated in the world's oceans, with over 4.5 million tonnes added each year. It becomes most problematic when its breaks up into tiny microparticles that are then ingested by sea creatures and so enter the food chain. A concept developed by the EU-funded SEA LITTER CRITTERS project could provide a solution to cleaning up this sea litter. Its feasibility study looked at the market appeal of a small automated waste collection vessel called the 'Sea Litter Critter', which not only picks up litter, but treats it on-board.

Project coordinator Ilaria Schiavi explains that the idea for the device came from observing a marine litter collection vessel operating at an Italian tourist resort: 'It was paid for by a local tourist association concerned that dirty beaches would put off visitors, but the high costs meant the vessel could only be used when there were significant quantities of debris.' This gave IRIS, a small start up based in Turin, Italy, the idea to use their expertise in plasma technology to come up with an improved solution. Using plasma – a very high temperature, very energetic state of matter – solid waste can be completely broken down with no risk of dioxines and furans emissions, which can form in other combustion-based waste treatment methods.

Currently, marine litter is everybody's problem but nobody wants to pay for cleaning it up, and there are no regulations stipulating who should be dealing with marine litter.

At SEA LITTER CRITTERS's core is IRIS's small scale pyroliser unit (patent pending), which treats thermally solid waste and transforms it into syngas, a mixture of hydrogen, carbon monoxide, and methane and a residue which can be recycled as aggregate for road material or concrete. The syngas could be exploited for producing electricity or fuelling the vessel's motor. Currently a fully unmanned, automated device is not possible due to regulatory and technology limitations but Schiavi says, 'Ideally, once automated navigation is fully developed, this vessel could be left to hoover up marine litter day and night.'

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In their feasibility study the team commissioned specific market research to ascertain if the device was attractive to coastal resorts, municipalities and aquaculture enterprises. While the idea was found to be of interest to the market, the main challenge was found to be securing the necessary investment for such equipment.

Schiavi notes, 'Currently, marine litter is everybody's problem but nobody wants to pay for cleaning it up, and there are no regulations stipulating who should be dealing with it.' Changes to the current regulatory climate, could kick-start a market for this device, as Schiavi explains. 'The EU is very active on the subject as the problem is growing to a level likely to affect European industries such as fishing. So we expect that the regulatory landscape will change, and there will be a requirement for local authorities to act.'

The project team is working towards developing a sea-ready vehicle to be tested within the next four years. It expects disposal of marine litter through thermal treatment will have a place in the future management framework for materials that cannot be recycled or for emergency situations such as spills and flooding events.

Project	**A compact, unmanned, renewables-powered and self-sufficient vessel able to pick up marine litter and to treat it on board for volume reduction and energy recovery**
Coordinated by	Ilaria Schiavi, IRIS srl, Italy
Funded under	Horizon 2020-SME, Horizon 2020-FOOD
Project website	N/A

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Tracking ocean pollution in real time

EU-funded researchers have developed a device that can detect traces of marine pollutants and send real-time alerts. This time-saving method could bring huge benefits to the seafood industry and environmental authorities, who can take quick and decisive action.

Marine pollution represents an environmental and economic threat by putting biodiversity at risk, disrupting the food chain and impacting fisheries, aquaculture and tourism. While scientists have sought to fine-tune monitoring methods in order to alert public authorities, industry and citizens, issuing these alerts can take time. Samples have to be sent to laboratories for analysis, while monitoring sometimes requires specialised workers, heavy equipment and expensive on-site inspections.

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In order to address these challenges, the EU-funded SMS (Sensing toxicants in marine waters makes sense using biosensors) project brought together scientists, SMEs and environmental agencies to develop a cost-effective, easy to use monitoring device that can deliver real-time results. The project designed an instrument that can be installed on an ocean buoy, and from there analyse seawater quality, delivering alerts through a wireless connection in around two hours.

Real-time water quality analysis

'This prototype device capable of monitoring different algal species and related toxins, all from the same sensory platform, has been our key achievement,' says SMS project coordinator Prof. Konstantinos Petropoulos from the University of Roma II in Italy. 'We are confident that seafood industries as well as environmental control authorities now have the potential to take advantage of this new technology, in order to protect human health and safety.'

Specifically, the device is equipped with sensors to detect marine algal toxins; toxic algal species; the presence of pharmaceuticals; as well as chemical compounds such as pesticides, herbicides and flame retardants. 'We were able to combine all these features and sensory platforms into one prototype,' says Petropoulos. 'We also figured out a way of achieving a WIFI connection for data transfer.'

All data collected is stored locally in coastal buoys and platforms before being forwarded to a remote central node. This allows competent authorities and professionals to make informed and quick ocean management decisions.

'Algal toxins can contaminate shellfish and therefore pose a real risk to human health,' says Petropoulos. 'This is why it is so important to be able to issue early alerts.' Indeed, the accumulation of toxins in shellfish such as mussels, oysters and clams can have severe repercussions on human health. Paralytic shellfish poisoning, which occurs from ingesting shellfish containing toxins, can cause life-threatening neurological effects.

Flame retardants were also taken into consideration as they are often found in paint used for boats and ships, while pesticides and antibiotics end up in the ocean as a result of poorly managed industrial waste. An important feature of the device is its ability to detect pollutants at very low concentrations.

Healthy economic benefits

SMS has only now ended but Petropoulos is confident that, in addition to bringing environmental and health benefits, the project's success will also create new commercial opportunities for SMEs involved with sensors and monitoring devices. 'Suppliers of commercial kits could be interested in this technology because the prototype device we developed is able to host many of the reagents that are already used in kits,' says Petropoulos. 'And of course, our device is able to perform real time analysis while in the ocean, rather than delivering samples to be tested in the laboratory.'

The next step, says Petropoulos, will be to work on miniaturising the device in order to make the concept as flexible and commercially viable as possible. Petropoulos and his team are also interested in developing even more sensitive and robust sensors using nanotechnology.

We are confident that seafood industries as well as environmental control authorities have the potential to take advantage of this new technology, in order to protect human health and safety.

Project	**Sensing toxicants in Marine waters makes Sense using biosensors**
Coordinated by	Università degli Studi di Roma Tor Vergata, Italy
Funded under	FP7-KBBE
Project website	http://www.project-sms.eu/

Protecting aquaculture by vaccinating fish

Researchers with the EU-funded TARGETFISH project are using vaccines to help combat the outbreak of disease in farmed fish species.

Aquaculture production in Europe is responsible for the employment of 100 000 people, generating an annual turnover of EUR 7 billion. However, partly due to a lack of authorised veterinary products for medicinal treatment, the consequential outbreaks of disease in farmed fish species can cost the sector up to 20 % of its production value. The most appropriate method for controlling the spread of disease is to prevent it from starting in the first place, through vaccination.

The EU-funded TARGETFISH project set out with one main objective: to effectively vaccinate fish. 'TARGETFISH was revolutionary in that it not only generated fundamental knowledge for the development of next generation vaccines and different routes of vaccine administration, but it also validated this knowledge by actively working on rapid implementation of improved or new prototype vaccines,' says Project Coordinator Geert Wiegertjes.

A long-lasting contribution

TARGETFISH aimed to provide a long-lasting contribution to the prevention of important fish diseases in the European aquaculture industry. Specifically, its research focused on the generation of knowledge on relevant antigens, new oral systems for delivering these antigens to mucosal body sites, and new adjuvants for improving the duration of immunity. This information was then evaluated against both mucosal and systemic protective immune responses.

Several research groups have confirmed the efficacy of this form of vaccination and, as a result, DNA vaccination against pancreas disease in Atlantic salmon may soon become a reality in Europe.

With this information in hand, researchers next turned their attention to learning from and improving upon, existing vaccines. They also focused on prototyping vaccines whose efficacy was then validated via *in vitro* assays and *in vivo* challenges. The efficacy of vaccines was validated for minimal side effects and maximum safety.

Lastly, vaccination protocols were scrutinised under field conditions, shortening the route for the implementation of the project's results. These results were then presented to policy makers, scientists and industry leaders.

Challenges and solutions

During the course of the work, researchers came up against several challenges that required innovative solutions. For example, although DNA vaccination by injection had already been shown to be effective, its application in Europe had been halted due to debates around the safety of DNA-based vaccines. 'Knowing this, we placed substantial effort on studying the genome integration aspect, for which we expect the final data on the integration of plasmid DNA in muscle tissue in the near future,' says Wiegertjes. 'In the meantime, several research groups have confirmed the efficacy of this form of vaccination and, as a result, DNA vaccination against pancreas disease in Atlantic salmon may soon become a reality in Europe.'

The project also specifically aimed to integrate the many SMEs who provide improved forms of antigens, vaccination and delivery methods. One important issue addressed with the help of these enterprises was the development of oral vaccines that protect antigens from degradation in the gastro-intestinal tract. 'Although we frequently measured a strong uptake of antigen and subsequent immune responses in the gut, we did not always find these to be protective when the fish were challenged,' says Wiegertjes. 'That being said, we do expect to see better protection in the future when doses and duration of feeding vaccines are optimised.'

As the project moves towards completion, it has already helped improve *in vitro* read out systems and *in vivo* procedures, as well as succeeding in producing improved vaccines and new vaccine prototypes.

Project	**Targeted disease prophylaxis in European fish farming**
Coordinated by	Wageningen University, the Netherlands
Funded under	FP7-KBBE
Project website	http://targetfish.eu/project

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