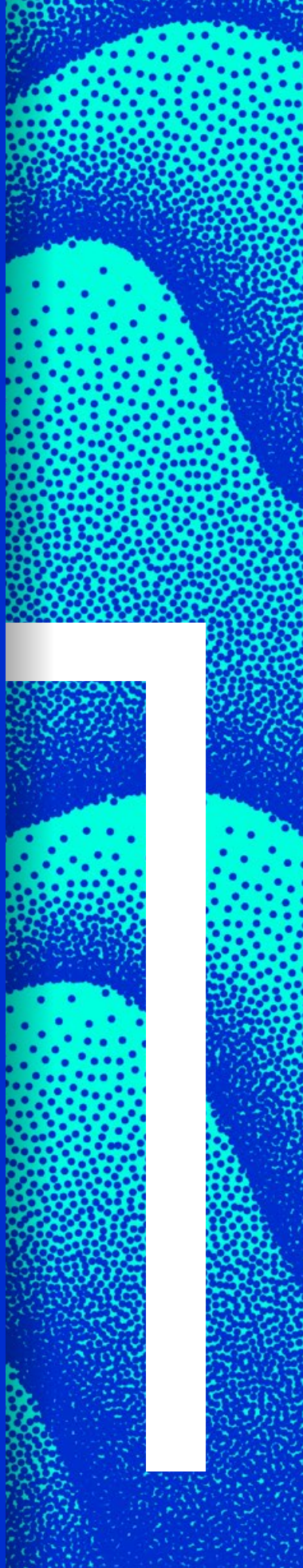


A year with Ifremer

2021



2021

**For beautiful,
useful, shared
ocean sciences**

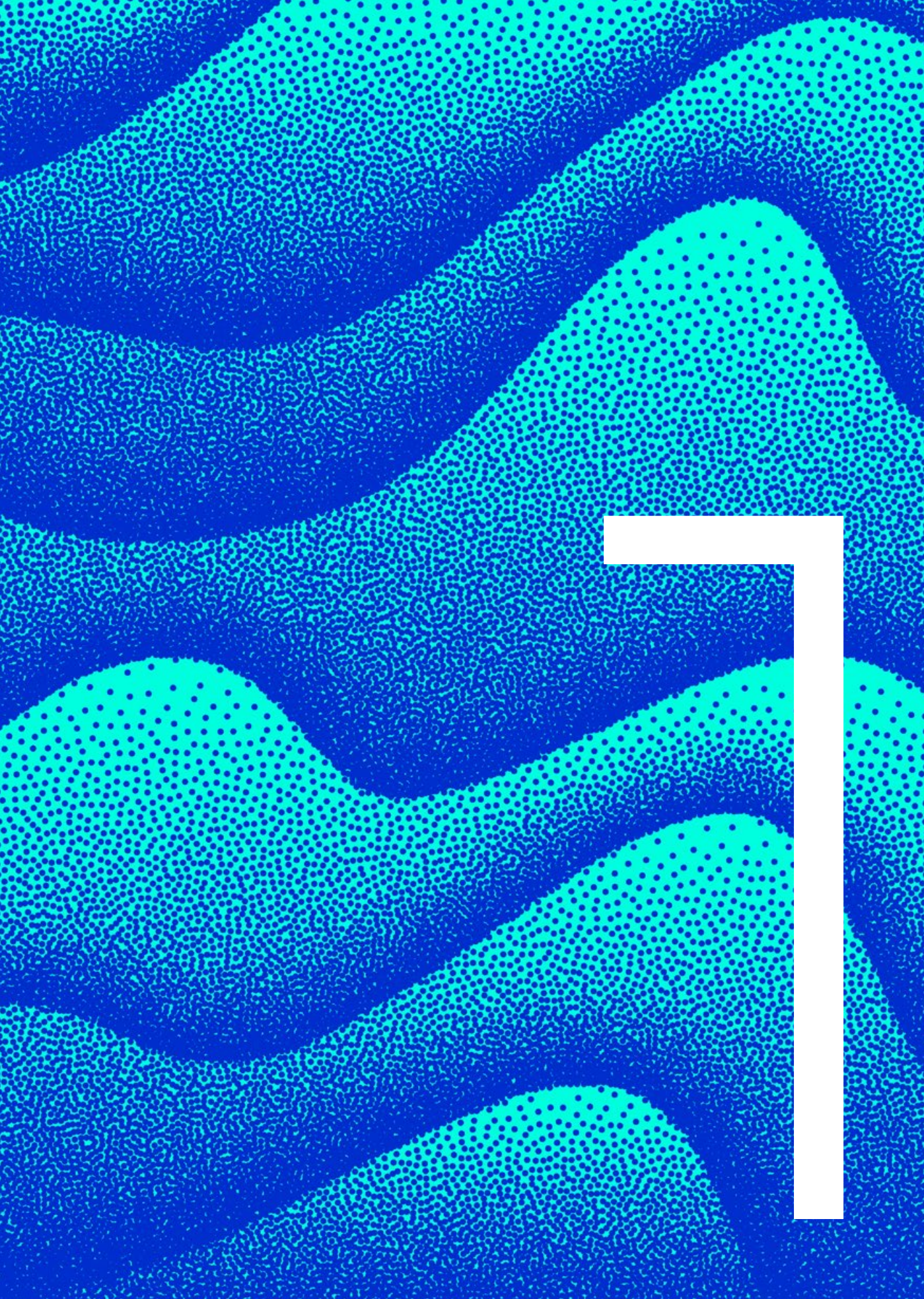


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Foreword by the UNESCO Director-General, Audrey Azoulay



Audrey Azoulay,
Director-General
of UNESCO.
Photo: UNESCO/
Christelle Alix

The ocean's health is deteriorating.

All the indicators are in the red: temperature, oxygen levels, acidification and the progressive disappearance of coral reefs and mangroves. According to UNESCO's latest data, which is particularly alarming, we are at the point where the ocean could stop being a valuable ally—it has absorbed nearly half the CO₂ produced since the industrial revolution—and instead become an emitter.¹

We can draw three lessons from this observation.

Firstly, we must better protect the ocean. Marine World Heritage sites cover less than 1% of the ocean's surface, yet they store the equivalent of 10% of carbon emitted in a year.² The importance of protective measures is therefore all too clear.

But protection alone is not enough. Our knowledge of the ocean is still incomplete. To protect and act, we must first know and understand. Yet only 24% of the ocean floor is currently mapped.

Finally, we must invest more heavily in raising awareness, particularly among young people. UNESCO has therefore committed to supporting its Member States to integrate ocean education into their school curricula by 2025.

However, we must do more—much more. The United Nations Ocean Science Decade, which kicked off last year and is coordinated by the Intergovernmental Oceanographic Commission of UNESCO, is an opportunity to mobilize the international community and all relevant actors, because we cannot remain in such a state of relative ignorance.

Scientific partners such as Ifremer play a central role in advancing ocean science. The 600 scientific publications mentioned in this 2021 Annual Report are proof of Ifremer's dynamism, its excellence and the commitment of the women and men who work there—like Tepoerau Mai, postdoctoral research scientist at Ifremer New Caledonia, who

was named a L'Oréal–UNESCO For Women in Science Young Talent for her work on toxic microalgae. This scientific expertise is immeasurable and makes Ifremer a particularly valuable partner for UNESCO.

As such, Ifremer, in Brest, is home to OceanOPS, the joint technical commission of the World Meteorological Organization and the Intergovernmental Oceanographic Commission of UNESCO.

Its objective is simple but essential: to increase the number of measuring tools in its network. To this end, in 2021, buoys were deployed by four Vendée Globe skippers. In the same vein, the Odyssey Project calls upon civil society, sailors, NGOs and the private sector so everyone can play a part in strengthening the global ocean observation system.

To protect the common good that is the ocean, UNESCO is proud to rely on a partner as essential as Ifremer. This Annual Report shows that, by mobilizing everyone, we can turn the tide in a major way, and act tangibly and efficiently for the ocean, our blue lung.

¹ Intergovernmental Oceanographic Commission of UNESCO, *Integrated ocean carbon research: a summary of ocean carbon research, and vision of coordinated ocean carbon research and observations for the next decade*, April 2021.

² UNESCO, *UNESCO Marine World Heritage: custodians of the globe's blue carbon assets*, February 2021.

François Houllier, Chief Executive Officer at Ifremer



François Houllier,
Chief Executive Officer
at Ifremer.
Photo : Olivier Dugornay /
Ifremer

Ocean sciences make waves on the national, European and international agendas

2021 saw the debut of the UN Decade of Ocean Science for Sustainable Development (2021–2030) and the European mission “Restore our ocean and waters.” It saw the announcement of the One Ocean Summit at the World Conservation Congress, with seabed exploration as one of the 10 priorities of France 2030. It saw the ongoing rise of offshore wind farms and the corresponding demand for knowledge in this field. Without a doubt, this year confirmed the prominence of ocean, marine science and marine technology issues at every level—national, European, and international.

This year was affected by the ongoing COVID-19 pandemic as well. The pandemic continued to disrupt teams’ activity and everyday lives, the Institute’s programs, and the French Oceanographic Fleet cruises that Ifremer operates with support from its subsidiary Genavir on behalf of the scientific community.

It was within this context, both exciting and demanding, that Ifremer pursued its missions and prepared for its assessment by the High Council for Evaluation of Research and Higher Education (Hcéres).

The Institute continued modernizing its infrastructures and began the implementation of the three major investment plans adopted at the end of 2020, with events including the inauguration by the French prime minister of the new Ifremer headquarters; the completion of the Seas

and Coastlines Center (CELIMER) in Sète, and new laboratory facilities dedicated to mollusk research in La Tremblade; the launch of the BATIMER project in Nantes; the renovation of the high seas vessel *L’Atalante*; the development of the underwater observatory projects off the coast of Mayotte and New Caledonia; the launch of the ARGO ocean observation cluster of projects and DeepSea’nnovation, which will add new sensors to remotely operated underwater robots; the creation of the subsidiary Ifremer-Innovation-Investissement and a partnership with new impact fund Blue Ocean; the creation of a project team with Inria and IMT-Atlantique on the digital ocean; and the preparation of the first Blue Research Chair position which will be launched in 2022 in Nantes on the general theme of “ocean and health.” All of these will set the stage for the future.

The Institute reaffirmed its desire to engage with the public by establishing the Stakeholders Committee; participating in the World Conservation Congress in Marseille; and orchestrating, along with the Centre national de la recherche scientifique, the National Research Institute for Sustainable Development, and thirty-four other partners from around the world, the online OneOceanScience campaign, which opened the Oceans session at the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP26) in Glasgow.

2021

Key figures

Research

600

scientific
publications

16

Institute
research units

11

mixed
research units

3

ongoing
ERC projects

Expertise

89

official opinions
and statements
produced

Innovation

14

invention
disclosures

Human resources

1,525
salaried employees

700

researchers
and engineers,
including **102** HDR
diploma holders

155

doctoral
students

33

post-doctoral
researchers

68

full-time staff
members recruited
in 2021
(CDI contracts)

Budget

240

million euros in expenses,
including 31.7 million euros
in investments

1,571

FTE
(annual full-time equivalents)

2021 Highlights



February 2021

Creation of PIIRESS, a research platform in Saint-Pierre and Miquelon

Along with representatives from the archipelago and other French and international research institutions, Ifremer participated in the creation of the "Plateforme Interdisciplinaire et Internationale de Recherche et d'Enseignement Supérieur en zone Subarctique" (PIIRESS) in Saint-Pierre and Miquelon. Its mission is to broaden scientific knowledge that could serve the social, economic, and cultural development and heritage of the archipelago; to provide logistical support for ongoing scientific research programs; and to share this knowledge with the population.

LES CHAIRES BLEUES DE L'IFREMER

May 11 & December 1, 2021

Call for candidates for the first two Blue Research Chair positions

In a new strategic move by Ifremer, the Blue Research Chairs aim to open up innovative fields of research. The first position will be located in Nantes and focus on "Contaminants, the sea, and health." The second will be in the Indian Ocean and study the seismic/volcanic disruption near Mayotte.



May 20, 2021

AFD-Ifremer alliance to preserve marine ecosystems

The agreement signed by Ifremer and the French Development Agency (AFD) to produce knowledge and tools to protect and manage marine resources has entered into its operational phase. Eight scientific projects have been launched to benefit developing countries. They are spread over the three major oceans and the Mediterranean Sea and tackle big topics: climate change, biodiversity, environmental observation and management, and more.



**PROGRAMME
PRIORITAIRE
DE RECHERCHE
OCEAN
& CLIMAT**

June 8, 2021

Launch of the “Ocean & climate” priority research program

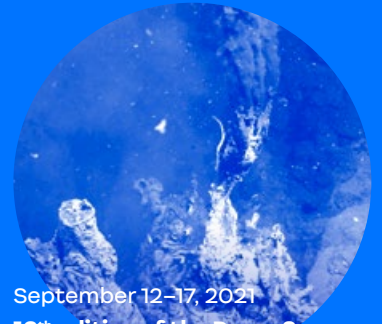
This new program, spearheaded by Ifremer and the CNRS, brings the French scientific community together around key ocean-related challenges. Endowed with a €40 million budget for six years, it encourages scientists to study seven significant interdisciplinary issues having to do with understanding, protecting and making sustainable use of marine environments.



September 4–11, 2021

Marine biodiversity at the Inter- national Union for Conservation of Nature (IUCN) congress

Ifremer attended the IUCN World Conservation Congress, the world's largest gathering focused on biodiversity, which drew close to 25,000 visitors to Marseille. This was an opportunity for our researchers to conduct public outreach, lead workshops, and participate in discussions featuring the 1,500 members of the IUCN, thousands of experts, and representatives from 160 countries.



September 12–17, 2021

16th edition of the Deep-Sea Biology Symposium

Ifremer hosted this flagship event at Océanopolis (Brest). For several years, the symposium has been making its mark on progress in science and specifically in the biology of the marine seabed. Nearly 600 participants from 46 countries came together to discuss this ecosystem—the largest and least-explored on the planet—through many presentations, posters, workshops, and a round table on biomimicry.



October 8, 2021

Cooperation with the European Molecular Biology Labora- tory (EMBL) to promote ocean sciences

By signing an agreement with the EMBL, a molecular biology research structure that combines forces from around thirty countries, Ifremer committed to strengthening scientific cooperation in the realms of marine biodiversity and host-pathogen-environment interactions.



October 7, 2021

Four researchers honored in 2021

Tepoerau Mai, a post-doctoral researcher within the Ifremer delegation in New Caledonia, was one of the thirty-five recipients of the **L'Oréal-UNESCO Rising Talents Prize for Women in Science**. Her research focuses on harmful and toxic microalgae in New Caledonia and their potential health impacts.



November 23, 2021

The 2021 Christian Le Provost prize

was awarded to Camille Lique, an Ifremer researcher at the Laboratory for Ocean Physics and Satellite Remote Sensing, for her research on ocean dynamics in the Arctic basin, where the ravages of climate change are the most visible.



November 30, 2021

Headed by Françoise Leroi, the Microbial Ecosystems and Marine Molecules for Biotechnology Laboratory (EM3B) in Nantes received the **Prix de l'Académie de Marine**. This distinction recognizes their work on a wide variety of marine bacteria and their potential uses (health, chemistry, human nutrition, environment). The marine data portal SeaDataCloud, co-coordinated by Michèle Fichaut, a researcher for Scientific Information Systems for the Sea (SISMER) at Ifremer, was named the winner of the 9th edition of the “**Étoiles de l'Europe**” trophy (with a special mention for open science).



February 12, 2021

How are the fish doing? 47% of fish caught in France come from sustainably fished populations

Many scientists are involved with the efforts to track exploited fish populations in France (their demographics, species renewal, ecosystem health, etc.). As it does each year, Ifremer presented its 2020 report on the subject during a digital press conference. The shift toward more sustainable fishing is undeniable, but there remains much to be done to reach the objectives set by the European Union.



September 6, 2021

Scientific support for the Blue Ocean fund

SWEN Capital Partners, a leader in sustainable investment, announced the launch of its second European impact fund: *Blue Ocean*. The fund's goal is to raise €120 million to finance innovative start-ups dedicated to ocean regeneration. Ifremer will provide support for this operation as an expert tasked with evaluating investment opportunities based on robust scientific and technical criteria.



October 25, 2021

The OneOceanScience appeal

Dreamed up by Ifremer in partnership with the CNRS and the IRD, this international ocean-focused event received support from the Ocean & Climate Platform, ESA astronaut Thomas Pesquet, and John Kerry, the United States Special Presidential Envoy for Climate. On this occasion, thirty-seven scientists from thirty-three countries created a series of short videos (viewable on the interactive website oneoceanscience.com) in order to alert the public and the COP26 delegations to the crucial role of the ocean in the fight against climate change.



November 8–9, 2021

Establishment of the Stakeholders Committee

With this new consulting body that reports to the Board, Ifremer wants to open its doors further to civil society. The committee's twenty-three members are people dedicated to protection of the marine environment, actors in the maritime sector, and local officials from coastal communities. The committee's objective is to add a societal dimension to research programs and increase communication of knowledge to the greater public.



February 6, 2021

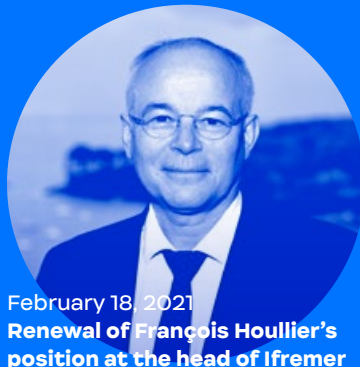
Inauguration of Ifremer's new headquarters

Cofinanced by national and local government entities, the new headquarters is located in Brest at the Institute's largest research center. It was inaugurated by the prime minister. The building was christened Bougainville in honor of the great French explorer.



February 12 & September 13, 2021
Visits from the Minister of the Sea

Annick Girardin, the Minister of the Sea, visited the Palavas experimental site and Ifremer’s La Seyne-sur-Mer Center in the company of local officials and institutional representatives. Her first visit focused on aquaculture and fish farming activities in Occitania. Her second concerned Ifremer’s activities in the southern region of Provence-Alpes-Côte-d’Azur (monitoring of chemical contamination, microplastics studies, ecological restoration, underwater operations, etc.).



February 18, 2021
Renewal of François Houllier’s position at the head of Ifremer

François Houllier has been the Chief Executive Officer of the Institute since September 2018. Following the Board’s proposal, his term was renewed for the next five years by the government. He took the opportunity to reaffirm his commitment to promoting “beautiful, useful, and shared science.” Openness to society, strong scientific ambition, a culture of innovation, and willingness to spearhead initiatives at the international level are key elements of the Institute’s 2030 strategic plan.



July 6, 2021
Creation of subsidiary I3 (Ifremer-Innovation-Investment)

A *société par actions simplifiée* (SAS) with capital of €7 million, the I3 subsidiary of Ifremer was created to support Ifremer’s equity participation within the context of its policies promoting innovation and research. On September 1, 2021, during its inaugural meeting, the board drew up a roadmap for the new entity.



October 14, 2021
Overseas France Action Plan (PAOM)

Ifremer is active in all three major oceans thanks to its overseas outposts. Ifremer has now created a 2021–2025 action plan with and for the French overseas territories. The PAOM aims to strengthen connections between sites, local scientific policies, tools, and regional cooperation efforts. The ultimate goal is to enable the overseas sites to assert themselves and to fully integrate them into the Institute’s strategy.



November 24, 2021
Renovation of La Tremblade for sustainable aquaculture

Expanded and modernized with support from the Nouvelle-Aquitaine region, the new Ifremer station at La Tremblade was inaugurated in the presence of regional and national actors. This infrastructure, dedicated to the study of marine mollusks, works to develop sustainable aquaculture that will better protect the health of consumers, animals and the environment.

Photos: Éric Brossier, PIIRESS, Olivier Dugornay, Ifremer, Anne-Laure Clément, J.C. Caslot, C. Coatanoan, S. Lesbats, É. Buffier, Gatis Marcinkevics

The French Oceanographic Fleet around the world



After a 2020 that was abruptly disrupted by the pandemic, 2021 seemed like a relative return to normalcy. While international conditions remained uncertain and volatile, the French Oceanographic Fleet was able to complete the most important of its activities. It upheld protective measures when scientists embarked on each of its 115 cruises and its scientific activity was calculated at 2,329 days, which is close to 2019 levels. Several of its operations merit special attention for their partnerships or exchanges of scientific and technical knowledge, as well as for the renewal of certain vessels and pieces of equipment.

Success of “Get to Know the Fleet”

This first online edition of “Get to Know the French Oceanographic Fleet” was a striking success. This event, held to strengthen ties with Fleet users, featured around fifty speakers and attracted over 400 participants. Many attendees, pleased by the different discussions on the Fleet’s operations, future cruises, and technological developments, said that they would love to see a second edition in the years to come.

20 years of partnership with the Navy and SHOM

Ifremer, the French Navy and the Service hydrographique et océanographique de la Marine (SHOM) began cooperating in 2001 to pool oceanographic and hydrographic resources. The Fleet wanted to mark the 20th anniversary of this agreement with representatives of the other two actors. Their reports evoke fruitful collaboration held in high regard and a shared desire to continue these efforts.

Remarkable scientific cruises

Understanding the ocean's role as a climate regulator, its evolution, its biodiversity and its deep-sea ecosystems: oceanographic cruises seek to get to the heart of these subjects and more.

GHASS 2

Under Ifremer's guidance, eighty scientists headed for the Black Sea to evaluate the threat posed to the climate and to marine seabed stability by methane emissions related to the dissociation of gas hydrates trapped at the bottom of the ocean.

ChEReef

For five years, through observations of the ocean's surface and a deep-water observatory, scientists will scrutinize cold-water corals in the Bay of Biscay in order to assess their health and the pressures they face.

AMAZOMIX

This multidisciplinary cruise integrates physical, biogeochemical and ecological approaches to the Amazonian slope and plateau, shedding new light on the poorly understood processes that unfold at the mouth of the Amazon and their impact on ecosystems.



Aboard the *Pourquoi Pas?*, the scientific team discusses and narrows down the diving and sampling objectives of the GHASS2 cruise, which focused on gas hydrates in the Black Sea.

Photo: S. Lesbats - Ifremer



The underwater robot *Ariane* goes out scouting. Its mission: to find the best place to put a seafloor observatory and observe the daily life of cold-water corals.

Photo: N. Floc'h

Continuing modernization of vessels and equipment

One of the primary concerns of the French Oceanographic Fleet is being able to offer scientists best-in-class equipment for their explorations. The Fleet has actively continued to upgrade its vessels and technology to ensure that its instruments and procedures are ever more efficient and sustainable.

Left: *R/V L'Atalante* underwent a significant renovation in 2021.
Right: *DriX*, an unmanned surface vehicle for collecting scientific data
Photos: F. Bertermin / Ifremer, Florian Schattner - iXblue



Modernization and deployment of ROV *Victor 6000*

The remotely operated vehicle (ROV) *Victor 6000* is one of the most powerful robots in its category in the world, and a valuable asset for the Fleet's seabed exploration. A modernization program was started to make it more powerful and improve its carrying, sampling, measuring, and imaging capabilities. Simultaneously, the Fleet's teams worked to adapt *R/V Marion Dufresne II* so that the vessel could deploy *Victor 6000* with all of its equipment.

Refitting of *R/V L'Atalante*

As one of the Fleet's main vessels, *R/V L'Atalante* transits through every ocean and regularly makes trips around the world. It was put into service in 1989 and refitted once before in 2009. This year, it benefited from a complete overhaul. From cutting-edge energy production (cleaner and cheaper) to improved handling equipment, upgraded living quarters, an updated IT system, new paint in the Fleet's colors, and heavy maintenance, no element of the ship was left out. It will continue to serve the Fleet until the end of the decade.

Evaluation of the potential of unmanned surface vehicles

As part of SEMNA (Multiplatform Expert Autonomous Navigation System), Ifremer is studying the potential of unmanned surface vehicles (USV) and their possible integration into the French Oceanographic Fleet. Alongside many public and private actors, our teams will work for several years to develop a multiplatform system for navigation and management of maritime operations.

More details can be found in the annual report of the French Oceanographic Fleet

Protecting and restoring the seas and oceans

A vibrant, healthy,
safe, and resilient
ocean

The ocean produces part of the oxygen that we breathe. It feeds us. It provides energy and it regulates our planet's climate. In observing and seeking to understand the marine world, Ifremer works to preserve our shared future and the goal of a vibrant, healthy, safe, and resilient ocean.

The coelacanth, an unexpectedly long-lived fish

An article published by scientists from Ifremer and the Muséum national d'histoire naturelle reveals that the coelacanth can live for almost a century. Its five-year gestation period is among the longest known, but its late reproduction, around age fifty-five, makes the species' survival more precarious.

100 years: the potential lifespan of coelacanths, based on recent estimations by Ifremer and MNHN researchers.
Photo: MNHN



The coelacanth is an legendary animal whose origins go back some 400 million years. It makes its home in the depths and can measure up to two meters long and weigh up to 110 kilograms. As a critically endangered species, its population amounts to just a few thousand individuals. Scientists had estimated its lifespan to be about twenty years, but the new study shows that, in fact, this is a very long-lived fish that grows slowly.

Using advanced methods and techniques from Ifremer's sclerochronology unit, researchers assessed the Museum's collection of coelacanths, which is one of the largest in the world. Examination of scales from

twenty-seven specimens ranging from embryos to adults revealed the exceptional longevity of the species and shed light on its progressive extinction: not many adults manage to reach reproductive age.

The scientists are continuing their work on the relationship between water temperature and coelacanth growth, because climate change could constitute an additional threat to the species' survival.

Sclerochronology Unit

Unique in France, this research unit at Ifremer is located in Boulogne-sur-Mer and studies fish growth by analyzing their scales and their otoliths, calcified structures located inside their inner ear.

Mahé Kelig, Ernande Bruno, Herbin Marc. "New scale analyses reveal centenarian *Latimeria chalumnae*." *Current Biology*, 2021. [https://www.cell.com/current-biology/fulltext/S0960-9822\(21\)00752-1](https://www.cell.com/current-biology/fulltext/S0960-9822(21)00752-1) DOI:10.1016/j.cub.2021.05.054

Better understanding and protecting cold-water corals

Placing MARLEY in the water. This "spy" is here to learn all of the secrets of cold-water corals.
Photo: Ifremer



A seabed observatory named MARLEY (*Monitoring Deep Sea Coral Ecosystem*) has been installed 1,000 meters deep in the Lampaul Canyon off the coast of Brittany. For the next five years, it will track information about cold-water corals and their reproduction; their conservation status is currently uncertain.

Coral reefs aren't limited to the tropics. They can be found up to 2,000 meters below the surface in areas of complete darkness, where currents are strong and the water temperature is 4–13°C. Like their tropical counterparts, cold-water corals are extremely valuable to their surrounding environment; they form a complex habitat that shelters many species during reproduction and more generally throughout their lives. This sensitive ecosystem, which is slow to recover from damage, is now threatened by trawling, pollution, and climate change.

To learn more about these little-known corals, Ifremer initiated a project ChEReef (Characterization and Ecology of Cold-Water Coral Reefs) within the framework of the European project MarHa (Marine Habitat). It consists of creating a very high-resolution map of the Lampaul Canyon, then taking samples and performing on-site experiments with the aid of a seafloor observatory. The observatory will make it possible to film a coral reef for fifteen minutes each day for five years and study polyp behavior as well as the fauna around the reef. Six oceanographic cruises are planned through 2026.

The first, carried out with R/V *Thalassa* and the submersibles *AsterX* and *Ariane* from the French Oceanographic Fleet, mapped out the zone and installed a seafloor observatory. Some of the dives were broadcast live at Océanopolis in Brest.

Until 2025, the Life MarHa project will supplement actions taken at 164 Natura 2000 sites in France (designated for their natural marine habitats) in order to reestablish a good conservation status. It is coordinated by the Office français de la biodiversité along with eleven other partners and aims to use every means necessary to reach its goal: governance, awareness-raising, training, data acquisition and management, site management, and more.

Birth of the Ocean Spy platform

Participatory science used to analyze underwater images

Catherine Borremans,
an engineer and biologist
specializing in imaging
at Ifremer and
the coordinator of the
Ocean Spy platform.
Photo: S. Lesbats -
Ifremer



As an engineer and biologist specializing in imaging in Ifremer's Deep Sea Laboratory, Catherine Borremans oversees the coordination of Ocean Spy, Ifremer's new participatory platform. This tool invites the public to lend researchers a hand by annotating underwater images from the seafloor, cold-water coral habitats, and coastal environments—a partnership in service of knowledge.

Where did you get the idea to call on the public to help annotate underwater images?

The often continuous acquisition of images of deep-sea fauna and habitats has become common practice and has led to astronomical growth in the volume of videos and images to be viewed and annotated. We sought to make this process automatic through artificial intelligence and machine learning (improving system performance through data).

The necessary first step for this approach is to create reference databases to train the algorithms on. Our idea was to get the public involved in annotating images and building these training data sets, which led to the creation of the Deep Sea Spy platform in 2016, then Ocean Spy in 2021. This idea dovetails perfectly with Ifremer's policy of openness to society. The platform is an opportunity to connect the greater public to science and give interested people a way to learn more about marine ecosystems on their own and contribute to our knowledge about the ocean.

What was the purpose of Deep Sea Spy, the first platform?

With Deep Sea Spy, we asked the public to look at images captured by deep-sea observatories near hydrothermal vents and identify certain species that live in these environments. The platform features a tutorial that explains how to analyze the images, an interface for annotating the images, and a gamified system of levels and rewards that players can obtain after annotating certain numbers of images. The platform graphics are fun and appealing. After annotation, we have a verification and approval process.

This project has worked well. We've had almost 3,000 contributors. Most are French, but some are foreign, because we made sure to create an English version of the game too. Student participation (from primary school through high school) has been a great way to raise awareness within a young audience about the importance of preserving marine environments.

What does the new Ocean Spy platform have to offer?

With Ocean Spy, we hope to attract more participants as well as other producers of images. Several of our partners have expressed interest. We suggested making the tool available for different ecosystems and tweaking its features to adapt it to the specificities of each one.

Ocean Spy has a main portal that gives access to each of these platforms, which range from coastal environments (Shore Spy) to cold-water coral habitats (Deep Sea Spy Coral) and more.

We've almost finished developing Ocean Spy. It should be online in 2022.

And at the same time, are you working on automation?

Yes, we already have one algorithm for automatic identification, but there's still a lot of work to do to make it fully operational. Public participation will be useful for this aspect too, because we will need people to approve the annotations suggested by the algorithm. Since we intend to integrate new types of images into the system too, we'll continue to need to build new training data sets with assistance from participatory science.

What does the future hold for the European flat oyster?

The artificial reefs built for the FOREVER project provide a welcoming environment along European coasts for wild European flat oysters, a severely threatened species.
Photo: S. Pouvreau - Ifremer



Scientists from Ifremer and professionals from the shellfish-farming sector have joined forces on project FOREVER (Flat Oyster Recovery), which shows that it could be possible to restore *Ostrea edulis* populations. This wild oyster, native to the European coasts, is in danger of extinction.

European flat oysters, the only oyster species native to Europe, have enjoyed several million years of existence. For a long time, they flourished along the coasts of France and many other countries from Norway to Croatia. However, two centuries of overfishing and mechanization, combined with the emergence of two destructive parasites, have put an end to their legendary abundance. In the early 2000s, the European flat oyster was added to the list of threatened species under the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR).

Growing awareness in Europe led to the launch of the research project FOREVER in France. The project thoroughly documented the ecology, genetics, and pathology of the last remaining populations. Most of the oyster populations still in their natural state were in Brittany. Scientists then turned their focus to the dynamics of these populations: larval abundance and dispersion, environmental factors, effects of predation, impact of parasitic diseases, and more. The final step was a new one: to design and test conservation and restoration solutions on the last representatives of the species

in their natural state. These studies showed that European flat oyster beds could once again repopulate the European coasts. Ifremer's scientists continue striving to make this a reality.

FOREVER (Flat Oyster Recovery)

Financed by the European Maritime and Fisheries Fund and coordinated by the Comité régional conchylicole de Bretagne Sud, this program (2018–2020) involved Ifremer for the scientific part and the on-site follow-up, the École supérieure d'ingénieurs des travaux de la construction in Caen for the creation of artificial reefs for the oysters to attach to, the [Comité régional de la conchyliculture de Bretagne Nord](#) and several engineering firms in Brittany.

Toxic microalgae and climate change: A major ecological challenge for coastline health

Scientists from Ifremer and the Université de Nantes conclude, from their study on *Dinophysis*, that toxic microalgae blooms will continue to appear in coastal European waters no matter which of the IPCC's climate predictions comes true. This phenomenon threatens biodiversity, human health, and shellfish farming operations.

Placed under close scientific surveillance, the toxic microalga *Dinophysis* will nevertheless continue to wreak havoc along the French coast until at least 2100, no matter what climate scenario plays out.
Photo: Ifremer



Present along the French coasts, *Dinophysis* microalgae produce toxins that are harmful to human health when consumed through shellfish. Their evolution is closely tracked by the [national networks monitoring phytoplankton \(REPHY, operated by Ifremer\) and phyco-toxins \(REPHYTOX, operated by the Ministry of Agriculture\)](#).

As part of the European project CoCliME, scientists sought to predict how *Dinophysis* would respond to different climate scenarios hypothesized by the Intergovernmental Panel on Climate Change (IPCC). They studied the microalga's development under different temperature, pH, rain-

fall, and irradiance conditions. The results showed that in all scenarios, *Dinophysis* would continue to form blooms until the year 2100 at the least, although their size remains difficult to predict.

Scientists also calculated that *Dinophysis* was responsible for 68% of bans on fishing and fish sales in Pays de la Loire and southern Brittany between 2004 and 2018. This statistic shows the outsized importance of these toxic microalgae. Other work performed jointly with the Université de Bretagne Occidentale and the Virginia Institute of Marine Science (USA) has also shown that *Dinophysis* has an impact

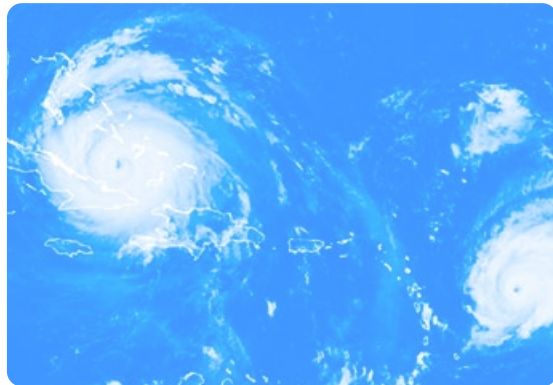
not just on oysters, but also on the gills of certain fish.

CoCliME (Co-development of Climate Services for Adaptation to Changing Marine Ecosystems) Initiated in 2017 and coordinated by the Marine Institute (Ireland), this project brought together researchers from eleven countries. It was financed by several European research agencies, including the ANR in France, and aimed to use case studies in the Mediterranean and the Atlantic to analyze the consequences of global warming for human health and human activities linked to marine areas.

Effect of tropical cyclones on sea surface salinity

Along with temperature, seawater salinity is a key geophysical indicator for understanding ocean dynamics. Ifremer scientists used ten years of satellite data to shed new light on cyclone-related variations in salinity.

In September 2017, an unusual series of cyclones hit the Antilles. Source: Météo France



Salinity and temperature determine water density and thus, in interaction with the atmosphere, play a major role in the formation of ocean water masses. Global ocean circulation is connected to sea surface salinity, a key indicator that scientists began measuring via satellite in the 2010s through NASA and ESA missions. Using this satellite data, scientists from the Laboratory for Ocean Physics and Satellite Remote Sensing at Ifremer were able to estimate the average global surface salinity response to the passage of tropical cyclones.

For years, scientists have observed that tropical cyclones affect the sea surface by decreasing its temperature and increasing its salinity. Our scientists were able to characterize this phenomenon statistically by showing how the response varies according to the strength and duration of the cyclone, the preexisting salinity of the water masses, and their position in relation to the center of the storm.

A better understanding of cyclone physics and how cyclones interact with the ocean will serve researchers who seek to model these events, which will become more frequent and intense due to climate change.

Reul Nicolas, Chapron Bertrand, Grodsky Semyon A., Guimbarde Sebastien, Kudryavtsev Vladimir, Foltz Gregory R., Balaguru Karthik (2021). "Satellite observations of the sea surface salinity response to tropical cyclones." *Geophysical Research Letters*, 48(1), e2020GL091478 (10p.). <https://doi.org/10.1029/2020GL091478>

When climate makes waves in the Arctic

Under the influence of climate change, sea ice is melting and generating unusually intense fields of ocean waves. As part of the Dark Edge expedition, Ifremer researchers equipped with a multitude of innovative instruments went to examine this phenomenon.

In northern Baffin Bay in Canada, scientists measure changes in the ice. Climate change is melting sea ice and increasing waves' intensity. Photo: P. Sutherland - Ifremer



Aboard the Canadian icebreaker *Amundsen* for oceanographic expedition Dark Edge, around forty Canadian, American, Norwegian, German, and French scientists observed the biological, chemical, and physical characteristics of ice formation in northern Baffin Bay. Collaborating with researchers from the Université du Québec à Rimouski, a team from Ifremer's Laboratory for Ocean Physics and Satellite Remote Sensing focused on the physical processes that unfold at the slippery border between ice and open water. Their work was part of the WAAXT project (Wave-Modulated Arctic Air-Sea Exchanges and Turbulence) and had received an ERC research grant from the European Research Council.

To collect their data, the teams used instruments that had been specially designed for the extreme environment of the Arctic. An electrically powered catamaran kitted out by Ifremer's Technical Unit for On-Site Observation evaluated turbulence, quantity of movement, and heat flows in the water at the edges of the sea ice. The teams also employed a canoe specially designed for easier navigation between sea ice and open water, using it to place a network of buoys on the ice and collect various kinds of data. Finally, drones (AUVs) came into play to map ice coverage, position, morphology, and type, along with turbulence.

Several factors were scrutinized: the spatial distribution of the ice and variability of its thickness; the height and power of waves and their effects on the sea ice; water temperature; wind strength; and observed turbulence and currents. The data has yet to be analyzed, but preliminary observations indicate that there are powerful interactions between waves and sea ice that nevertheless take place on such small spatial and temporal scales that digital simulations fail to capture them.

About the Dark Edge expedition: Dark Edge partners: IRL Takuvik, Université Laval in Quebec, CNRS, LOPS, LOV, IBENS, LCQB, UQAR, Memorial University, Arctic University of Norway, NTNU, AWI
Funding: Amundsen Science, NSERC, ERC, ArcticNet, Sentinel North

Ongoing monitoring and investigation of underwater volcanic activity in Mayotte

In parallel with operations led by the network monitoring the Mayotte volcano (REVOSIMA), the scientific cruise GeoFLAMME and dives performed by submersible *Victor 6000* yielded remarkable data to help researchers understand the formation, evolution, and environmental impact of the volcano.

First images of lava flow from the latest French underwater volcano. It appeared off the coast of Mayotte in 2019, 3,000 meters deep. Photo: REVOSIMA – GeoFLAMME 2021



This brand-new active volcano, located at a depth of over 3,000 meters and discovered off the coast of Mayotte in 2019, remains a center of attention. Scientists rarely have the opportunity to observe a geological phenomenon like this in real time.

The MAYOBS19 cruise in 2021 continued the work of the series of monitoring operations already carried out by the REVOSIMA network by using a corer to sample sediment in different areas around the island. The physical and mechanical properties of the sediment will be analyzed in order to assess the stability of Mayotte's underwater slopes and

improve tsunami risk modeling.

At the same time, the GeoFLAMME scientific cruise focusing on the underwater volcano was carried out on R/V *Pourquoi Pas?*. For forty days, seventy scientists explored the 820-meter volcano. Thanks to ROV *Victor 6000*, they were able to obtain samples and the first ever images of the entirety of the volcano, two meters from its surface. This crucial data will be used by volcanologists seeking to learn more about lava flows and morphology. The images even showed the first signs of life colonizing some areas of the volcano.

GeoFLAMME Coordinated by Ifremer and the Institut de physique du globe de Paris, along with the CNRS, the BRGM and the Université de Paris Saclay, the cruise was facilitated by assistance from many laboratories and institutions. Carried out in partnership with the REVOSIMA network, the cruise was financed by the French Ministry of Higher Education, Research and Innovation through the French Oceanographic Fleet with support from Ifremer and interdisciplinary research institution ISblue (Université de Bretagne Occidentale).

Placing seafloor seismometers quickly and precisely

Successfully tested by Ifremer teams, the “Ballast-Cage” improves precision and speed when deploying ocean-bottom seismometers —a breakthrough for seafloor seismic monitoring.
Photo: Ifremer



The Marine Geosciences research unit at Ifremer has perfected their “Ballast-Cage,” a system that can place seismometers on the ocean floor more quickly and precisely than before in order to let them take passive measurements.

The study of continental and oceanic crusts and underwater volcanoes relies on knowledge of the geometry and nature of geological layers, which in turn requires the use of geophysical measurement tools like ocean bottom seismometers (OBS). These devices are typically placed via free fall, which has the two major downsides of imprecise positioning and a relatively long descent time. While this method is acceptable for active seismic applications, it is very unsatisfactory for passively monitoring seismic events. The seismometer’s position must be known and precise for these applications

since it can’t be calculated after the fact from the data collected.

Facing this situation while attempting to monitor the Mayotte volcano, Ifremer’s researchers devised an apparatus that could solve these problems. The OBS is placed in a 450-kilogram cage that serves as ballast and makes it possible to direct the seismometer in real time. The seismometer’s position can be adjusted as it descends and the research vessel’s winch can be used at full speed, which is a welcome advantage on scientific cruises where time is of the essence.

The Ballast-Cage was successfully tested during the MAYOBS18 cruise. Six sets of seismometers were placed at 1,480 meters and 2,135 meters deep in the exact spots that the scientists had requested. These results suggest that Ifremer could benefit from the Ballast-Cage system during other similar operations.

Successful deployment of two innovative inclinometers off the coast of Nice

These TIPS rods, never before used in a marine environment, make it possible to measure submarine landslides to better evaluate potential instability.
Photo: Olivier Dugornay - Ifremer



The TIPS (Temperature, Inclination, Pressure Sensors) rods developed during the MODAL project and tested off the coast of Nice offer new possibilities for measuring submarine landslides.

The ability to measure ground movement on natural slopes is essential for understanding and potentially mitigating landslide phenomena. The underwater environment has fared poorly in this respect because no equipment had yet been devised for these conditions.

This need has now been filled by the National Research Agency's MODAL project, which mobilized Ifremer's multidisciplinary teams within the MERS Carnot Institute. Starting with flexible rods normally used for geotechnical surveying, engineers and technicians created instruments capable of measuring the slope, interstitial pressure, and temperature of underwater sediments.

Two prototypes covered in electronics (thirty pressure sensors, forty five accelerometers, and seventy five temperature sensors) were assembled at Ifremer, then placed offshore of the Nice airport in an area known for its instability. The operation was performed during the MaRoLiS expedition with R/V *Pourquoi Pas?* and the Penfeld penetrometer, a geotechnical measuring device used to drive the rods into the sediment. The TIPS were connected to the EMSO-Ligure Nice seafloor observatory which has been providing them with electricity and recording their data in real time.

This is a significant advancement in the study of active processes that may lead to underwater slope instability. It opens up new possibilities for characterizing these phenomena.

Using paleogenetics to trace plankton evolution and assess ecosystem resilience

By studying ancient DNA buried in seafloor sediments, scientists have been able to show the impact of industrial-era pollution, especially from intensive agriculture, on plankton—which may have escalating consequences for all marine ecosystems.

What sorts of plankton species lived in the Bay of Brest 1,400 years ago? Aboard *R/V Thalia*, Ifremer researchers went hunting for answers. Photo: O. Dugornay - Ifremer



Organisms leave traces of the DNA in the sedimentary layers that make up the ocean floor. By extracting cores from the seafloor and analyzing the DNA in each layer, scientists can trace the evolution of plankton and thus evaluate the resilience of coastal ecosystems that are impacted by human activity.

This study of ancient DNA (paleogenetics) was carried out in the Bay of Brest by Ifremer biologists aboard *R/V Thalia*, making it the first marine operation of its kind in France.

Sampled from three distinct areas, the sediment cores yielded a wealth of plankton species spanning roughly the past 1,400 years. Analysis of the cores showed that the greatest

changes dated back to WWII and the 1980s–1990s, first due to bombings (heavy metals) and then to chronic pollution primarily from intensive agriculture. The study revealed an increase in toxic microalgae abundance as well, particularly for the dinoflagellate *Alexandrium minutum*, starting in the 1980s.

Published in the journal *Current Biology*, these results attest to the irreversibility of the changes that have affected coastal marine plankton, but leave open the question of the environment's capacity for resilience following these types of disruptions.

The challenge of toxic microalgae for public policy

This study was performed as part of the PALMIRA project (Paleoecology of *Alexandrium minutum* in the Bay of Brest), which was launched in 2017 upon the request of the Brittany regional authorities. The initial aim was to determine whether the works undertaken on the new polder in the port of Brest might encourage toxic blooms of the microalga *Alexandrium minutum*. In providing an answer to this research question, the scientists demonstrated the feasibility and utility of paleogenetics in the study of coastal ecosystems.

Chemical contamination in the Mediterranean

After twenty years of joint coastal monitoring, the Rhône-Mediterranean-Corsica Water Agency and Ifremer agree that the situation is generally positive: 90% of the points monitored have chemical contamination levels below the regulatory limit. However, vigilance remains crucial.

Mussels serve as invaluable sentinels in the monitoring system for chemical contamination. Here, a "control" sock is hauled on board for analysis during the SUCHI Med cruise. Photo: O. Dugornay - Ifremer



The Mediterranean coast of France is one of the best-monitored coasts in Europe. To keep an eye on it, Ifremer operates a variety of monitoring networks in cooperation with the Rhône-Mediterranean-Corsica Water Agency and examines data from around 100 stations lining the entire coast. The two entities recently took stock of the chemical pollution data collected during their twenty-year partnership and scrutinized the results of the actions taken to reduce sources of contamination.

The data indicates improvement, although there are some longstanding and new sources of pollution that merit vigilance. The areas around large cities and industrial sites continue to present high levels of sediment contamination due to lead, hydrocarbons, nickel, and other substances. Furthermore, mercury and PCBs are readily detectable in some types of fish.

Eager to expand their investigations, Ifremer and the Water Agency collected valuable data from the SUCHI Med cruise. Over the course of fifty days on board R/V *L'Europe*, the scientists invol-

ved in this operation tracked sixty five water contaminants via artificial mussel stations placed at seventy different locations in the sea and twenty in lagoons.

The aim of the sampling and analysis work was to detect emerging contaminants and evaluate their impact on the area's biodiversity. The broader goal was to improve monitoring protocols and better target pollution-reduction actions.

Sustainably managing marine resources for the well-being of human communities

An ocean of solutions

Ifremer conducts research, innovates, and lends its expertise to help develop sustainable solutions for feeding, looking after, and producing energy and materials for what will soon be 8 billion humans on Earth.

Decoding the pearl colors of the black-lip pearl oyster

Red, yellow, or green: Genetics has revealed the magic behind the black-lip pearl oyster's pearls.
Photo: Chin-Long Ky - Ifremer



By decoding the genes responsible for pearl color and showing that color varies depending on the depth at which the oysters are farmed, scientists have unearthed valuable knowledge for the French Polynesian pearl farming industry.

The black-lip pearl oyster (*Pinctada margaritifera*) produces so-called “black” pearls whose pigments, in reality, are variations on three main colors: red, yellow, and green. Controlling pearl colors is a major challenge for Polynesian cultivators whose jeweler clients have high standards for pearl homogeneity. This issue inspired the AmeliGEN project for improving scientific understanding of the genetic and environmental factors at play in pearl quality variation.

To determine which biological processes were involved, scientists started with genetic selection in order to obtain a set of oysters that produced a specific color of pearl. They then sequenced these oysters' tissues to identify the genes associated with different pearl colors. They were able to identify the main pigments present and the molecular pathways controlling their formation.

A complementary study demonstrated that genetic factors were not the only ones behind color variations. Environmental differences affect gene expression within pearl oysters, blocking the synthesis of certain pigments. Oysters cultivated deep underwater (~30 meters) produce darker pearls than oysters at the water's surface.

While the goal is to have better control over pearl production, exploitation of these environmental factors could offer alternatives to the use of genetic selection (which could make the species more vulnerable to diseases or other types of disruption).

AmeliGEN (Genetic Improvement of Pearl Oysters in French Polynesia)

This project was conducted by Ifremer's Polynesian Marine Resources unit in Tahiti, in partnership with the Centre de recherches insulaires et

Observatoire de l'Environnement (CRIOBE—CNRS, École pratique des hautes études, Université de Perpignan Via Domitia) and private actors (D. Devaux of the Regahiga Pearl Farm & Hatchery, located on Mangareva Island in the Gambier archipelago). It was co-financed by the French Polynesian Marine Resources Office.

Pierre-Louis Stenger, Chin-Long Ky, Céline Reisser, Julien Duboisset, Hamadou Dicko, Patrick Durand, Laure Quintric, Serge Planes, and Jeremie Vidal-Dupiol. “Molecular pathways and pigments underlying the colors of the pearl oyster *Pinctada margaritifera* var. *cumingii* (Linnaeus 1758).” *Genes*, 15 March 2021. “Environmentally driven color variation in the pearl oyster *Pinctada margaritifera* var. *cumingii* (Linnaeus, 1758) is associated with differential methylation of CpGs in pigment- and biomineralization-related genes.” *Frontiers in Genetics*, 19 March 2021.

How temperature and genetics affect the sex of sea bass

If the water temperature increases, a young female sea bass can become male. This masculinization has been studied by Ifremer scientists, who dissected the genetic mechanisms at play.

Male or female? Sea bass sex can change, as discovered during a study conducted on more than 2,000 specimens at Ifremer.
Photo: Ifremer



Unlike other animals, fish can change their sex in the early stages of their lives. Increased temperature, more acidic water, and population densification are among the environmental factors that can trigger this transformation. Higher temperatures lead to higher percentages of males within sea bass populations. This phenomenon was well-known, but the reasons behind it were not, until now.

To learn more about this phenomenon, scientists conducted an experiment on a population of over 2,000 sea bass in Ifremer's tanks in Palavas-les-Flots. They tracked the physiological characteristics of each individual, which had never been done before at this scale. The result? Twenty-five percent of the fish had a weaker form of female genetic orientation that made them more liable to masculinization in the event of a temperature increase. The crucial gene in this process was isolated. Other experiments showed,

in contrast, that domestication of individuals and low stocking density fostered the emergence of females. This is good news for fish farmers who prefer female fish for their faster growth rate.

These results were published in *Proceedings of the National Academy of Sciences of the United States of America*. The researchers are continuing their investigations with the project WARMFISH in order to evaluate sea bass behavior in their natural environment under the effects of climate change.

3S Project (Seabass, Sex, and Stress)

These experiments took place within the framework of the 3S project, led by Ifremer in partnership with the French Poultry and Aquaculture Breeders Technical Center and with support from the European Maritime and Fisheries Fund.

Video evaluation of sea cucumber biomass in Saint-Pierre and Miquelon

Given the growing demand for sea cucumbers, the Fishing Office of Saint-Pierre and Miquelon requested Ifremer's expertise to conduct a precise assessment of their population status. It was the perfect occasion to test out new video technologies used to survey populations.

Artificial intelligence, a less intrusive technology used in Saint-Pierre and Miquelon to assess sea cucumber abundance.
Photo: Ifremer



Cucumaria frondosa, a kind of holothurian, or sea cucumber, has recently become one of the more popular species fished in Saint-Pierre and Miquelon. In order to preserve this resource, local authorities solicited Ifremer to perform a thorough and consistent evaluation of the populations present in the French exclusive economic zone.

Rather than resorting to traditional survey methods, which consist of capturing fish in a net and then counting, sorting, and weighing them, the researchers deployed more modern imaging processes and technologies, which have the advantage of being less intrusive. Aboard the fishing boat *Marcel Angie*

3, a professional sea cucumber dredger kitted out for the occasion by Ifremer, scientists spent two weeks traveling around the areas where sea cucumbers are fished. They collected over eighty video recordings covering about thirty-four kilometers of seabed.

The scientists on the expedition were enthusiastic about the video survey process, which had already been used with great success during the Game of Trawls project and cruises like LANGOLF-TV to evaluate langoustine stocks in western Europe. They observed many juvenile cucumbers, which would typically escape trawl net evaluations. The results are being assessed and local authorities as well as local

industry actors are eager to learn more. They will help prepare a sea cucumber management notice as soon as possible after the spring 2022 survey expedition ends.

The cruise received much media attention (in French): <https://la1ere.francetvinfo.fr/saintpierremiquelon/saint-pierre-spm/une-https://la1ere.francetvinfo.fr/saintpierremiquelon/saint-pierre-spm/concombres-de-mer-l-ifremer-satisfait-de-sa-mission-d-exploration-1015393.html>

Toxic microalgae in swimming areas in the Basque Country

Ostreopsis ovata, a toxic microalga identified on the Basque coast for the first time by Ifremer teams.



On August 2, 2021, following several reports of ENT complaints, headaches, and vomiting from beachgoers in the region, the Basque authorities decided to reach out to Ifremer. The perpetrator was quickly unmasked: a toxic microalga that had never before been found on the French Atlantic coast.

Ifremer was alerted in early August by the Basque regional authorities, the Bordeaux Poison Control Center, and the Nouvelle-Aquitaine Regional Health Agency. Its first action was to bring in teams from the Arcachon Environmental Resources Laboratory to take water samples from where people had been swimming. The samples confirmed unequivocally the presence of strong concentrations of *Ostreopsis*, a toxic microalga that had thus far only been detected along the Portuguese coasts.

Ifremer then helped set up a monitoring system and taught representatives from the regional government and the regio-

nal health agency how to take water samples and identify the microalga in question. The Institute also lent its expertise to the Operational Cell for Regulating and Addressing Social and Public Health Emergencies created to handle the crisis. Finally, Ifremer mobilized its Phycotoxins Laboratory in Nantes to culture and determine the toxin profile of the microalga, and its Western Brittany Environmental Resources Laboratory (based in Concarneau) to work on the molecular identification of the species. The results confirmed that two species of *Ostreopsis* were present in the water (*O. siamensis* and *O. ovata*).

The threat now identified, regional elected officials requested the emergency launch of a project to document the species present along the Basque coastline, improve detection and investigation methods, and increase knowledge of these toxins' different impacts. Ifremer's teams will roll up their sleeves and get involved with a research program along with the Basque coastline Scientific Interest Group.

Extraction under the sea: How does the marine environment heal its wounds?

A multitube corer, used on a coastal vessel for the first time, is submerged at the Pilier site in the Loire-Atlantique region to take sediment samples and assess the marine environment's resilience following thirty years of exploitation.
Photo: Ifremer



With its RESISTE series of cruises, Ifremer is studying the long-term resilience of a former extraction site for sand and marine gravel. The Pilier site, near the Loire estuary, was subjected to thirty years of industrial exploitation and now serves as a textbook example of such a site.

Aggregates (sand and gravel) are essential for the construction sector and are some of the world's most exploited resources after water. Their extraction, however, does not come free of consequences for natural environments, particularly for the seabed areas that they come from. Creation of depressions, changes in sediment typology, and destruction of fauna and their habitats are some of the most striking impacts that can in turn have repercussions on fish resources and even on current dynamics.

Though these impacts are well known, the resilience of the ecosystems affected remains an open question. What happens

after industrial activity stops? How fast can a site heal and how does it do it? These are the main questions that RESISTE seeks to answer.

One of the particularities of this research project is that it involves monitoring over a long period of time—close to ten years. Another is the multidisciplinary nature of its scientific team, which is composed of geologists, physicists, fish resources specialists, and benthologists (experts in deep-sea macrofauna) from several different Ifremer laboratories. Their wide range of skills and knowledge makes it possible to study all of the resilience dynamics at the Pilier site, which was abandoned in 2017.

The goal of RESISTE is to better understand the resilience of former extraction sites in order to make this industrial activity less traumatic for the environment.

The first round of observations and samples was launched in 2020 and these efforts are now starting to bear fruit. The researchers have been able to measure the heavy siltation in certain areas and observe the recolonization of the site by bivalves and annelids (worms).

Reducing vessel fuel consumption with “whale tails”

The start-up Blue Fins and Ifremer have invented a hydrofoil that uses sea swell to help propel ships. This solution could reduce large vessels’ energy consumption by 20–30%.

A “whale tail” to reduce ships’ carbon footprints: The wave energy system designed by the start-up Blue Fins and Ifremer is tested in a tank at Ifremer’s Brittany Center.
Photo: O. Dugornay - Ifremer



Methane tankers, oil tankers, container ships, and cruise ships, whose tonnage has only increased over the decades, consume enormous amounts of fossil fuels. Since the reduction of greenhouse gas emissions has become a priority and regulations on maritime transport are tightening, the sector is looking for ways to reduce its carbon footprint and, therefore, its fuel usage.

This is the challenge that the start-up Blue Fins and Ifremer have taken up by creating a hydrofoil suitable for very large ships. The fin sits underwater and is attached to the back of the ship by a jointed arm. It uses physics in two ways to help pro-

pel the ship. First, it supports the vessel, reducing friction between the water and the hull. Second, it uses the movement of the sea swell to move forward, as whales do with their tails. The resulting fuel savings can be as high as 30%. Another advantage of this system is that it can be combined with other solutions (kite wings, sails on deck) which are starting to be tested on some vessels.

The innovation, now patented by Ifremer, is an excellent example of the support that the Institute can provide to project holders. Olivier Giusti, the naval architect who started Blue Fins, approached Ifremer with an idea that he had tested on a digital model. He obtained an eighteen-

month contract and support from the Ocean Structures Behavior Laboratory (a MERS Carnot Institute member) and from the Innovation Department (Emergys incubator) to bring his business idea to maturity and orient its product toward the appropriate market. The adventure is continuing with support from CITEPH (the Concertation for Technological Innovation in the Energy Industry). The goal is to be able to test a prototype on a commercial vessel in 2023.

Launch of Octo'pousse, Ifremer's innovation competition

Ifremer launched the Octo'pousse competition to accelerate the creation of start-ups in the maritime sector—with great success. The jury selected two of the forty projects submitted. The first proposed a system for communication during dives and the second suggested a method for using abyssal microorganisms to produce hydrogen.

The Octo'pousse contest

After receiving many diverse and high-quality projects in 2021, Ifremer scheduled the second edition of the contest for early 2022. Octo'pousse will continue to spread its tentacles and latch onto the best ideas for the blue economy.

Agile, creative, and ready to take risks, start-ups are a must for developing disruptive innovations. This is why Ifremer launched the Octo'pousse innovation contest. Its objective is to identify and support the projects that aim to tackle the big challenges facing our society and our ocean.

Anyone with an innovative idea can submit a proposal to Octo'pousse. It offers financial, technical, and human resources to help structure a project and create a start-up in the best possible conditions.

Contest winners receive:

- An 18-month work contract at the Ifremer site best suited to their project
- €60k to get the project off the ground
- Access to testing equipment, the ocean, and Ifremer laboratories
- And the opportunity to collaborate with an Ifremer research team!

The initiative received support from the Ministry of the Sea.

The Octo'pousse jury chose the project GRHYN, spearheaded by Jordan Hartunians. GRHYN explores solutions from the abyssal depths for producing green hydrogen.
Photo: Ifremer



Gabriel Guerche, one of the winners of the Octo'pousse competition, tests the Talky-Divy. This underwater walkie-talkie facilitates communication between divers.
Photo: Ifremer



Communicating naturally with dive partners thanks to the Talky-Divy

Such is the objective of the prototype developed by brothers Jonas and Gabriel Guerche, creators of the start-up 52 Hertz, whose name was inspired by the frequency of a certain whale's song. This project aligns with studies performed by Ifremer on communication between sea and land. For the general public, the Talky-Divy could revolutionize the diving experience and their whole approach to the underwater world.

What did you study in school?

Gabriel Guerche (GG), age 24: After a degree in physics from the Sorbonne, I started a master's in nuclear energy at Université Paris-Saclay.

Jonas Guerche (JG), age 29: I studied fundamental physics, innovation management, and renewable energy engineering.

How did you come up with the idea for this communication device?

GG: We were both in a university club for scuba diving and we wondered why, in a super-connected modern world, we were limited to twentyish hand signals for communicating underwater. That's where the 52 Hertz project came from.

JG: Our goal is to create a natural underwater communication device, the Talky-Divy, that will work with typical diving equipment.

How does the Talky-Divy work?

GG: These days, 95% of scuba diving is practiced and taught with a scuba tank, a BCD, a mask, and a regulator to control the flow of oxygen. There's a mouthpiece on the regulator and that's where our technology goes.

The idea is to use bone conduction to transmit the sound through vibration, without needing to go through the ears. Using your teeth to put pressure on the mouthpiece of a regulator equipped with our system makes it possible to transmit and receive sound.

What assistance are you hoping to receive from Ifremer?

JG: Right now, our prototype is functional but not fully operational. That's why we participated in the Octo'pousse contest. Ifremer is one of the most renowned marine institutes in France and the world, particularly due to its multidisciplinary teams. We hope that its skills in electronics and underwater acoustics will help us develop our prototype.

GRHYN: Producing hydrogen with deep-sea microorganisms

Whether in electricity production, heavy transport, or steelmaking, hydrogen seems poised to become a key ingredient in the decarbonization of our economy. Unfortunately, current hydrogen manufacturing processes emit colossal amounts of CO₂.

The GRHYN project offers an alternative by relying on the capacities of certain Archaea, deep-sea microorganisms, to produce hydrogen with a much smaller carbon footprint. This project lies at the intersection of two objectives within Ifremer's France 2030 investment plan: green hydrogen and seabed exploration.

Could you tell us a bit about yourself?

My name is Jordan Hartunians, I'm 29 years old, and I have a doctorate in microbiology. I worked on my doctorate at the Microbiology of Extreme Environments Laboratory at Ifremer, studying the metabolism of microorganisms associated with deep-sea environments.

What inspired you to create GRHYN?

The desire to fight climate change. Our CO₂ emissions are one of its major causes. Hydrogen could be the ticket to reducing emissions. But for this to work, we need to make "green" hydrogen through a low-carbon process.

I discovered through my research that the ocean may have a solution. There are marine microorganisms that have natural hydrogen-producing capacities.

The idea behind GRHYN is to find a way to capitalize on these specific microorganisms.

How do you intend to produce large quantities of hydrogen with these microorganisms?

With GRHYN, we're trying to develop an industrial hydrogen production solution that is profitable, decarbonized, and potentially even based on the reuse of some of our agricultural and industrial waste. We want to create hydrogen "breweries" with vats of microorganism cultures that could reach several thousand liters.

How will Octo'pousse help?

For now, the project is based on theoretical approaches. This collaboration with Ifremer will enable me to benefit from cutting-edge expertise on marine microorganism cultivation and physiology, and on the chemistry and thermodynamics of the processes that I want to develop.

I will be able to collaborate with two Ifremer laboratories specialized in seafloor biology and chemistry and get access to bioreactors that fit my needs. This is an amazing opportunity to bring my project to fruition and facilitate the creation of my company.

Test of the DIKWE wave energy dike prototype at sea

The Sainte Anne du Portzic experimental station in Plouzané, which is associated with the MERS Carnot Institute, was mobilized to test a prototype of a “positive energy” dike designed by the company GEPS Techno and Legendre Group.

Installation of the structure that the DIKWE positive-energy dike prototype will be mounted on.
Photo: S. Lesbats - Ifremer



Waves and tides are sources of energy that humans have long been seeking to harness. Interest in these marine renewable energies has increased considerably in the last few years as electricity decarbonization objectives have loomed larger. Capitalizing on this trend, GEPS Techno, a company specialized in this type of innovation, worked with major construction and energy actor Legendre Group to develop a positive-energy breakwater that holds great potential as a hybrid solution to the energy problem.

The principle is to combine a dike, a protective structure that sea level rise will likely render more and more necessary, with

a system that can capture wave energy (the DIKWE concept). The structure consists of a large tunnel composed of modules (4 × 4 × 6 m) and equipped with a flap that the waves push back and forth, enabling DIKWE to recover mechanical energy.

First trialed in Ifremer’s test tanks, the prototype was then installed at the experimental ocean site in Sainte Anne du Portzic, which has a broad array of marine and meteorological instruments. This step is essential for observing the prototype’s behavior in realistic wind, current, and wave conditions.

In fact, Ifremer developed the Sainte Anne du Portzic site in the Bay of Brest just for this purpose—to support this type of research and development. This experimental site is part of the TheoREM research infrastructure, shared with the École centrale de Nantes and Université Gustave Eiffel. It is also associated with the MERS Carnot Institute, created in 2020.



New natural microalgae extract patented to fight acne

The microalga *Skeletonema* reveals its acne-fighting powers.
Photo: R. Kaas - Ifremer



Using a microalga that is relatively common in the Atlantic and easy to cultivate in a laboratory, scientists have produced a solution that fights bacteria responsible for mild forms of acne.

Combining their forces, Ifremer, La Rochelle Université, the Centre national de la recherche scientifique, the Université de Limoges, and the University Hospital Center of Nantes have applied for a patent for a dermatological composition that takes action against skin bacteria, including those that cause acne. The formula uses a natural extract from the microalga *Skeletonema marinoi* to create a solution that can then be mixed into a cream or gel. Once applied to the skin, the composition must be exposed to light for the molecules to activate. This causes them to release energy and create other molecules that then attack acne-provoking bacteria.

The efficacy of the formula was lab-tested on three species of bacteria that cause more or less severe forms of acne. The results show its capacity to treat mild acne. The compound can thus ward off more severe forms of acne and present an alternative to the use of antibiotics and retinoids. These promising results must be confirmed by clinical studies, as is standard when developing a commercial product with industry actors.

The Phasma maturation project

This operation aligns with the strategy that Ifremer initiated in 2018 to promote the development of the blue economy through innovation (InOcean), and more specifically the Phasma maturation project, which focuses on biotechnology for health and cosmetics. This project aims to select proposals that could capture a market within 18–24 months. The Phasma project emerged after Phenomer (2008–2012), which was supported by the National Research Agency.

Outcome of the DynAlgae project, on the microalga *Tisochrysis lutea*

Gregory Carrier and Aurélie Charrier, both Ifremer researchers, work on microalgae cultures on a phenotyping platform. This experimental physiology device was developed by the Algae Physiology and Biotechnology Laboratory, which is based at Ifremer's Atlantic Center in Nantes.
Photo: O. Dugornay - Ifremer



Geneticist Gregory Carrier started working on marine environments in 2011 when he joined the Algae Physiology and Biotechnology Laboratory at Ifremer. Turning to genetics, especially for the DynAlgae project, has helped make this laboratory a pioneer in microalgae improvement.

How does genetics facilitate microalgae selection?

For a long time, we used domestication to tease out the best profiles of the organisms that we use and eat. Genetics is revolutionizing the field because it gives us the means to be much more precise during the selection process, with less trial and error.

When I started working on this subject, the microalgae exploited in the industry came directly from the natural environment. There was great potential for development and strong interest in starting research on domestication and the implementation of genetics-assisted selection. The laboratory began working on improving microalgae for aquaculture, biofuel production, pharmacology, and cosmetics.

In 2017, this led us to launch the DynAlgae project, which received financial support from the National Research Agency as a “Young Researcher” initiative. It will come to a close in 2022.

What were the goals of the DynAlgae project?

We estimate that phytoplankton are composed of more than 1.5 million genes, while we only have partial knowledge of 25% of them. There’s a lot of genetics work to be done there. The project’s first ambition was to decode part of this microalga’s genes to identify and understand the ones involved in the production of molecules of interest. We were especially interested in omega-3 fatty acids, carotenoids, and antioxidants.

Next, we wanted to take advantage of the connections identified between genetics and phenotypes (the observable traits of an organism) to develop genetic selection markers. These selection methods are already used successfully in agriculture, but this had never been done before with microalgae.

Why did you choose this microalga in particular?

Tisochrysis lutea is both easy to cultivate and rich in antioxidants. What’s more, it has already been studied by the laboratory because it’s used in aquaculture to feed oyster and shrimp larvae. This microalga is not particularly abundant, but it can be found everywhere on Earth.

Have you developed special methods or instruments for this research?

Yes, we refined and patented a specific type of phenotyping platform. We needed to cultivate large volumes of microalgae in repetitive and controlled conditions. So we had to develop an appropriate tool for this. We now use it for other research as well.

What are the results and what applications are you considering?

We’ve reached our goal in that we’ve decoded some of the genes that determine genetic markers associated with the production of antioxidants. The final results will be published soon.

We also identified some molecules with remarkable antioxidant properties that could be used in cosmetology and health care. Studies are underway to determine how they could be best put to use.

What are you going to work on now?

The laboratory is changing tack and turning to the study of toxic microalgae whose blooms pose a threat to public health. From a genetic point of view, we’re basically starting from scratch. I will study the genetics of these toxic algae to learn more about them and anticipate their reactions to changing conditions in their environment.

Creating and sharing a digital ocean

An ocean of data and services

As in all fields, the digital transition is transforming marine and maritime activities as well as professional practices. Managing the increasing amount of data on the ocean and transforming it into services for people, companies, and public authorities is now essential in order to share ocean knowledge and promote economic growth in a way that is sustainable for the marine environment. The mass of data also serves as a foundation for models that can test hypotheses, recreate the past, and imagine the future.

Three new types of equipment for ocean sciences

High-performance Argo floats, a seafloor observatory near Mayotte, and innovative sensors for deep-sea vehicles: three of Ifremer's priority projects were chosen by the National Research Agency (ANR).

Preparation of a Deep-Argo float before its deployment during the RREX 2017 cruise in the North Atlantic.
Photo: Kevin Balem / RREX 2017 / Ifremer



The EquipEx+ call for expressions of interest aims to develop the new scientific equipment that French researchers need. Fifty of the 135 proposals were selected and will receive dedicated funding, including the three proposals that Ifremer submitted. Each of them involves several Ifremer teams and collaborations with national and international partners.

The first one has to do with the international Argo 2030 program. With its 4,000 autonomous floats scattered around the world's oceans, Argo has become an essential monitoring system that is constantly measuring water temperature and salinity up to 2,000 meters deep. By developing new floats that are equipped with more environmental sensors (BGC-ECO) and that can dive up

to 6,000 meters deep (Deep-6000), Ifremer will boost Argo's investigation capabilities exponentially.

The second project, MAR-MOR, concerns the installation of a seafloor observatory in Mayotte in order to increase geophysical monitoring activities in the area. The French scientific community (fourteen different actors are involved) will then have high-performance equipment transmitting more information in real time about ground deformation, seismicity, tsunamis, volcanic activity, and several key environmental mechanisms at play in ocean and coastal areas.

Deep Sea'nnovation, the third project, will focus on improving deep-sea research vehicles. More specifically, it will flesh out efforts initiated by the French

Oceanographic Fleet (a Very Large Research Infrastructure) to deploy ever better sensors and sampling instruments on its remotely operated underwater vehicles (both ROVs and AUVs).

Ifremer is also a partner on the Oceans section of the GAIA Data project submitted by the Centre national de la recherche scientifique, which was selected by the National Research Agency as well. GAIA Data will give the scientific community, public authorities, and socioeconomic actors access to different types of data (satellite, airborne, ground, in situ, model) through a variety of portals.

Improvement of test equipment in the wave and current tank at the Boulogne-sur-Mer site

Already a high-performance site for studies of wave-current-structure interactions in complex environmental conditions, the Boulogne-sur-Mer tank received an upgrade that has improved its testing and measurement capacities even further.

A unique test facility within Europe, Ifremer's wave and current tank in Boulogne-sur-Mer now has a new three-component laser velocimetry system. The objective: to better quantify turbulence phenomena upstream or in the wake of different types of crafts. Photo: G. Germain - Ifremer



Ifremer's wave and current tank in Boulogne-sur-Mer is unique in Europe. Its complementary experimental and digital resources have built its reputation as a renowned center for hydrodynamics expertise and testing that hosts many different research and development projects.

Thanks to the MARCO project (2014–2020), which sprang from the planning contract between the national government and the Hauts-de-France region, the test tank benefited from two new pieces of equipment. The old treadmill from the 1990s was replaced by a modular raised floor that instruments can be integrated into and that offers adjustable anchoring points. This system includes a rotating plate that makes it possible to

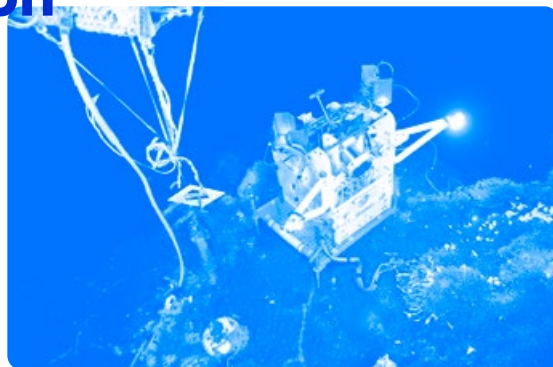
change the orientation of models during tests.

The tank was also fitted with a new three-component system for laser velocimetry, which was specifically developed to better quantify turbulence phenomena both upstream and in the wake of the devices being tested. This system is coupled with a high-precision automated positioning system and was designed to limit probe vibrations as much as possible during measurements.

This modernization will keep the laboratory at the cutting edge for hydrodynamic experiments involving deep-sea vehicles, ocean structures, and systems for recovering current energy.

Launch of the One Ocean Network for Deep Observation

The ambition of the One Ocean Network for Deep Observation is to connect observatories and monitoring technology already deployed in the ocean. This is Tempo, a surveillance device developed at Ifremer that monitors underwater ecosystems in real time with an HD camera and physicochemical sensors.
Photo: Ifremer / Ocean Neptune Canada



Endowed with the UN Decade of Ocean Science for Sustainable Development label, this partnership program coordinated by Ifremer offers an incredible opportunity to join forces internationally to explore the ocean's depths and establish a more sustainable approach to the ocean.

The UN Decade of Ocean Science for Sustainable Development, inaugurated in February 2021, aims to raise awareness about the considerable challenges and opportunities that the ocean offers and encourage people to take action. Its ambition is to use science to help countries make progress on Sustainable Development Goal #14 (better sharing and protecting the ocean and improving its health). The Ocean Decade is especially relevant to scientists, governments, and companies that seek to make international partnerships.

Among the first actions approved and initiated are four major programs on deep-sea exploration. Ifremer is leading one of them, the One Ocean Network for Deep Observation,

in partnership with other international scientific entities: the Japan Agency for Marine-Earth Science and Technology, the European Multidisciplinary Seafloor and Water Column Observatory, and Ocean Network Canada. The observation that seeded the idea for the program was the fact that 80% of seafloors have never been mapped or explored, though they hold secrets about the origin of life, resources for humanity's sustainable development, and threats like earthquakes and tsunamis of tectonic, volcanic, and sedimentary origin. To make progress on these subjects, One Ocean Network for Deep Observation suggests connecting the multidisciplinary monitoring technologies and observatories already established at diffe-

rent sites in the world's oceans. This coordination will continue to enrich understandings and spread knowledge about the functioning of deep-sea ecosystems and reduce certain natural risks stemming from contemporary planet-wide changes. Additionally, it seeks to direct the greater public's attention to the ocean depths, which human activities are subjecting to more and more pressure.



2021 United Nations Decade
of Ocean Science
2030 for Sustainable Development

Two days of discussions on autonomous measurement systems for observing the marine environment

Aurélien Ponte, an oceanographer and researcher at Ifremer and one of the organizers of the water drone workshop.
Photo: S. Lesbats - Ifremer



A researcher and oceanographer at Ifremer, Aurélien Ponte was one of the organizers of this workshop, a very successful event that combined the interests of two different communities: experts who study technology and scientists who need to upgrade their tools.

Why are these autonomous measurement systems so important?

The ocean is home to an unbelievable number of physical, biological, and chemical processes that we oceanographers do our best to characterize, understand, and predict. For centuries, we've been conducting our observations from aboard research vessels during scientific expeditions. These trips are absolutely necessary, but they're also expensive and limited in duration and geographical scope.

That's why we've been developing other types of observation platforms over the past few years. They're lighter, autonomous, and therefore more environmentally friendly. They increase our observation capacities exponentially.

What types of equipment make up these systems?

There are all kinds. It could be moorings, sea-floor monitoring stations, or profiling floats (buoys that can float and also move between two different water masses). In addition to drifting instruments, we have motorized devices such as autonomous underwater vehicles (AUVs) and hybrid devices like gliders, which are buoys with fins that can move around horizontally. These technologies are mature and widely used nowadays.

There are more recent developments as well, like unmanned surface vehicles (USVs), autonomous platforms with motors and autonomous platforms with sails that look like little boats. They can take measurements at the ocean surface and potentially within the water column. They're still in the testing phase and the oceanographic community is figuring out how best to make use of them, but they should be very useful for ocean observation in the years to come.

What were the specific subjects and goals of the workshop?

Our overarching goal is to break free of current systems' limitations. This means that we first need to identify the sticking points hindering scientists' work and then see what recent or nascent technological developments could dissolve them.

During the first day of the workshop, researchers in physical oceanography, geosciences, and marine ecosystems all explained their various needs. And during the second day, new technological possibilities were presented. We had round tables on a few subjects that are key to the improvement of current platforms: improving battery life, reducing environmental impacts, better communicating about the data collected, and increasing the intelligence of these systems. We also discussed the industrial development of these technologies, which is no less significant.

What's your takeaway from these two days of discussions?

They were excellent. Many participants from both communities expressed their satisfaction with the event and their desire to go further.

There were valuable discussions among oceanographers on common needs and possible ways to pool observation resources. Other very constructive conversations centered on the USV *DriX*, which could soon become part of the French Oceanographic Fleet. The workshop really helped identify which of the scientists' needs this type of equipment can fulfill.

Since technology evolves so quickly, I think it would be worthwhile to continue having these conversations. I hope that we'll be able to host another edition of this event.

<https://wwz.ifremer.fr/Recherche/Atelier-SMA2M-Systemes-de-Mesures-Autonomes-pour-l-observation-du-Milieu-Marin>

Organization and facilitation of the water drone workshop

This event was initiated by Ifremer's Science Division and organized and facilitated by a committee of thirteen people associated with Ifremer, the CNRS and the Université de Toulon:

- Aurélien Ponte, Chantal Compère, Jean-Romain Lagadec, Julie Tourolle, Stéphanie Dupré, Jan Opderbecke, Mathieu Doray, Patrick Farcy, Viorel Ciausiu, Karenn Bucas, Claire Dune-Maillard, Séverine Martini, and Olivier Soubigou.
- There were around fifty speakers and close to 250 attendees from Ifremer and many other scientific institutions: INSU, IRD, OFB, UBO, CEA, CNES, Ensta-Bretagne, IMT-Atlantique, LabSTIC, ENIB, LIRMM, ISIR, LS2N, LAAS, COSMER, Univ. Toulon, Univ. Montpellier, ARAGO, LIENSs, IPGP, LOCEAN, Sorbonne Univ., LSCE, and Centrale Marseille.
- The workshop took place over two days (February 3 and 4, 2021) and was fully online due to the pandemic.

Developing the digital ocean with the Internet of Things and nanosatellites

Kinéis's nanosatellites, which will be deployed starting in 2023, will reinforce marine and maritime services that rely on the Internet of Things.
© HEMERIA



Ifremer and Kinéis are launching a call for expressions of interest in order to accelerate the development of new marine and maritime services that use the Internet of Things through a constellation of nanosatellites.

Kinéis is a subsidiary of the Centre national d'études spatiales and the company Collecte Localisation Satellites (CLS). In 2023, it will deploy a first constellation of twenty-five nanosatellites dedicated to the Internet of Things. The ambition underlying this project is to provide high-quality and affordable worldwide coverage that will connect devices around the world, open them up to remote operation, and enable them to communicate with each other. This infrastructure will create new possibilities for the digital transformation of the marine and maritime sectors.

As part of its policy to support the blue economy through research and innovation, Ifremer acquired a stake in Kinéis in 2020. This year, in collaboration

with Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée, the Institute confirmed its commitment by participating in the launch of a call for expressions of interest centered on developing the Internet of (Marine) Things using Kinéis technology. The selected projects, which will involve at least one scientific team from Ifremer and a socio-economic partner over a maximum duration of twenty-four months, will receive financial aid, support from the scientific team, and development kits provided by Kinéis.

Proposals are expected to arrive from all fields related to ocean observation, ocean monitoring, and the sustainable use of ocean resources: tracking of biodiversity, fish, and fishing

boats; connectivity of ocean infrastructures and equipment (buoys, floats, profiling floats, autonomous vehicles, observatories, watercraft); safety and security of structures and personnel; land-based maintenance and monitoring; and more.

Two partnerships were signed into being in 2021. The AIOS project, with the company eOdyn, uses Kinéis AI and Argo technology to improve maritime safety and fight pollution. The B-Connect project, with the companies CLS, NKE Instrumentation, and Notilo Plus, uses Kinéis technology to improve observation of coastal areas and marine ecosystems.

Six years of operational oceanography at the Copernicus Marine Service

Ifremer has contributed actively to the success of this European Union service, which provides free, regular, systematic information about the evolution of the blue (physics), white (sea ice), and green (biogeochemistry) ocean worldwide.

Digital model of ocean currents in 2021.
<https://myoceanlearn.marine.copernicus.eu>



Copernicus is the European Union's Earth observation program. Its maritime branch, the Copernicus Marine Service (CMS), was created in 2014 to provide free and open marine data and services to enable marine policy implementation, support blue growth, and boost scientific innovation. The European Commission gave the reins of the service to Mercator Ocean International (MOi), a nonprofit organization whose scientific support focuses on the preservation and sustainable use of ocean and marine resources. Its mission was inspired by one of the United Nations Sustainable Development Goals (SDG 14). As a founding member of MOi and an active part of its governing

body, Ifremer has been a bastion of support for the Copernicus Marine Service. For example, Ifremer coordinated its on-site data center and contributed to several satellite data centers. Over the past six years, the CMS has excelled in its role, providing key information that has informed European and international policies in several fields: reduction of pollution, protection of the ocean, improvement of maritime safety and navigation, sustainable use of ocean resources, development of marine energy resources, climate monitoring, weather forecasting, blue growth, and more.

In 2021, the European Commission showed its esteem for MOi by renewing its mandate for

the next deployment phase of the CMS (2021–2027). An ambitious plan was laid out in alignment with the European Green Deal. It aims to fulfill the primary needs of users as well as the needs of ocean-related European policies.

ISIS Fish: A fisheries simulator constantly maturing and reaching new audiences

Stéphanie Mahévas, senior research mathematician, and Sigríd Lehuba, senior modeling and ecology engineer, are continuously refining the fisheries dynamics simulator ISIS Fish. Photo: S. Lesbats - Ifremer



Combining three categories of data (regulations, fishing activity, and marine biological resources), ISIS Fish creates maps simulating monthly fish population abundance and fishing boats' catch. These maps can be used to hypothesize about fisheries' evolution and to study the consequences of changes in fishing regulations.

As soon as she arrived at Ifremer in 1998, mathematician **Stéphanie Mahevas** (SM) got involved in the creation of ISIS Fish, a project that was spearheaded by **Dominique Pelletier**. Sigrid Lehuta (SL), an engineer specialized in modeling and ecology, joined her to continue developing this fisheries simulator, which is used for both academic and business purposes.

Could you remind us why and how ISIS Fish was created?

SM: The initial goal was to use mathematical simulations to evaluate the repercussions of certain regulations. Specifically, we wanted to understand how the creation of protected marine areas had affected fish populations and fishing fleets. ISIS Fish was always meant to be a tool for both research and real-world operations.

We first created a mathematical model that described the dynamics of the fishing fleets and the marine populations being fished, across both time and space. Then we brought in computer scientists to develop the complementary open-source software, the first version of which was released in the early 2000s.

SL: At the time, it was one of the first models to have a spatial dimension. Its flexibility was innovative too. It can be adapted to different types of marine ecosystems and fishing activities, which is rare, and integrate changes in regulations, economic data, information about fishermen's behavior and responses, etc.

What improvements were made in order to get to the current version?

SM: We've made the model more flexible, precise, and realistic in the way it simulates different ongoing processes. We've also integrated other scientific knowledge as it has become available while expanding the range of disciplines involved (economics, fish physiology, geography, etc.). More recently, to continue improving our understanding of fish population dynamics, we integrated expert knowledge from professionals in the fishing industry.

At the same time, we also reinforced ISIS Fish's robustness. It's more operational and more accessible to users who aren't the original developers.

SL: How to manage uncertainty is another subject that has always been on our minds. ISIS Fish relies on information and understanding that is constantly evolving. We've developed methods for detecting and analyzing uncertainty to calibrate the model as rigorously as possible. Managing uncertainty to the best of our ability is our trademark.

What is ISIS Fish used for today?

SM: We use it to test hypotheses and flesh out scenarios. The tool has an international user community now. The model is used for research in France, New Caledonia, New Zealand, Australia, the Baltic Sea, Canada, and elsewhere. The most fully fleshed-out applications are in the Gulf of Lion, the English Channel, and the Bay of Biscay. There, we're putting ISIS Fish head-to-head with what we know about these fisheries to see if the model can reproduce them faithfully.

Have there been any operational breakthroughs in 2021?

SL: One of the highlights of the year was the usage of ISIS Fish within the Scientific, Technical and Economic Committee for Fisheries (STECF). This entity provides expert opinions as needed for the European Commission. Given the level of effectiveness we've reached in the Mediterranean, we were able to offer our model to the STECF to help them assess the fisheries management plan in that area. It's been a great success. We've also made progress in the Bay of Biscay on getting a model for deep-sea fishing working.

We've been working more and more with professional fishing organizations and this participatory approach to the model facilitates understanding of what's at stake and acceptance of certain regulations.

What's up next?

SM: We're working on automating updates so that ISIS Fish will automatically integrate the most recent scientific data. We're still working on the management of uncertainty as well, and on how to communicate about uncertainty to a variety of actors and the greater public. Our goal is to have a fully operational model for each of the three French seafronts: the Gulf of Lion, the Bay of Biscay, and the English Channel.

SL: One of our priorities is our participation in the European project SEAwisE, which will be a culmination of the work done over the past few years. Within this framework, we'll bring together several models, integrate ecosystemic knowledge, and analyze the impact of uncertainty in fish stock evaluation.

ISIS-Fish : <https://isis-fish.org>
Bay of Biscay, MACCO project: <https://macco.fr>

DEFIPEL project: <https://www.ifremer.fr/peche/Le-role-de-l-Ifremer/Recherche/Projets/Description-projets/DEFIPEL>
SEAwisE : <https://cordis.europa.eu/project/id/101000318/fr>

Open archive Archimer begins its transformation

Doriane Ibarra, head of Scientific and Technical Information Service La Pérouse Library and lead administrator of Archimer.
Photo: S. Lesbats - Ifremer



Doriane Ibarra is the head of the La Pérouse Library, a Scientific and Technical Information Service that administers the open archive Archimer. This data bank provides free access to a wide swath of Ifremer's scientific publications. This service is thus naturally one of the actors involved in the creation of Ifremer's open science policy.

What is the role of this Scientific and Technical Information Service that you direct?

La Pérouse is a documentation hub and a research library. We manage the collections and acquisitions while offering monitoring and bibliometrics services and training to scientists. As part of our role, we administer the open archive Archimer (publications) and the Océanothèque (images).

What is Archimer?

Archimer was created in 2005 as an open archive for archiving, flagging, and freely disseminating Ifremer's scientific publications and thereby increasing the Institute's visibility. This database of documents contains articles published in journals, texts from colloquia, and gray literature that wouldn't otherwise be made available to a wider audience (dissertations, reports, official stances, and expert opinions).

We add full texts to Archimer and grant access rights depending on the confidentiality status of each document and its usage rights. By now, our archiving system is nearly exhaustive, because the process of depositing documents into the archive has become routine for the scientists. We also conduct regular digitization campaigns to enrich our database with older documents that we don't have digital files for. Archimer currently contains close to 60,000 documents, around 50% of which are open access.

Did you undertake any new projects in 2021?

With the Information Systems Engineering department as the project manager, we started a complete overhaul of the information system base shared by Archimer, the Océanothèque, and SEA-NOE (a repository for marine science data sets). An operation of this scope hasn't been performed on the IT system since 2005. Despite the upgrades made over the years, the system is no longer up to modern standards in terms of interoperability (data exchange), functionality, and ease of use.

We're currently drawing up the specifications for the new system. A lot of collaboration is necessary because the three databases must remain interoperable even though they contain different sorts of elements. We also want to improve the quality of the metadata that describes and references different documents. And we'd like to retain some particularities of these house tools, like geo-referencing (very useful in oceanography), and a network of connections between different resources: the data, the publications that use them, the scientific expedition during which the data was collected, and the instruments used. All of this enriches our databases and adds value.

What are the current challenges within open science?

This movement defends the idea that science is a common good that should be accessible to a wide audience within society. It gained more prominence at the end of the 1990s, mainly in response to the influence acquired by large private publishers. We've become captives in a system for evaluation of scientific work that relies heavily on the publication of articles in a handful of prestigious journals controlled by these private operators. This system has restricted access to science (through the sale of authors' rights, high journal subscription costs, etc.) and given rise to much-disparaged practices (long waits before publication, subject favoritism, uneven article quality). Archimer faces these problems regularly. We no longer have the right to make certain articles open access because the rights have been ceded to journals, even though the articles come from the work of our own researchers.

Ifremer is already well on its way with regard to open science, particularly in making its databases accessible to the public, and is continuing its efforts. In line with the national plans from the Ministry of Higher Education, Research, and Innovation, Ifremer is currently finalizing its "open science plan," which will clarify its position on this complex subject by setting several main principles to be followed.

The La Pérouse Library

This center for ocean-related documentation is a joint initiative by the Université de Bretagne occidentale, the National Research Institute for Sustainable Development, and Ifremer. Its primary mission is to ensure that all staff and students at the partner establishments have access to scientific and technical information.

OneOceanScience: A digital world tour of ocean sciences

Géraldine Guillevic,
head of external
communication,
orchestrated the digital
campaign
OneOceanScience.
Photo: S. Lesbats -
Ifremer



Géraldine Guillevic is Ifremer’s head of external communication and the Assistant Director of Communication. She orchestrated OneOceanScience, a campaign to raise awareness about the essential role of ocean sciences in combating climate change. Bringing together thirty-seven scientists on five continents, the event opened the Oceans day of COP26 and its message—“Ocean Science Matters”—reached nine million people around the world.

Where did the idea for OneOceanScience come from?

The idea came from François Houllier, Chief Executive Officer of Ifremer, who wanted to mobilize an international scientific consortium to remind the public why marine science researchers' work is essential to the world. The goal was also to shine an international spotlight on the ocean and ocean sciences.

In the past, we talked about "the oceans" in the plural, but now we know that there's just one ocean connected to all of the continents. One ocean and one scientific community determined to find solutions to the biggest problems facing this ecosystem under pressure. Through this initiative, coordinated by Ifremer in partnership with the National Research Institute for Sustainable Development (IRD) and the Centre national de la recherche scientifique (CNRS) with support from the Ocean & Climate Platform and the participation of Thomas Pesquet from the European Space Agency (ESA), French research showed its dedication to this objective.

How did the campaign play out?

OneOceanScience was created around a digital platform that served as a window onto the latest ocean sciences knowledge related to climate. Thirty-seven scientists from thirty-four countries took the opportunity to create short videos that show extensive geographic, cultural, and subject matter diversity while all responding to the same question: Why does the ocean matter?

The platform's launch on October 25, 2021, went hand in hand with an international campaign on the social media of our partners and participants that was relayed by influencers from around the world. A press campaign helped draw attention to the event, which, having received the UN Decade of Ocean Science for Sustainable Development label, opened the Oceans day of COP26 on November 5, 2021, in Glasgow.

How do you organize an international event of this scope?

You need to spend a lot of time building relationships of trust and communicating on a personal level with each institution to work on the subjects' angles. Our high-level partnership with the CNRS, the IRD, the Ocean & Climate Platform, the ESA, and the Ocean Decade team was a crucial factor in OneOceanScience's success. We also contacted around 200 influencers around the world so that OneOceanScience would be shared by the greatest number of people possible and have the farthest reach possible. I'd like to highlight the participation of Thomas Pesquet and John Kerry (the United States Special Presidential Envoy for Climate) and their teams. Each supported OneOceanScience in a video shared on their social media.

We collaborated closely with the Ocean & Climate Platform as well, which allowed us to be present at COP26, and with the UN Decade of Ocean Science for Sustainable Development team, which provided support throughout the project. I'd also like to express my sincere thanks to Théo Tanguy, the head of digital communication at Ifremer, who did a spectacular job managing the digital communication elements of the project from the very beginning until COP26.

What were the results of this campaign?

They made us very proud! It was a pleasure to work with researchers around the world and help them network. We are thrilled with the audience reached by the campaign, which was accessed fifteen million times online. The videos alone received 3.5 million views. Overall, we reached more than nine million people with our message—Ocean Science Matters—and generated over 700 posts on social media. OneOceanScience will live on at OneOcean-Summit in Brest in February 2022. Other exciting avenues in science will open up thanks to this consortium that will serve as a signal booster for scientists' voices.

The online platform for *OneOceanScience*
<https://oneoceanscience.com/>

Guidance and support

Living with the COVID-19 pandemic

The year 2021 was largely overshadowed by the pandemic once again. However, we have moved past the initial phase of shock upon the arrival of SARS-CoV-2. We have had to learn from our acquired experience, update our health and safety protocols, and continue living and working alongside the pandemic as it became clear that it is here to stay.

Remote work is the norm in laboratories and offices

To adapt its work to the public health requirements, Ifremer updated its health and safety protocols for employees throughout the year. These actions were performed in dialogue with employee representatives and after consultation with the committees and commissions for workplace health and safety. Remote work remained dominant where feasible, and policies loosened up as the pandemic receded over the summer. Other temporary measures were taken—for example, to maximize safety when staff were eating on site.

Tried and tested embarkation protocol for scientific cruises

After tremendous disruption in 2020, scientific expeditions returned almost to normal levels in 2021. The safety protocol implemented in October 2020 on the French Oceanographic Fleet's vessels remained in force. The protocol calls for starting monitoring of the staff boarding the vessel fourteen days before departure, performing PCR tests at regular intervals until boarding, and then holding to strict protective measures and vigilance on board for the first seven days. This system proved effective. Only two cases of infection were reported and neither had serious health consequences.

At the end of July, an expedition off the coast of Iceland aboard *R/V L'Atalante* for the Service hydrographique et océanographique de la Marine had to be put on pause due to a case of COVID (most likely due to a stopover in Reykjavik). Around ten people tested positive soon after, so the ship returned to Brest. Eight days later, after a period of disinfection and lockdown, the ship and her crew were able to set sail again. A positive case was also detected on *R/V Pourquoi Pas?* during the GHASS2 cruise in the Black Sea. The cruise was able to continue under the watchful eye of the ship's doctor. The COVID patient and the few unvaccinated people aboard were isolated in their cabins.

Marine SARS-CoV-2 monitoring efforts scaled back

As early as April 2020, Ifremer began monitoring coastal waters to see if SARS-CoV-2 could be detected there, since it had been clearly identified in wastewater. Since no traces of the coronavirus were detected in the 406 shellfish samples extracted over the year, Ifremer decided to scale back the operation at the beginning of summer 2021. Its scientists remain vigilant and are ready to resume monitoring if there are any accidental wastewater spills that could affect the marine environment.

Ifremer, a participant in the France Relance plan

To soften the blow that COVID-19 dealt to the French economy, the government rolled out a €100 billion recovery plan called France Relance. Ifremer is eligible for financial aid for two categories of projects: renovation of buildings' energy systems and support for research and development jobs within companies. The Institute has committed to thirteen projects that will improve the energy performance of its buildings, at a total cost of €7 million. Most of this will be dedicated to the construction project BATIMER at Ifremer's Atlantic Center in Nantes.

Furthermore, Ifremer has worked with companies eligible for the "Supporting R&D Jobs" funding to potentially develop around twenty full-time equivalent positions by opening its laboratories to private-sector researchers and engineers and by making recent graduates and post-doctoral researchers hired for short-term contracts at Ifremer available to companies. Hiring is underway under the supervision of the National Research Agency.

A glimpse at the Science Council's work

Patrick Landais, Chair
of Ifremer's Science
Council.
Photo: L.Godart / CEA



The Science Council, which reports to Ifremer's CEO, gives its opinion on the cohesiveness of Ifremer's science and technological development programs. It issues recommendations, performs evaluations, and writes proposals for research orientation.

2021, an intense year

As a geoscientist, Patrick Landais has worked at ELF Aquitaine, COGEMA, the Centre national de la recherche scientifique (CNRS), the Bureau de Recherches Géologiques et Minières (BRGM), and the French National Radioactive Waste Management Agency, where he acquired extensive experience in mineral and energy resources, oil and environmental geochemistry, and radioactive waste management. He is currently the High Commissioner for Atomic Energy at the French Alternative Energies and Atomic Energy Commission. He joined Ifremer's Science Council as its chair in 2015.

Looking back on your first term, how would you describe the position of Ifremer's Science Council?

I'm starting my second term as chair in the same state of mind as back then. The Science Council is meant to serve the Institute, and in my opinion, its actions should hew to several principles.

Above all else, we must be rigorous and vigilant about ethical quandaries in our evaluation and advising process. Next, we must act in good faith and not forget that our mission is to help Ifremer with its functioning, policy orientations, and scientific strategy. Working as a collective is very important. We try to issue opinions that reflect the viewpoints of each member. Finally, we strive to maintain a trusting relationship with executive management and the Science Division, which plays an essential role in the preparation of our sessions.

All of this must be balanced with our desire to be efficient and to give rapid, detailed responses to Ifremer's questions.

What were the main themes of the Council's activity in 2021?

This was a very intense year, and even though it was a difficult time to hold meetings, we managed to have three plenary sessions and one partial session. The Board created two work groups to lend support to specific projects.

Two themes were especially prominent for Ifremer and the Science Council. First, there was the national launch of the second wave of priority research programs and facilities. Then we were asked to weigh in on topics related to Ifremer's investment plan and help monitor certain operations. Through this, we touched on a wide variety of subjects like the creation of the Blue Research Chairs, the Overseas France Action Plan, and innovations like the MARMOR observatory and the new Argo buoys.

Were there specific subjects that caught your attention?

Absolutely. The first was the Seabed Strategy, which involves mineral resources and related environmental functions, and also has political and social aspects concerning overseas France. This is a really important topic that Ifremer, the CNRS, the BRGM, and the National Research Institute for Sustainable Development are all working on. It's essential for us all to be on the same page.

The other interesting subject was the digital ocean. Ifremer has been working on it for several years. It's a crucial initiative for the Institute. But we have to stay alert, especially to opportunities to pool forces with other research entities that may be rolling out digital-twin projects applied to their respective fields.

The Science Council unanimously commends the Overseas France Action Plan and its associated floating school. It's a remarkable idea and a well-coordinated project that's set up for success.

What were the missions of the two work groups?

One helped create the Blue Research Chairs, which was important to Ifremer. The action plan was very clear and thorough. Our recommendations had to do with setting up these chair positions and orienting them over the long term.

The other work group focused on the preparation of Ifremer's self-evaluation. It's important for the Board to weigh in on this report, which is drawn up every five years and assesses Ifremer's performance and what could be improved.

What issues do you think will take priority in the future?

As Chair of the Science Council, I'm keeping a close eye on our investments, which have been significant, to ensure that they do translate into scientific progress. Ifremer must also keep developing its partnerships within the national and international research spheres, and increase its visibility in order to boost the appeal of the ocean. The Science Council is here to help Ifremer with these challenges. The Council is hardworking, eager, and certain of the value of its work.

Four research entities, one ethics committee

Ifremer aims to be exemplary in all its work. Its ethics policy and code of conduct form the bedrock for the trust that public authorities, scientific partners, and all of society have placed in the Institute.

Michel Badré, new chair of the Joint Ethics Committee.



In April 2016, Ifremer joined the Joint Ethics Consulting Committee, founded in 2007 by the National Institute for Agricultural Research and the French Agricultural Research Centre for International Development. The National Research Institute for Sustainable Development followed in Ifremer's footsteps in 2019. These four organizations share many of the same challenges regarding scientific policy. Forming a joint ethics committee enables them to pool their questions and broaden their reflections on ethics. These organizations are also represented in other bodies such as the Alliance

nationale de recherche pour l'environnement.

The Ethics Committee's mission is to undertake reflections, provide advice, raise awareness, and occasionally to sound an alert. It considers science's responsibility to society when examining ethical issues inherent in research activities in France and abroad in different fields: food, agriculture, the ocean, the environment, and sustainable development. The Ethics Committee studies specific topics and issues statements upon the request of the chairpersons of the four organizations.

Michel Badré takes over from Axel Kahn as Chair of the Ethics Committee

An engineer by training (civil, forest, and water resource engineering), Michel Badré held high-level positions within the Ministry of the Environment before joining the Economic, Social and Environmental Council. He was especially involved in the integration of environmental concerns within large development projects and programs. Vice-chair of the Ethics Committee since 2016, he has now succeeded Axel Kahn, who passed away on July 6, 2021.

What memories of your predecessor, Axel Kahn, do you hold onto?

I didn't know him at all before joining the Ethics Committee, but his commitment struck me right away. Despite his many obligations, he was personally involved in the Committee's operations. He had high intellectual standards and an incredible sense of perspective and was a very attentive listener. It's not often that you meet someone who has all of these qualities. His passing is a great loss for all of us.

How would you describe the role of the Joint Ethics Consulting Committee?

Its role is to provide food for thought. The Committee reflects on the ethics matters that may come into play for researchers during their everyday work. Sometimes they're more abstract. For example, how do we position ourselves to avoid conflicts of interest when we're solicited as experts as part of the drafting process for public policy? Or, how do we reconcile activists' demands and scientific expertise? We're also involved with more specific subjects.

What themes have you worked on, particularly in 2021?

Two years in a row, we've worked on new genome editing technologies applied to plant and animal species (CRISPR-Cas9). This is high-level biotechnology that poses many ethical questions. Our aim is to determine how far we should go when manipulating living things.

And we've addressed another topic that's more general and more directly relevant to Ifremer: balancing the need to protect the biosphere with the needs of human activity (agriculture, fishing, leisure, etc.). This concerns all contexts, whether terrestrial, maritime, or marine. We started by studying the management of coastal waters, where these two types of needs often collide. The Committee published a preliminary statement on the subject in 2021. We're now finishing up a statement on land use.

In all cases, we first identify the objectives and orientations that may seem contradictory or incompatible. Then we propose a framework for our position or potential paths of investigation.

How does the Committee work?

It functions in a pretty typical way. All of the members of the Committee are chosen from outside these four organizations. A secretariat serves as the link between them and us. The Committee takes action when it receives letters of request. We narrow down the subject and create a work group with one or two rapporteurs. The group prepares a draft opinion with field-specific specialists, often from the four member organizations. Finally, we work together to produce a summary text with our recommendations. The Committee has a nice atmosphere. It's really a pleasure to be part of it.

Could you tell us what you've planned for 2022?

We're going to address the issue of human intervention in areas with very little human activity. The initiative came from Ifremer, but the three other organizations are interested in this subject too. It is relevant to ocean environments, seafloors, protected natural areas, the Arctic, the Antarctic, and also indigenous peoples.

The Committee would equally like to improve its communication with researchers throughout the reflection process, from the letter of request up to the publication of their official statement and its subsequent use. We're working on an interactive website that would make this easier.

Finally, we'd like to honor Axel Kahn, but not with a eulogy. Instead, we'd like researchers from the four organizations to join us for a day of discussions on intellectual and moral rigor, a topic that was very important to him.

Social responsibility at Ifremer

In 2021, Ifremer consolidated its corporate social responsibility strategy (CSR) and aligned it with the UN Sustainable Development Goals. Several new actions were undertaken and a national event was coordinated to bring employees together around these subjects.

Drawn up during the previous year, the Institute's CSR strategy was presented in March 2021 to the Board as well as certain stakeholders: its employees, its academic partners, and the Public Entity Sustainable Development Club (CDDEP). Five strategic pillars outline the issues at stake and define progress objectives. Each pillar has its own operational fact sheet and dedicated action plans:

- Promoting "one ocean"— a common good to be shared
- Limiting environmental impacts from scientific cruises
- Creating shared value
- Reducing Ifremer's environmental footprint
- Ifremer, a responsible employer

Several projects have been spearheaded in the name of this strategy and some have already been completed. The Institute published a discovery report on the use of digital technology, revealing several ways in which its impacts can be reduced at different levels (equipment procurement and end-of-life management, eco-friendly service design, data storage, restraint in individuals' resource use, etc.). An online training course on this subject will be offered to employees. Ifremer has drawn up a report on its greenhouse gas emissions (including the main categories from Scope 3: business travel, employee commuting, capital

goods, and purchased goods and services). As a member of the CDDEP, the Institute has contributed to the objectives of the Eco-friendly Public Services Plan by producing regular reports on the twenty metrics that represent environmental action in public services' daily activities. Ifremer was also chosen by the CDDEP to join its technical monitoring committee.

Furthermore, the Institute has created an environmental reporting dashboard to track its carbon reductions through different indicators. CSR compliance evaluation has received special scrutiny as well. The Institute appointed the law firm E&Y to conduct a series of interviews with division managers. The goal is to evaluate several aspects of CSR compliance at Ifremer: protection of employees' inventions, data protection (GDPR), environment, corruption, public procurement, and Ifremer's current CSR practices.

A national CSR day called "Time for Sustainable Development" was organized on November 10, 2021, at the Maison de l'Océan in Paris. Accessible online for all employees, this event was led by the Chief Executive Officer, the Deputy Chief Executive Officer, and the Head of CSR at Ifremer. A much-anticipated guest, Laurence Monnoyer-Smith (Director of Sustainable Deve-

lopment at the Centre national d'études spatiales), and several consultants were invited to speak about the Institute's CSR policy, its objectives, and its implementation. Two round tables got discussions started on the main themes:

- CSR at Ifremer: All hands on deck!
- Reducing Ifremer's environmental footprint: Challenges and opportunities concerning digital technology and greenhouse gas emissions

The videos were uploaded so that employees could view them at their leisure. Results from the satisfaction survey revealed that employees would like the event to be held every year and would like to be informed more regularly about CSR projects. New means of internal communication are being developed (an ideas box, Institute-wide challenges, etc.).

Awareness-raising actions continue as part of the Interreg Preventing Plastic Pollution project.

Human resources and labor relations

Despite the challenges posed by the pandemic, a recruitment campaign was conducted and negotiations regarding updates to the employment agreement were initiated.

As of December 31, 2021, Ifremer had 1,525 employees, of which 700 were researchers and engineers. Women represented 46% of the total workforce.

Despite the ongoing pandemic, 68 positions were filled through external recruitment in 2021.

As in 2020, Ifremer hosted a webinar on remote work during pandemic conditions to provide guidance for its employees and help them adapt to the potential complexities of their daily activities. Along with this initiative, a training course for managers was developed to give them advice and tools for managing their teams remotely. This training course was composed of an online webinar and an e-learning session.

Aside from management of the pandemic, skill development remained a high priority for the Institute.

The guidelines and action plan for HR development drawn up by HR and approved by the Steering Committee were presented to the Central Works Council as part of the consultation process for the Institute's strategic guidelines. These guidelines and the action plan focus on three themes: identifying professions, skills, and their potential evolution; adding value to managerial

roles; and digitizing HR development processes. Some actions have already been initiated, but the majority will begin in 2022.

In 2021, 819 employees received training as part of the skills development program. What's more, an e-learning course for all employees and a complementary course held via videoconference for the employees most exposed to risks of corruption were implemented as part of compliance with the Sapin II law. The Institute has also continued to develop its work-study opportunities by recruiting fifty-six new employees for apprenticeship and professional-training contracts.

In the realm of labor relations, work on an updated version of the employment agreement was ongoing throughout 2021 and should continue in 2022. In accordance with the arrangements and schedule specified in the method agreement signed at the end of 2021, four work group meetings (attended by representatives of the upper management and the employee unions) and nine negotiation sessions took place.

In 2021, an amendment to the agreement on the creation of new employee representative bodies within the Works Council was signed, with the aim of bring-

ing greater clarity to certain provisions within the agreement.

An amendment to the 2020 agreement on remote work was also negotiated and signed. This amendment broadens employees' access to remote work and makes remote work scheduling more flexible while ensuring enough regular on-site presence to preserve the community spirit of the Institute. Further, it includes a certain amount of employee compensation due to the costs incurred by remote work.

Quality management: A policy of continuous improvement for the Institute and its teams

Marie-Laure Chao,
the new National Quality
and Safety Coordinator
at Ifremer.
Photo: M.L. Chao -
Ifremer



As a Quality, Safety, and Environment executive specialized in research and laboratories, Marie-Laure Chao worked at the Institut Pasteur for over twenty years with a variety of responsibilities. Succeeding Pierre Masselin in February 2021, she joined Ifremer as the National Quality and Safety Coordinator.

What is your take on the role of quality at Ifremer?

Quality is first and foremost a management tool that serves the Institute and its teams. It sets the stage for successful activities and efficient attainment of Ifremer's goals. As emphasized in the 2030 strategic plan, Ifremer is very attentive to the quality of its results and its partnerships, which depends on how effectively it uses its skills, resources, and expert technical and scientific knowledge.

The Institute prides itself on a robust organization and a quality management system that embeds continuous improvement into its regular operations. External recognition of this quality management system, in the form of ISO 9001 certification, attests to the importance that Ifremer places on the quality of its work and methods.

What is the quality management system?

Ifremer's quality system is broken down into fourteen processes: one for steering the Institute, eight for its main activities, and five for supporting functions. Each process embodies Ifremer's quality policy at a different level in goal-setting, coordinating the subsequent activities, and implementing continuous improvement based on the Plan-Do-Check-Act approach.

This takes place through process reviews, internal quality audits, risk reduction, and client feedback. Each process is overseen by a supervisor chosen from within the Steering Committee and assisted by a process lead. To coordinate everything at the national level and provide support for each process, Ifremer relies on its National Quality Coordinator and Quality Advisers. Of course, the system wouldn't work without the involvement of its main actors, which are Ifremer's teams.

What were the key quality operations that took place in 2021?

First of all, we reviewed our quality commitments and updated Ifremer's quality policy. We also updated the quality management system dashboard to improve the visibility of our quality commitments at the process level as well as the visibility of the results obtained.

Ifremer successfully renewed its ISO 9001 certification, as well. This achievement is the culmination of our teams' hard work, demonstrating the aptness and efficacy of our quality management system.

In 2021, Ifremer maintained its COFRAC accreditations and activated its new system for electronic document management; the rollout will continue into 2022.

Ifremer's four new quality commitments:

- Listening to clients and ensuring their satisfaction
- Respecting our commitments to clients
- Optimizing the use of our experimental facilities and research vessels
- Improving the scientific, technological, and functional quality of our results

Budgetary and financial data

The main significant accounting and financial data for the 2021 financial year are the following:

- –€2.809M in pre-tax income
- €6.576M in self-financing capacity
- €101.585M in working capital
- €107.517M in cash flow

Funds

The Institute's overall revenue was €237.6 million during the 2021 financial year:

- Public subsidies (for public service responsibilities and operating expenses from the government and other public entities) amounted to €209.4 million.
- Direct income from activity amounted to €28.3 million.

Expenditures

The Institute's overall expenses were €240.4 million during the 2021 financial year:

- Expenses directly related to activity represented €130.9 million.
- Payroll costs were €109.5 million. Ifremer's workforce represents 1,571 FTE positions.
- Expenses related to investment were €31.7 million during the 2021 financial year.

Property assets

The main points to retain are:

- Working capital variation of –€12.7 million, leading to a final working capital figure of €101.6 million
- Cash flow of €107.5 million
- €64.4 million in accounts receivable (€49.3 million held for public entities) and €12.5 million in accounts payable

Budget appropriation

Commitment authority reached €250 million in 2021.

- €244.1 million were allocated to payment appropriations.
- Revenues collected amounted to €231.8 million.
- The budget balance therefore shows a deficit of €12.3 million for 2021.

Conclusion

Despite the negative result, which is mainly due to the delay in income tied to project advancement (many scientific projects were delayed), the Institute's financial situation remains good and matches the forecasts.

Working capital sits at €101.6 million, in accordance with the Institute's major investment plans. In this context, the large programs and plans that should have a significant impact on the 2022 financial year are the following:

- Ifremer's major investment plans: the medium-term schedule for the French Oceanographic Fleet, the Real Estate Investment Plan, and the Exceptional Scientific Investment Plan
- Escalation of the internal Overseas France Action Plan
- Beginning of the EquipEx+ projects in the third wave of PIA3 (a French program for investment in innovation): underwater observatories (MARMOR), upgrades to underwater vehicles (DeepSea'nnovation), development of Argo profiling floats (Argo2030), and digital infrastructure (GAIA Data)
- The Ocean & Climate priority research program
- Work performed to inform public policies, especially data acquisition to track fisheries and marine species

Appendices

Year-end financial statement before allocation of earnings

BALANCE SHEET – ASSETS	2021 GROSS	AMORTIZATIONS AND DEPRECIATIONS	2021 NET	2020 NET
FIXED ASSETS				
Intangible assets	56 759 911,84	41 533 907,34	15 226 004,50	15 284 417,73
Tangible fixed assets	636 877 609,05	438 652 985,12	198 224 623,93	199 291 843,90
Land	8 754 016,16	1 986 407,10	6 767 609,06	6 842 576,06
Buildings	128 196 553,69	89 163 752,69	39 032 801,00	40 622 460,00
Technical facilities, equipment and tools	406 326 756,34	313 490 073,34	92 836 683,00	98 248 449,00
Collections	872 856,49	0,00	872 856,49	872 856,49
Historical and cultural property	0,00	0,00	0,00	0,00
Other tangible fixed assets	42 540 848,57	34 012 751,99	8 528 096,58	4 664 759,00
Fixed assets under concession	0,00	0,00	0,00	0,00
Tangible fixed assets in progress	622 426,08	0,00	622 426,08	622 426,08
Advances and deposits on orders	49 564 151,72	0,00	49 564 151,72	47 418 317,27
Fixed assets subject to rights	0,00	0,00	0,00	0,00
Tangible fixed assets (living organisms)	0,00	0,00	0,00	0,00
Financial assets	21 249 460,69	695 231,72	20 554 228,97	14 703 945,20
TOTAL FIXED ASSETS	714 886 981,58	480 882 124,18	234 004 857,40	229 280 206,83
CURRENT ASSETS				
Stocks	0,00	0,00	0,00	0,00
Accounts receivable	64 387 304,69	634 339,41	63 752 965,28	56 997 358,99
Accounts receivable on public entities (national government, other public entities), international bodies and the European Commission	49 312 726,80	0,00	49 312 726,80	46 803 720,82
Customer and related accounts receivable	7 391 044,04	634 339,41	6 756 704,63	3 877 532,67
Accounts receivable on tax owed (income from earmarked taxes)	0,00	0,00	0,00	0,00
Advances and deposits on orders	953 064,34	0,00	953 064,34	190 519,17
Accounts receivable corresponding to operations on behalf of third parties (intervention plans)	0,00	0,00	0,00	0,00
Accounts receivable on other debtors	6 730 469,51	0,00	6 730 469,51	6 125 586,33
Prepaid expenses	20 745,82	0,00	20 745,82	0,00
TOTAL CURRENT ASSETS	64 408 050,51	634 339,41	63 773 711,10	56 997 358,99
CASH FLOW				
Securities	0,00	0,00	0,00	0,00
Cash	107 517 483,93	0,00	107 517 483,93	122 050 683,29
Other	0,00	0,00	0,00	0,00
TOTAL CASH FLOW	107 517 483,93	0,00	107 517 483,93	122 050 683,29
Accrual and deferral accounts	0,00	0,00	0,00	0,00
Unrealized foreign exchange losses	0,00	0,00	0,00	0,00
OVERALL TOTAL	886 812 516,02	481 516 463,59	405 296 052,43	408 328 249,11

BALANCE SHEET – LIABILITIES

2021

2020

LIABLE EQUITY CAPITAL

Funding received	155 186 148,78	160 142 355,04
Asset funding by the State	104 534 680,49	108 071 920,43
Asset funding by third parties	36 496 033,31	37 200 255,63
Equity capital from foundations	0,00	0,00
Revaluation differences	14 155 434,98	14 870 178,98
Reserves	125 276 819,59	63 164 159,37
Retained earnings	18 688 977,64	19 104 507,72
Financial year result	-2 809 281,72	61 397 916,22
Regulated provisions	0,00	0,00
TOTAL LIABLE EQUITY CAPITAL	296342664,29	303 808 938,35

PROVISIONS FOR CONTINGENCIES AND EXPENSES

Provisions for contingencies	3 170 194,53	2 954 700,04
Provisions for expenses	35 443 240,45	36 728 110,67
TOTAL PROVISIONS FOR CONTINGENCIES AND EXPENSES	38 613 434,98	39 682 810,71

FINANCIAL LIABILITIES

Bond debt	0,00	0,00
Loans taken out from financial institutions	0,00	0,00
Financial liabilities and other loans	0,00	0,00
TOTAL FINANCIAL LIABILITIES	0,00	0,00

NON-FINANCIAL LIABILITIES

Trade accounts payable and related accounts	12 462 534,66	7 874 012,45
Tax and social security payable	28 115 568,45	27 773 972,63
Advances and prepayments received	28 198 166,79	26 393 163,13
Accounts payable corresponding to operations on behalf of third parties (intervention plans)	0,00	0,00
Other non-financial liabilities	906 868,92	2 165 489,72
Deferred income	656 390,00	629 862,12
TOTAL NON-FINANCIAL LIABILITIES	70 339 528,82	64 836 500,05

CASH FLOW

Other elements of passive cash flow	424,34	0,00
TOTAL CASH FLOW	424,34	0,00
Accrual and deferral accounts	0,00	0,00
Unrealized foreign exchange gains	0,00	0,00
OVERALL TOTAL	405 296 052,43	408 328 249,11

Income statement

EXPENSES	2021	2020
OPERATING COSTS		
Purchases	0,00	0,00
Consumption of goods and supplies, performance of work and direct consumption of services by the organization for its activities as well as expenses related to change in stock	104 230 398,80	93 550 076,08
Salaries and benefits	100 009 398,29	95 306 302,94
Salaries, appointments and misc. payments	68 112 108,06	65 256 136,17
Social contributions	26 701 117,65	25 903 313,59
Other staff expenses	0,00	0,00
Other operating costs	12 761 136,62	16 197 845,08
Amortization, depreciation, provisions and net book value of assets sold	23 202 583,11	26 339 002,79
TOTAL OPERATING COSTS	240 203 516,82	231 393 226,89
INTERVENTION COSTS		
For intervention on own behalf	24 500,00	5 000,00
Transfers to households	0,00	0,00
Transfers to companies	0,00	0,00
Transfers to local or regional authorities	0,00	0,00
Transfers to other entities	24 500,00	5 000,00
Costs due to exercise of the Institute's guarantee	0,00	0,00
Depreciation and provisions for loss in value	0,00	0,00
TOTAL INTERVENTION COSTS	24 500,00	5 000,00
TOTAL OPERATING AND INTERVENTION COSTS	240 228 016,82	231 398 226,89
FINANCIAL EXPENSES		
Interest fees	645,00	119,08
Net loss from sale of securities	0,00	0,00
Exchange losses	22 939,85	20 812,49
Other financial charges	0,00	0,00
Amortization, depreciation and financial provisions	353 037,11	249 093,05
TOTAL FINANCIAL EXPENSES	376 621,96	270 024,62
Corporate income tax	597 638,00	597 638,00
ACTIVITY RESULT (PROFIT)	0,00	61 397 916,22
TOTAL EXPENSES	240 441 701,78	293 663 805,73

INCOME	2021	2020
OPERATING INCOME		
Income without direct consideration (or subsidies, grants and similar income)	209 365 138,72	205 140 169,48
Subsidies for public service responsibilities	175 639 074,00	173 359 654,00
Operating subsidies from the State and other public entities	33 726 064,72	31 773 015,48
Subsidies from the State and other public entities specifically earmarked to cover certain intervention costs	0,00	0,00
Donations and bequests	0,00	7 500,00
Income from earmarked taxes	0,00	0,00
Other financial charges	0,00	0,00
INCOME WITH DIRECT CONSIDERATION (OR DIRECT INCOME FROM ACTIVITY)		
Sale of goods or services	12 297 968,27	13 303 651,20
Gains from sales of assets	23 006,61	52 712 407,92
Other management income	1 728 914,49	2 201 497,96
Inventories and capitalized production	0,00	0,00
OTHER INCOME		
Write-off of amortizations, depreciations and provisions (operating income)	1 617 929,56	6 997 236,60
Write-off of financing related to an asset	12 576 101,47	12 937 606,59
TOTAL OPERATING INCOME	237 609 059,12	293 292 569,75
FINANCIAL INCOME		
Income from shares and loans	15 733,08	8 988,90
Interest on non-fixed receivables	0,00	0,00
Income from investment securities and cash flow	0,00	0,00
Income from sale of securities	0,00	0,00
Exchange gains	7 627,86	12 268,11
Other financial income	0,00	0,00
Write-off of amortizations, depreciations and financial provisions	0,00	349 978,97
TOTAL FINANCIAL INCOME	23 360,94	371 235,98
ACTIVITY RESULT (LOSS)	2 809 281,72	0,00
TOTAL INCOME	240 441 701,78	293 663 805,73

Board

Chair

François Houllier
Chief Executive Officer

Members representing the State

*Ministry of Higher Education, Research,
and Innovation*

Lise Fechner, incumbent
Didier Marquer, alternate

Ministry of the Sea

Thierry Courtine, incumbent
Marie Feucher, alternate

*Ministry of Maritime Fishing
and Marine Aquaculture*

Laurent Bouvier, incumbent
Laureline Gauthier, alternate

Ministry of Europe and Foreign Affairs

Jérémie Forrat-Jaime, incumbent
Baptiste Bondu, alternate

Ministry of the Armed Forces

Gilles Boidevezi, incumbent
Bertrand Drescher, alternate

Ministry of Industry

Laurence Mégard, incumbent
Hugues de Franclieu, alternate

*Ministry for the Economy, Finance,
and Recovery*

Isabelle Thirion, incumbent
Colin Thomas, alternate

Ministry for the Ecological Transition

Fabienne Ricard, incumbent
Isabelle Terrier, alternate

For their expertise in the Institute's fields of study

Françoise Gaill
Julien Lamothe
Frédéric Moncany de Saint-Aignan

For living resources

Elsa Cortijo
Valérie Verdier

Members elected by Ifremer personnel

CFDT

Catherine Tréguier
Loïc Le Dean
Marie-Anne Cambon Bonavita
Abdellah Benabdelmouna

CGT

Eric Abadie
Carla Scalabrin
Jean-Michel Schramm

Members voting in advisory capacity

Government Commissioner

Vincent Motyka

Secretary General for the Sea

Denis Robin
Patrick Augier, alternate

General Comptroller for Finance and Economy

Jean Bémol

Ministry of Overseas Territories

Camille Servetto

Chair of Ifremer's Science Council

Patrick Landais

Head Accountant of Ifremer

Didier Jaouen

Science Council

Chair

Patrick Landais

Members appointed by decree

Denis Allemand
Chris Bowler
Pascale Braconnot
Annie Cudennec
Jean-François Ghiglione
Anne-Marie Gue
Gonéri Le Cozannet
Edwige Quillet
Hervé Roquet
Frédérique Viard

Members representing

Ifremer personnel

Jean-François Pepin
Marie-Anne Cambon Bonavita
alternate
Caroline Montagnani
Christophe Desbois
alternate
Julien Normand
Ricardo da Silva Jacinto
alternate

Permanent Guest Members

Nicolas Arnaud
Didier Gascuel
François Lallier
Frédéric Menard
Sylvie Rebuffat

Joint Ethics Committee

Chair of the Ethics Committee

Michel Badré

Vice-chair of the Ethics Committee

Bernadette Bensaude-Vincent

Madeleine Akrich
Céline Boudet
Catherine Boyen
M. Denis Couvet
Mireille Dosso
Mark Hunyadi
M. Youba Sokona
Louis-Etienne Pigeon
Marie-Geneviève Pinsart
Pere Puigdomenech
Hervé Théry

Stakeholders Committee

Co-chairs

Geneviève Pons
Sébastien Treyer

Panel of businesses and artisans in the maritime sector

Laurent Castaing
Anne Guillaumin Gauthier
Sarah Lelong
Alexandre Luczkiewicz
Stéphane Alain Riou

Panel of local elected officials and representatives

Gil Bernardi
François Gatel
Michel Gourtay
Stéphane Haussoulier
Gaël Le Meur
Patricia Telle

Panel of associations and NGOs

Laurent Debas
Raphaëla Le Gouvello
Céline Liret
Jean-Yves Piriou
Christophe Sirugue

Panel of maritime workers

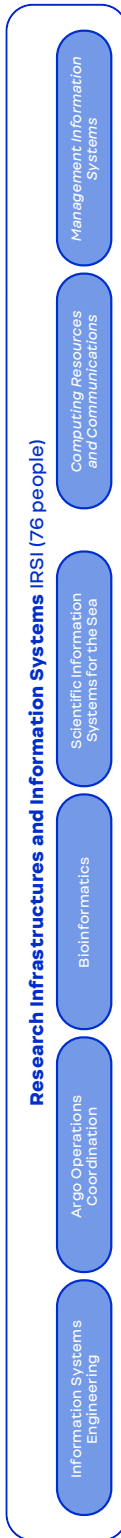
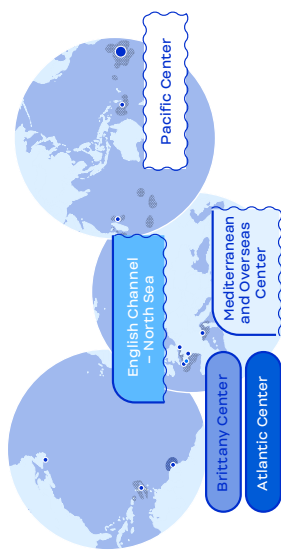
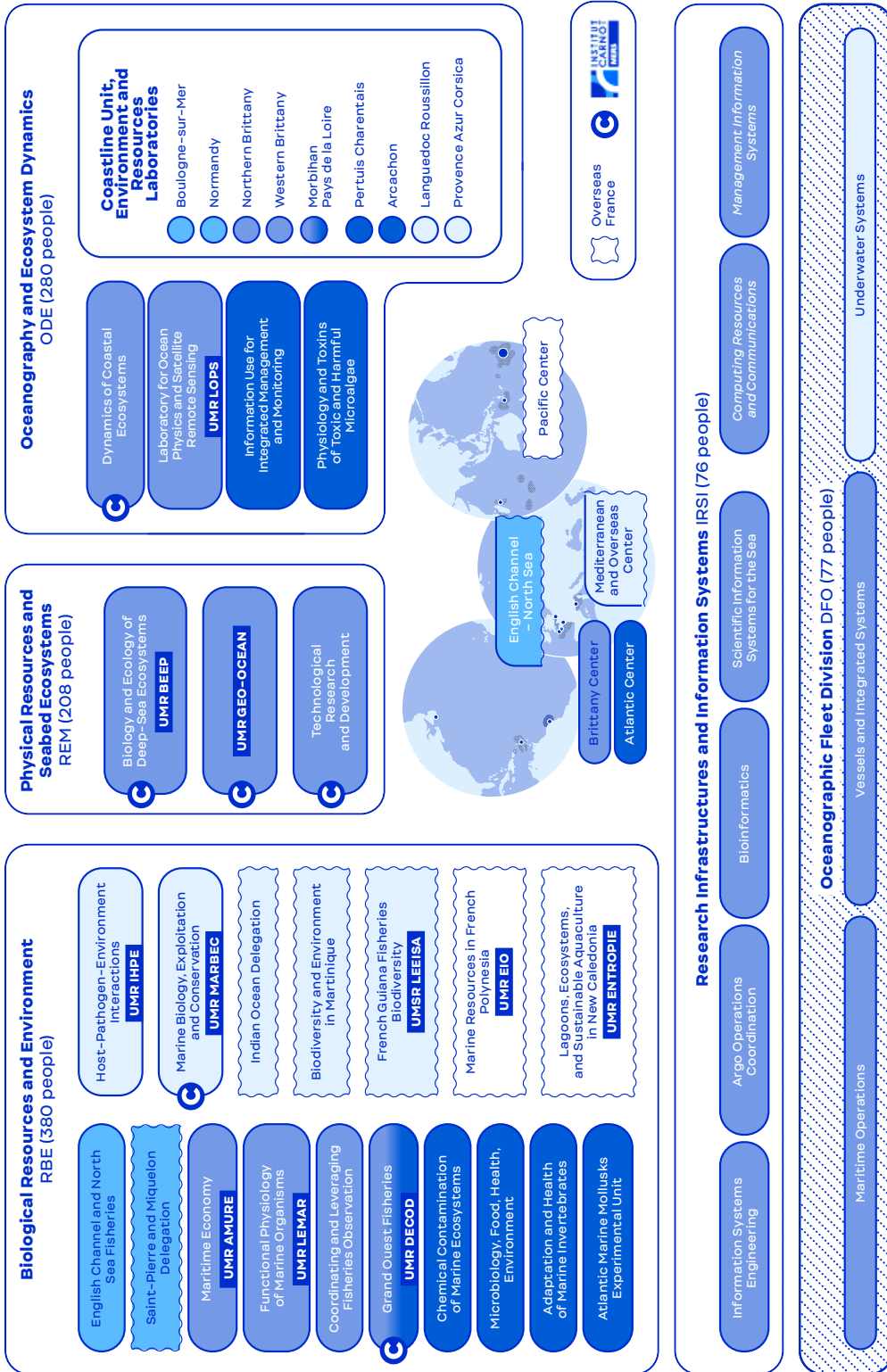
Thierry Le Guevel
Marie-Noëlle Tine Dyevre

Panel of citizens

Marion Bourhis
David Guillerme
Simon Rondeau

Organisation of research and Research and research support units

Organization of scientific and technological departments and research units within the four scientific divisions — As of January 1, 2022



General organisation

Security and defense official
Vincent Rigaud

Delegate for professional conduct and scientific integrity
Marianne Alunno-Bruscia

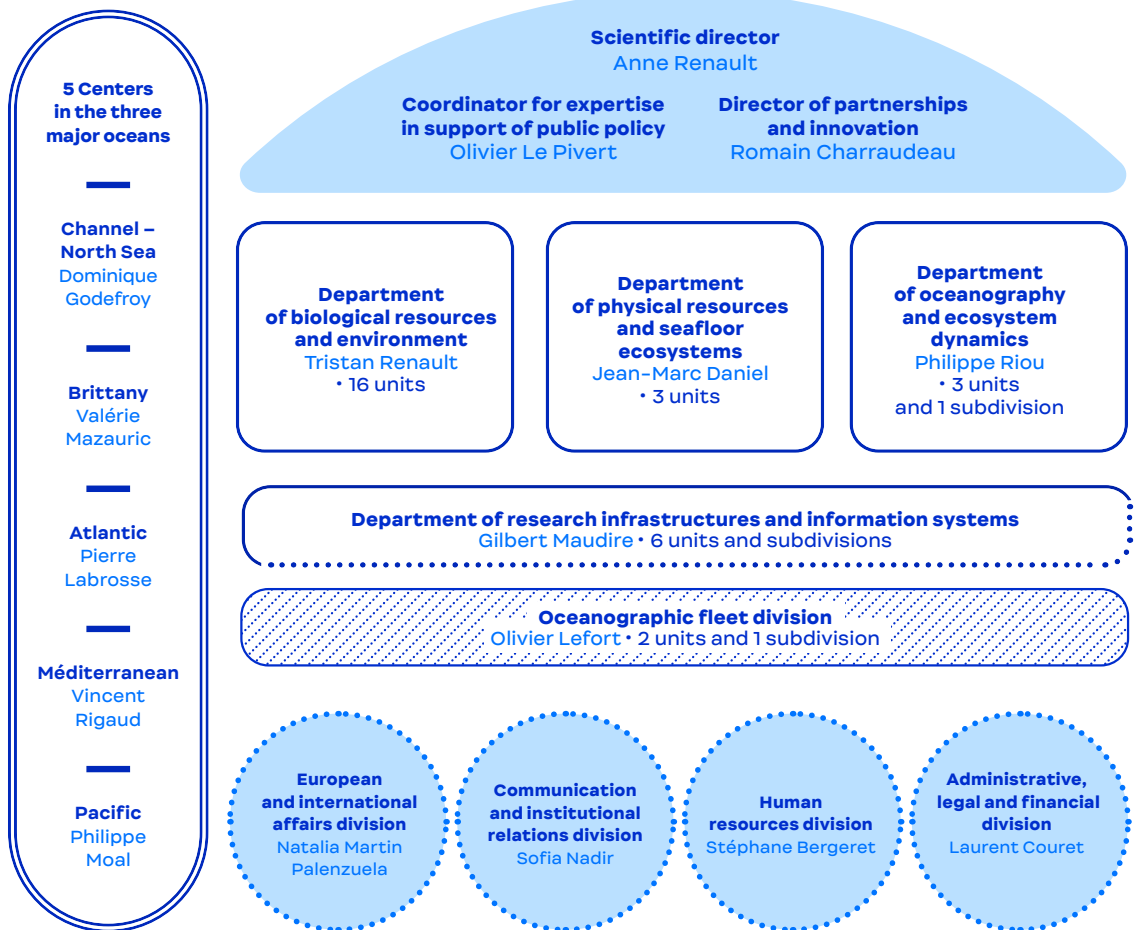
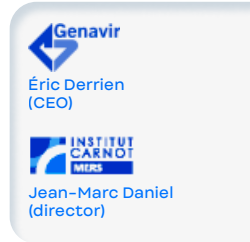
Delegate for data protection (gdpr) sd-csr
Jean-Marc Sinquin

National quality and safety coordinator
Marie-Laure Chao

François Houllier
Chairman & chief executive officer

Patrick Vincent
Deputy chief executive officer

Head of accounting
Didier Jaouen



Colophon

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Our thanks to everyone who contributed to the creation of this annual report.

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