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A Year of Ocean Sciences

2021

2023

From the abyss to the surface, from the coast to the high seas, IFREMER is the only French research institute entirely dedicated to the Ocean.


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Annual report 2023

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Editorial

Pierre Bahurel
General Manager,
Mercator Ocean International

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From Brest to Nice, from 2022 to 2025, from the One Ocean Summit to the United Nations Ocean Conference, France has been at the forefront driving change for more aggressive and dynamic governance of the Ocean. Three years might not seem like much, and every one of the decisions to be made presents its own challenges. Nonetheless, 2023 brought us some wins, including the adoption of the long-awaited BBNJ Agreement on the Conservation of Marine Biodiversity of Areas beyond National Jurisdiction.

We must be courageous in our decision-making about the ocean. The longer we wait, the more the issues at stake will increase in importance, in difficulty, and in their likelihood to end up disrupting known situations. The ability to rely on solid scientific knowledge when making decisions, and to shed light on their impact using reliable, certified tools, will become essential.

Three important pillars will support the changes to come, and IFREMER is a key player in all of them, as this report will show.

First: knowledge. This 2023 annual report distills IFREMER's efforts in this area. The Institute explores the Ocean on our behalf, in all its many aspects—climate patterns and sudden events, physics and biogeochemistry, biodiversity and human activity, expert advice and digital data, ambitious research and technological prowess. This report shows how international organizations and private individuals, together with personnel from IFREMER and its stakeholders, have mobilized to provide cutting-edge insights.

Second: a platform of services. A digital infrastructure that can aggregate and structure those insights to transform them into information services. IFREMER created Mercator Ocean twenty-five years ago to respond to this very need, in collaboration with the Centre national d'études spatiales (France's space agency), the National Centre for Scientific Research, the National Research Institute for Sustainable Development, Météo-France (the French meteorological service), and the Naval Hydrographic and Oceanographic Service. The European Commission and its "Mission Ocean" have expanded that work today, throwing their support behind the creation of a digital ocean "twin." But the goal—bringing information where decisions are made—remains the same, even as that information is enhanced via the latest in computer technology, including artificial intelligence, interactive tools, ability to networking and interconnection of local solutions.

Third: quick-moving oversight. Creating a place where decision-making, expertise, and operations work side by side, and where people can analyze, decide, and act all in one go. In this interplay between state power, scientific insight, and operational capacity, we can get governments more involved in overseeing operational science. That's what IFREMER aims to accomplish by transforming its Mercator Ocean subsidiary into an intergovernmental organization. We can also invite scientists into the places and moments where governments make decisions—which is the goal of the scientific congress being organized by IFREMER and the National Centre for Scientific Research to open the United Nations Ocean Conference in Nice.

On these three elements, the year 2023 has created the necessary impetus to build the decision-making tool that this new dynamic governance the ocean needs.

Let's continue.

Editorial

François Houllier
Chief Executive Officer, IFREMER

© Franck Betermin

In 2023, on the eve of its fortieth anniversary, IFREMER accelerated its efforts toward creating green solutions.

As I write this, the Institute is celebrating forty years of commitment to the ocean—forty years of exploration, research, discovery, and shared innovations and solutions, all aimed at clarifying what our future will look like. IFREMER works in both metropolitan and overseas France, and is proud to have spent four decades as the only French research institution entirely dedicated to the ocean, from the abyss to the surface and from the coast to the high seas. We are equally proud to send the scientific community forth across the world's oceans with the French Oceanographic Fleet. A common theme of the Institute's 2023 activities was its desire to take an active role in fostering transitions.

When it comes to transitions, special attention must be paid to climate change, resources, pollution, and understanding the role of human activity in driving these changes.

IFREMER has something special to offer: long time series of data that open doors to understanding what paths our ocean and our planet are on, thanks to the observations and expertise of our scientists. This data provides a crucial foundation for modeling and predicting future developments. In 2023, the French Ocean Observing System began to harmonize ocean observation devices; European coastal observatory network JERICO made plans to become a European Research Infrastructure Consortium; and the Datarmor supercomputer, France's only data repository solely dedicated to the ocean, received upgrades.

Bringing science into the wider world has always been and will always be in IFREMER's DNA. Our ties with marine professionals have remained strong for forty years and counting, and we are working to better understand developments in social-ecological systems.

This year, the RETROSCOPE project helped shellfish farmers prepare for the future of the industry by taking a look in the rearview mirror at its past. Meanwhile, as MicroCO2sme studied resilience in European flat oysters, researchers created closer ties with the general public by spending ten months carrying out their work in front of an audience.

IFREMER also made moves this year to develop green solutions and reduce its own impact on the ocean and the planet.

We have strengthened our presence in the field of marine renewable energies (MRE), providing support to national policymaking efforts through our technological research, testing capacity, and expertise on the ecological and socioeconomic impacts of MRE use. We also drafted the first sustainable fishing assessment of the French overseas territories, to support marine resource sustainability.

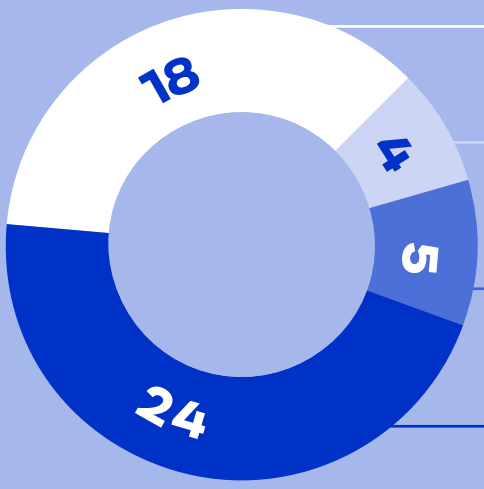
As operator of the French Oceanographic Fleet, the Institute launched a process allowing all fleet users to provide input on future efforts to decarbonize scientific cruises. It also formalized and accelerated the implementation of its corporate social responsibility policy.

In 2024, let us stay the course. Let us continue to make progress and undertake responsible scientific activity that supports our understanding of the ocean's role and ongoing changes, addresses the needs of other actors in wider society, and celebrates the ocean as a powerful lever for change. And let us continue to prepare for the One Ocean Science Congress, Science for Ocean Action, to take place in Nice in 2025.

2023 Key figures

Research

484
scientific publications



- 18 projects funded under Horizon Europe
- 4 ERC projects (European Research Council)
- 5 Marie Sklodowska Curie actions
- 24 scientific and technological research units, including 11 mixed research units

Expertise

105 opinions or expert reports produced

Innovation

17 invention disclosures

110 collaborations with businesses

Human resources

1,572 employees,

47% are women

797 scientists,

including **111** accredited to supervise research (HDR diploma holders)

775 engineers, technicians and administrative staff providing direct support for science

137 doctoral students in our laboratories

887 employees trained in 2023

Budget

263.5 million euros in expenses

31.7 million euros in investments

2023 Highlights

January

Grand opening of BATIMER at IFREMER's Nantes Center

IFREMER's Nantes site boasts a new 3,000-square-meter building devoted to studying toxic and harmful microalgae, observing and restoring coastal ecosystems, and coordinating fisheries monitoring. Its goal is to augment synergies around the theme "Marine Ecosystem Health for One Health" and develop external partnerships in that realm. The eco-friendly building uses 65% less energy in its offices than previous facilities.

Construction was funded by NextGenerationEU, the French government, the regional government of Pays de la Loire, the European Regional Development Fund, and the City of Nantes.

BATIMER (Microalgae Environment and Resources Building), the newest building at IFREMER's Atlantic Center in Nantes. Photo: Stéphane Lesbats / IFREMER (CC BY)

January 24–26

International POGO meeting drops by IFREMER

IFREMER welcomed the twenty-fourth annual meeting of POGO (Partnership for Observation of the Global Ocean) in La Seyne-sur-Mer, bringing together the fifty-five institutions from around the globe working to observe the world's oceans. Participants had the opportunity to review recent advancements, share best practices, and define priorities for better observation. The 2023 meeting featured a presentation on development plans through 2030 for Fr-OOS, a research infrastructure that will coordinate French ocean observation infrastructures.

More than 100 scientific and industrial experts and directors of scientific institutions met at IFREMER's Mediterranean Center (La Seyne-sur-Mer, Var) to discuss the future of ocean observation. © IFREMER

March

Fr-OOS: Improved coordination for ocean observation

The French Ocean Observing System (Fr-OOS) was set up in 2023 to coordinate long-term ocean observation efforts by French organizations (CEREMA, CNES, IFREMER, INSU/CNRS, IRD, Météo-France, and SHOM). Fr-OOS oversees offshore, deep-sea and coastal observation networks used for research, climate tracking, environmental monitoring, and operational oceanography. Under its umbrella are the national research infrastructures for observation (Argo, EMSO, ILICO, OHIS) and other networks, which handle operations. Fr-OOS acts as the French node of the European Ocean Observing System and the Global Ocean Observing System.

Floats being trialed in the testing tank at IFREMER's Brittany Center. Photo: Olivier Dugornay / IFREMER (CC BY)

March 21

OPEN-C: Europe's largest network of offshore test sites

The OPEN-C Foundation, led by IFREMER and nine other public and private founders, integrates and coordinates France's five offshore testing sites, including the one managed by IFREMER in Sainte-Anne du Portzic. That site covers a wide range of renewable energy technologies, including floating wind turbines, tidal power, wave energy converters, offshore hydrogen, and floating solar panels. Pooling these resources will speed up validation in real-world conditions for prototypes and pilot tests, so that energy transition objectives can be met more efficiently.

The Sainte-Anne du Portzic testing site, run by IFREMER in the Bay of Brest, is one of five offshore testing sites that comprise the OPEN-C Foundation. Photo: Olivier Dugornay / IFREMER (CC BY)

April 4

Renewed partnership with ANSES

IFREMER signed a five-year framework agreement with France's National Agency for Food, Environmental and Occupational Health and Safety (ANSES). The two organizations will continue working together to conduct research and provide expert insights on the health of fish and mollusks as well as the safety of their derived food products. The approach taken to human, animal, and environmental health issues will be both more interdisciplinary and more open to public input. They also intend to enhance the support they provide to policymakers and increase IFREMER's involvement in ANSES's calls for projects.

From left to right: François Houllier, Chief Executive Officer of IFREMER (CEO), and Benoît Vallet, Director General of ANSES. © Anses

June 2

CELIMER inaugurated in Sète

IFREMER has expanded its Sète site with a new hub aiming to bridge the worlds of research and business. The Seas and Coastlines Center (CELIMER) was born of a scientific partnership between IFREMER, the National Research Institute for Sustainable Development (IRD), the National Centre for Scientific Research, and the University of Montpellier. It will bolster research and innovation dealing with marine ecosystem resilience in the face of climate change. The center provides support for development of the blue economy and heightens international visibility for research in this field.

The project was sponsored by the government of the Occitanie/Pyrénées-Méditerranée Region, the government of France, Sète Agglopôle Méditerranée, Montpellier Méditerranée Métropole, IRD, and IFREMER.

IFREMER's Sète site; in the foreground, the new CELIMER building. Photo: Stéphane Lesbats / IFREMER (CC BY)

June 12

Support for marine renewable energies

IFREMER reaffirmed its partnership with the Ministry for the Ecological Transition to guide project development in marine renewable energies (MRE). The Institute has agreed to assist the French government during public hearings on offshore wind farm planning, and to help define initial environmental conditions for future offshore MRE sites. IFREMER will also make use of its expertise in data and environmental monitoring protocols to help train national service providers.

Floatgen, a two-megawatt floating wind turbine anchored at the SEM-REV testing site (off the coast of Le Croisic), is the first floating wind turbine installed on the French coast. Photo: Olivier Dugornay / IFREMER (CC BY)

July 4

IFREMER and NOAA: Another five years together!

IFREMER and NOAA (the US National Oceanic and Atmospheric Administration) renewed their bilateral agreement for five more years. The agreement signifies both parties' desire to keep working together to better understand and preserve the ocean. Three priorities for the partnership have been outlined: climate science and ocean observation systems, coastal marine ecosystems, and ocean exploration.

From left to right: Steve Thur, director of research at NOAA; Vincent Guérend, French ambassador to Ireland; and François Houllier, IFREMER CEO. © IFREMER

2023 Highlights

August

Doctoral candidate honored by the Deep-Sea Biology Society

The Deep-Sea Biology Society celebrated a 2020 article published in Ecology by scientists from IFREMER's Biology and Ecology of Deep-Sea Ecosystems unit. The study was conducted as part of Joan Manel Alfaro-Lucas's dissertation work. It shed light on the processes and factors governing macrofauna communities in one of the deep sea's most precious habitats: the Lucky Strike hydrothermal vent field, which lies 1,700 meters below the surface of the ocean to the north of the Mid-Atlantic Ridge.

Alfaro-Lucas *et al.* 2020. High environmental stress and productivity increase functional diversity along a deep-sea hydrothermal vent gradient. *Ecology*, 101(11). https://doi.org/10.1002/ecy.3144

A colony of modiolus mussels, bivalve mollusks typical of hydrothermal ecosystems, seen here on the Lucky Strike hydrothermal site. Photo: IFREMER (CC BY)

August 16, November 14

IFREMER's Pacific Center receives ministerial visits

First came the French Interior Minister Gérald Darmanin, the Minister for Sports and the Olympic Games, Amélie Oudéa-Castera, and the Deputy Minister for Overseas France, Philippe Vigier. Together with the president of French Polynesia, they finalized the technical and logistical partnership between IFREMER and the French government for the surfing event at the Olympic Games, taking place near IFREMER's Vairao site. Then Hervé Berville, secretary of state for the sea, paid a visit in November to learn about IFREMER's activities in the Pacific region, including aquaculture and seabed exploration. Berville reiterated the French government's opposition to any and all deep-sea mining activity.

From left to right: Delegate Steve Chailloux; Moetai Brotherson, president of French Polynesia; Delegate Mereana Reid-Arbelot; Ministers Gérald Darmanin, Amélie Oudéa-Castera and Philippe Vigier. © Claude Soyez

September 10

UlyX hits the 6,000-meter milestone

The AUV UlyX, launched in 2020, hit a symbolic milestone when it dived to a depth of 6,000 meters during sea trials aboard the *Pourquoi pas?* in the Atlantic between Brest and the Azores. This achievement highlights the engineering expertise brought to the table by IFREMER, operator of the French Oceanographic Fleet. The Institute is the only organization in France with the skills necessary to design and build submersible vehicles that can explore the deep sea.

The UlyX submersible surfaces. Photo: Olivier Dugornay / IFREMER (CC BY)

October 11

Award for doctoral candidate Cinzia Alessi

Cinzia Alessi is a doctoral candidate in New Caledonia at the ENTROPIE joint research unit (co-supervised by IFREMER and the National Research Institute for Sustainable Development), studying the strategies corals have developed to live in extreme environments. Her dissertation work on coral ecophysiology won the 2023 L'Oréal-UNESCO French Rising Talents Prize for Women in Science. The prize is awarded by the L'Oréal Foundation, which is committed to supporting the ambitions of young female researchers and fighting underrepresentation of women in science sectors and jobs.

Cinzia Alessi, winner of the 2023 L'Oréal-UNESCO French Rising Talents Prize for Women in Science. Photo: IFREMER (CC BY)

October 17

IFREMER Oceanography Prize awarded to Fabrice Ardhuin

Fabrice Ardhuin, director of research for the National Centre for Scientific Research at the Laboratory for Ocean Physics and Satellite remote sensing (CNRS/IFREMER/IRD/University of Western Brittany) received the IFREMER Oceanography Prize for his work exploring interactions between waves, ocean currents, and sea ice, and their acoustic and seismic signatures across the Earth system.

Fabrice Ardhuin, winner of the 2023 IFREMER Oceanography Prize. © IRD

November 21

Damien Desbruyères wins 2023 Christian Le Provost Prize

The Christian Le Provost Prize was awarded to Damien Desbruyères, IFREMER researcher at the Laboratory for Ocean Physics and Satellite remote sensing (CNRS/IFREMER/IRD/University of Western Brittany). The award was given in recognition of his work on in situ observations of the North Atlantic Ocean and on uncovering the mechanisms behind dynamics and variations in that region in the context of global warming.

Damien Desbruyères, honored with the Christian Le Provost Prize in 2023.
© INUA Production

November 24

The Minister of Higher Education and Research visits IFREMER headquarters

On the schedule: overviews of the French Oceanographic Fleet, Argo profiling floats, and models of offshore wind turbines. The minister approved the €65 million budget for building a vessel capable of moving through sea ice, and called for IFREMER and the French Polar Institute Paul-Émile Victor to work more closely together to bolster French polar research.

Sylvie Retailleau, minister of higher education and research, visiting the test tank at IFREMER's Brittany Center.
Photo: Olivier Dugornay / Ifremer (CC BY)

December

Ongoing collaboration with WHOI

Fourteen years after they signed their first memorandum of understanding, IFREMER and the Woods Hole Oceanographic Institution (WHOI) have renewed their partnership and will continue to work together to seek ocean-based solutions for the fight against climate change. With co-publications, increased mobility for scientists, and technology sharing, there will be ample shared resources to generate new ocean insights.

Peter de Menocal (left, WHOI) and François Houllier (right, IFREMER) signed a memorandum of understanding at the COP28 Ocean Pavilion.
© Elise Hugus / Woods Hole Oceanographic Institution

The French Oceanographic Fleet around the world

Wide-ranging research cruises overcoming major logistical challenges were the trend in 2023, coordinating work between multiple research vessels. Four trips even added a satellite to the mix!

Key 2023 research cruises

The French Oceanographic Fleet (pictured here, R/V *Pourquoi pas?*) pursued scientific advancements across the world's oceans. Photo: Olivier Dugornay / IFREMER (CC BY)

Despite rising costs due to geopolitical tensions, the Ministry of Higher Education and Research allocated additional funding to the French Oceanographic Fleet under its "Energy" budget, allowing the fleet to perform all planned research cruises for the year and maintain its normal level of activity. A number of landmark missions were carried out in 2023, enhancing the data available to the scientific community.

Four cruises under SWOT's watchful eye

The launch of an Earth observation satellite last December kicked off the international SWOT mission (Surface Water and Ocean Topography, SWOT), co-piloted by the Centre national d'études spatiales (CNES) and the National Aeronautics and Space Administration (NASA). SWOT will provide real-time satellite data and imagery at ten times the resolution of current technologies, opening new horizons in satellite altimetry. Scientists will now be able to observe previously undetectable fine details of ocean topography caused by eddies and currents. In 2023, four research cruises on three different vessels were performed in conjunction with SWOT, for a total of 133 days at sea. Three of these cruises took place in the Mediterranean: The first two aimed to calibrate and validate the new satellite's fine-scale measurements, with teams from IFREMER, the National Centre for Scientific Research (CNRS), and the Naval Hydrographic and Oceanographic Service carrying out simultaneous operations aboard R/V *L'Atalante* and R/V *Téthys II*. The third cruise used data collected by the *L'Atalante* and SWOT to study the impact of ocean dynamics on plankton diversity. Meanwhile, over in New Caledonia, R/V *Antéa* visited a seamount-filled region to investigate internal tides using data gathered by both the vessel (ocean density profiles, sea levels, etc.) and the satellite.

The Atlantic biological carbon pump and sediment cores from the mouth of the Amazon: Climate science driving research

The CNRS-directed APERO project sent R/V *Thalassa* and R/V *Pourquoi pas?* on a joint mission to discover the secrets of the biological carbon pump in the Celtic Sea. Combining large-scale sampling with fine-scale stationary measurements, scientists hope to reconcile estimates of particulate organic carbon inputs at the surface with the needs of mesopelagic fauna at depths of 200 to 1,000 meters.

R/V *Marion Dufresne*, along with its world-class giant marine sediment corer, sailed between Brazil and Barbados to take samples from the alluvial cone formed by Amazon sediment deposits. Scientists on this project (a merger of AMARYLLIS and AMAGAS) hope to improve their understanding of the role the Amazon Basin plays in the global climate system.

A dozen fisheries monitoring surveys

Finally, as always, R/Vs *Thalassa*, *L'Europe*, and *Thalia* participated in several of the twelve total fish population survey cruises that take place every year in the English Channel, the Bay of Biscay, and the Mediterranean. These cruises inform decision-making on EU fishing quotas.

Learn more at the French Oceanographic Fleet website: https://www.flotteoceanographique.fr/en

L'Atalante rushes to assist *Titan* submersible

The French Oceanographic Fleet, operated by IFREMER and its outfitting subsidiary Genavir, participated in search operations for OceanGate's *Titan* submersible, which left to tour the wreck of the *Titanic* on Sunday, June 18, 2023. Despite the massive rescue effort, tragedy ensued: The vehicle had sunk near the wreck, off the coast of Newfoundland.

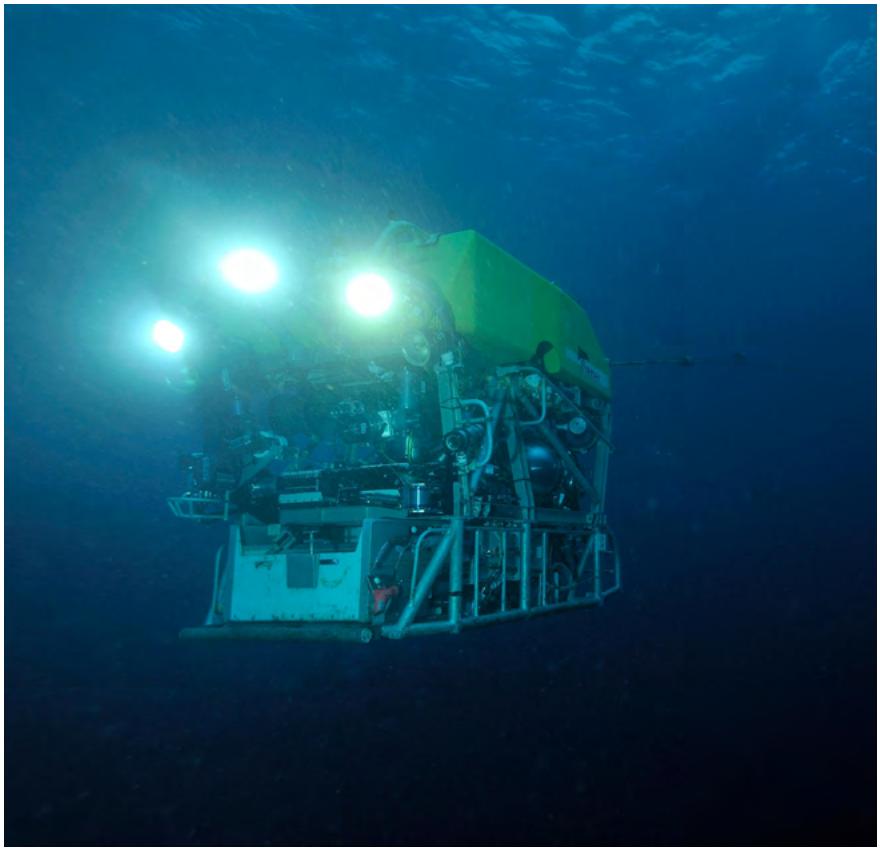
IFREMER's help was requested by the US Navy and the Woods Hole Oceanographic Institution, as the French Oceanographic Fleet's *L'Atalante* was located 48 hours' travel from the accident site and could contribute deep-sea search tools to the rescue efforts.

The captain therefore diverted the vessel from its planned route toward the presumed location of the incident. Genavir teams in Toulon were also immediately dispatched to the area to operate AUV Victor 6000, which was being carried on R/V *L'Atalante*. Victor is designed to reach depths of up to 6,000 meters; the wreck of the *Titanic* lies just 3,800 meters below the surface.

The administrations of IFREMER and Genavir commend the dedication of the teams from the Oceanographic Fleet Division and Genavir. In accordance with maritime law, they did everything they possibly could to help recover the submersible and its five passengers as quickly as possible.

In memory of Paul-Henri Nargeolet, lost aboard the *Titan*

French explorer Paul Henri Nargeolet was one of five people who died aboard the *Titan* submersible, lost during a dive to the wreck of the *Titanic* on June 18, 2023. A pioneer of underwater exploration, he devoted more than ten years of his life to probing the depths of the ocean with Genavir, the outfitter and sea operator for all research vessels and submersibles belonging to the French Oceanographic Fleet. Over the course of his career, Nargeolet performed thirty-nine dives with the *Nautile*, including twenty to the site of the legendary wreck. He left Genavir in early 1996 to devote himself full-time to his one true passion: exploring the *Titanic*.



AUV Victor 6000's high-resolution optical photo and video imaging system gives the best possible view of the underwater environment at depths of up to 6,000 meters.
Photo: Olivier Dugornay / IFREMER (CC BY)

The French Oceanographic Fleet is reinventing itself

Christine David-Beausire, deputy director and director of science for the French Oceanographic Fleet. Photo: Stéphane Lesbats / IFREMER (CC BY)

The French Oceanographic Fleet is one of the top five scientific fleets in the world, boasting seventeen vessels and six submersibles. Operated by IFREMER and its outfitting subsidiary Genavir, it has spent more than a century sailing the oceans in service of the science community. Christine David-Beausire, the fleet's deputy director and director of science, looks back at a year of major announcements and discusses new opportunities for this French research jewel.

What was the status of the French Oceanographic Fleet at the start of 2023?

Let's start off with a reminder that in 2018 the fleet was consolidated into a single research infrastructure under a single operator, IFREMER. It sprang out of national policy—it's a government creation. And the government, via the Ministry of Higher Education and Research, is the one that provides its budget, with funds earmarked for the fleet's activities. It's a big responsibility for IFREMER to take control of this national instrument and wield it for the benefit of all the associated academic research organizations, but it's also a great recognition of the Institute's ability to manage, develop, and deploy these tools. A research vessel has an average lifespan of forty years. Three deep-sea vessels and three coastal-class vessels will reach their end of life between 2029 and 2035. The need to replace so many vessels in such a short period became the starting point for our discussions, with, implicitly, a firm intention to reduce the fleet's environmental impact.

Introducing a forward-looking approach, making R/V *Thalia's* replacement official, creating an ice-going vessel (the R/V *Michel Rocard*), 2023 has been the jumping-off point for some major projects that will shape the future of the fleet. What do we need to know?

Our prospectus, "Envisioning the French Oceanographic Fleet of 2035," was released in March 2023. The first goal was very practical: determining how to modernize our fleet. Beyond the need to account for new findings and new technologies developed since our previous prospective discussion in 2017, the most remarkable part was the outlook on decarbonization, underpinned both by the question of purpose and by a recognition of the fleet's social and environmental responsibility. That, again, is an issue we're naturally very aware of. The paradigm shift will start with R/V *Thalia*'s future replacement. It's been designed with basic green features like usage of biofuels, energy recovery for heating and hot water, and smooth propulsion that reduces energy consumption. But we'll also be able to modify it, so that over the course of its lifespan it can be outfitted with further carbon-reducing features as they become available. This regional-class vessel will also carry more passengers, which creates new opportunities for interdisciplinary work on longer cruises that could last two to three weeks. As for R/V *Michel Rocard*—which should launch in 2028 and will operate in the Pacific and sometimes the East Antarctic—what we're talking about there is something brand-new for the French Oceanographic Fleet. Before we do any other work, we'll need to surround ourselves with specialized partners to help create a design that meets the needs of two different communities, and that can handle two different environments imposing different constraints. Then, later, we'll need to plan the Antarctic missions in concert with our partner, the French Polar Institute Paul-Émile Victor. This vessel will eventually replace R/V *Antéa*. Like its predecessor, it will have its home port in Nouméa, and spend around three months per year in the Antarctic, during the Southern Hemisphere's summer. Dumont d'Urville Station will be its only anchorage during this time.

What does all this mean for France's future plans and IFREMER's role in them?

First of all, beyond the modernization I've already mentioned, this is a testament to the fact that our fleet is an essential tool for the French scientific community in the current context of climate change, biodiversity loss, and the well-established effects of pollution. It seems clear that this represents a strong endorsement from the political sphere regarding the need to understand and protect our oceans. The resources that have been allocated demonstrate exactly how much support we're receiving. We might now be able to hit new milestones.

But I have to emphasize that even as we receive and implement new resources, we're also going to be revamping our approaches and techniques, and taking on a larger role in the global research community. By improving our planning and pooling more of our resources with other actors, we won't just be able to reduce our carbon emissions—we'll be able to create efficiencies, optimize how we use our time at sea, and increase our visibility in the medium term.

Protect and restore the seas and oceans

A vibrant, healthy, safe, and resilient ocean

In seeking to understand the marine world, monitoring it, and analyzing the threats it faces, IFREMER helps preserve our shared future for a vibrant, healthy, safe, and resilient ocean.

Uncovering the mysteries of life in the abyss

In October 2023, scientists boarded R/V *Pourquoi pas?*, the flagship of the French Oceanographic Fleet (operated by IFREMER and its subsidiary Genavir). Their mission: to study five hydrothermal vent fields lying up to 3,700 meters below the surface and distributed along a stretch of the Mid-Atlantic Ridge spanning more than 800 kilometers. This project, BICOSE 3, is part of IFREMER's ongoing research into identifying hidden species in the deep sea and understanding their life cycles.

The deep sea is bursting with unexpected biodiversity perfectly adapted to a harsh environment. It's not just bacteria and viruses, but also shrimp and giant mussels—life flourishes around hydrothermal vents under extreme pressures. Since 2014, IFREMER has been sending research cruises along the Mid-Atlantic Ridge to figure out how these species adapted themselves and colonized these environments. Along the way, they've learned that vent fields separated by hundreds of kilometers are home to the same species, even ones that don't usually migrate, like shrimp, mussels, snails, tubeworms, and bacteria. Scientists are interested in finding out how these species have traveled from site to site.

Forty-seven days investigating the deep sea

BICOSE 3 (Biodiversity, Interactions, Connections and Symbioses in Extreme Environments) brought together thirty scientists from IFREMER, the National Centre for Scientific Research, the National Research Institute for Sustainable Development, Sorbonne University, and University of Western Brittany. They aimed to perform a total of thirty dives with the *Nautile* submersible in order to create a detailed map of hydrothermal vent field species along an 800-kilometer span of the Mid-Atlantic Ridge, which will help them better understand the inner workings of these environments.

Each time they went exploring, the scientists observed large numbers of *Rimicaris* shrimp, a prevalent species on hydrothermal vents. The shrimp thrive in these extreme environments by cooperating with "friendly" bacteria that live in their heads.

Scientists are fascinated by this shrimp-bacteria symbiosis during the early phases of the crustacean's life, and they hope to eventually shed light on this mystery. In order to do that, however, they'll need to figure out where the shrimp larvae live. BICOSE 3 aimed to find that missing piece of the puzzle by setting out in the fall, a season where exploration hadn't yet taken place. The discoveries from this project will not only clarify the *Rimicaris* shrimp's biology, but also provide new insight into how hydrothermal vent ecosystems function. And, ultimately, it will help scientists better assess the impact of human activities on life in the abyss.

BICOSE 3 chief science officer: Marie-Anne Cambon, Microbiology of Extreme Environments Laboratory, IFREMER
Set sail with BICOSE 3 (in French): https://www.ifremer.fr/fr/ressources/bord-de-la-campagne-bicose-3

Scientists are piecing together the mysterious biology of the *Rimicaris exoculata*, a ubiquitous shrimp on hydrothermal vents. (Pictured here: Snake Pit, which lies 3,600 meters below the surface.)
Photo: BICOSE / IFREMER (CC BY)

First results from ROME, a trailblazing environmental DNA network

Traces of DNA from microorganisms (viruses, bacteria, unicellular organisms) are present in water and oyster samples. Analyzing these traces provides a novel way to observe coastal microbial biodiversity.
Photo: Stéphane Lesbats / IFREMER (CC BY)

ROME (Observatory Network for Integrated Coastal Environmental Microbiology) is the first national observatory in Europe ever to observe coastal microbe biodiversity via environmental DNA and RNA* (eDNA/eRNA). Nearly thirty IFREMER scientists are participating in this project, which began in 2020 and covers all of France's major coastlines. Three years in, it has yielded promising results, creating a strong foundation for a larger-scale operation.

Marine organisms leave traces of their DNA in the environment. Through analysis of DNA samples found in water and oysters, it's possible to identify which microorganisms are present. The ROME eDNA/eRNA observatory is designed, run, and funded by IFREMER. It debuted in September 2020 at four oyster-farming sites representing all of mainland France's coastlines: the Bay of Veys (Manche), the Bay of Brest (Finistère), Marennes-Oléron (Charente Maritime), and the Thau lagoon (Hérault). The observatory comprehensively investigates biodiversity levels in various microbiological population segments (viruses, bacteria, unicellular organisms) present in the water as well as in shellfish in coastal areas influenced by drainage basins. Using a new molecular technique reflecting the "One Health" approach (unifying human, animal, and environmental health), it aims to explore new threats to the environment (river effects), to aquaculture resource sustainability (detection of new shellfish parasites), and to human health (emergence of human pathogens), all at once.

The first phase of the project experimented with sampling methods, developed new sequencing techniques, and analyzed the added value provided by the new eDNA/eRNA approach. That phase wrapped up in 2023. Over the course of three years, ROME has connected interdisciplinary efforts from a number of teams and laboratories across IFREMER's Oceanography and Ecosystem Dynamics department, Biological Resources and Environment department, and Research Infrastructures and Information Systems department.

More than 3,000 eDNA samples already in the bank

Eleven complete protocols for taking and analyzing samples of water and biological material have been published online as a result of ROME. The project also created a bank of more than 3,000 water eDNA samples and 110 shellfish eDNA/eRNA samples.

A full scientific review of the past three years' work is still in progress, but some takeaways can be gleaned from initial indicators:

- IFREMER's logistical and operational capacity for deploying this new kind of observatory based on eDNA
- The potential of eDNA to link issues in human, aquaculture, and environmental health
- The relevance and additional benefits of using the eDNA technique to assess the emergence of new microbiological threats by detecting rare or unknown species in fragile ecosystems

ROME will continue to make strides in 2024 toward creating an eDNA-based operational framework that can offer new tools and options for observing and monitoring coastal areas, as well as meet needs in public policy support.

* DNA: deoxyribonucleic acid
RNA: ribonucleic acid

ROME chief science officer and project lead: Raffaele Siano, Pelagic Ecology Laboratory, IFREMER
Project website (in French): https://rome.ifremer.fr

Optimizing marine spatial planning to resolve growing maritime conflicts

Growth in marine renewable energies is fueling tensions over the use of marine spaces. Photo: Olivier Dugornay / IFREMER (CC BY)

Ocean use is expanding even as marine spaces face increasing pressures. An IFREMER team is building tools for making inclusive, equitable, flexible decisions about complex marine use issues and mitigating conflicts between users.

As human use of the ocean grows, sharing the marine environment becomes more and more complicated. Adding fuel to the fire is the rapid development of renewable energies, driven by the climate crisis. For example: France plans to add forty gigawatts of offshore wind power between now and 2050. Those installations will take up around 8,000 square kilometers of space. Offshore wind farms have thus become a major competitor to more traditional ocean enterprises. At the same time, French national policy aims to create marine protected areas to keep marine biodiversity and ecosystems safe from the various impacts of anthropogenic pressures. However, spatial planning for these marine protected areas and marine renewable energy zones often fails to consider the needs of fisheries, leading to frequent opposition from the fishing industry.

Inclusive, equitable, flexible marine spatial planning

Decision-making tools for ocean planning are currently used primarily by scientists and conservationists. They haven't yet been systematically integrated into the processes used by those in charge of planning marine space usage. To encourage all stakeholders to apply these tools, IFREMER teams have developed an inclusive, equitable, flexible methodology. They began by defining a number of indicators related to human activity, ecosystem services, and biodiversity, consulting with at least one stakeholder in each category along the way. After gathering and mapping the related data, they used an optimization algorithm to explore possible locations for renewable energy farms and marine protected areas.

The team applied this approach to the Grande Vasière, a massive social-ecological system covering 21,000 square kilometers in the Bay of Biscay. Here, marine renewable energies brush up against biodiversity needs, ecosystem services, and fishing. This test case demonstrated that equitable solutions aren't necessarily the most expensive ones. Moreover, they allowed for a whole assortment of alternatives. The study also underlined the importance of exploring multiple possible plans. It accomplished that task using Shiny, an application developed to visualize the results of different scenarios and stimulate dialogue among stakeholders and decision-makers.

Boussarie G., Kopp D., Lavialle G., Mouchet M., Morfin M. 2023. Marine spatial planning to solve increasing conflicts at sea: A framework for prioritizing offshore windfarms and marine protected areas, *Journal of Environmental Management*, 339, 117857. https://doi.org/10.1016/j.jenvman.2023.117857

Mission "Restore Our Ocean and Waters": Integrating scientific expertise to solve major societal issues

The European Commission launched Mission "Restore Our Ocean and Waters"* in September 2021. IFREMER is firmly invested in the project, which helps societies and decision-makers familiarize themselves with the ocean and the latest findings in marine science by using new research methodologies. Its highly cross-disciplinary, coordinated model of solutions and initiatives, measurable objectives, and specific deadlines will translate into massive social impact.

Pollution, biodiversity loss, extreme weather events—the global ocean is severely threatened by human activity. The world must step up its research efforts and concentrate on eliminating scientific barriers in order to find successful solutions. That's why the European Commission launched Mission "Restore Our Ocean and Waters" in September 2021, seeking to protect and restore ocean health by 2030 through research, innovation, and engagement with citizens and investors. The mission's objective is clear: Pave the way for new collaborative research methods that include all stakeholders, researchers, decision-makers, actors in related fields, and individuals in every step of the research process.

Implementation will take place in two stages:

- 2021-2025: Encouraging development of new research methodologies by setting up Lighthouses, maritime regions where all actors collaborate to make progress toward specific mission objectives. The Lighthouses project receives €110 million in annual funding from the European Union.
- 2026-2030: Deployment and scaling of EU-funded solutions.

An active role for IFREMER

IFREMER was involved in the mission's preplanning and coordinates PREP4BLUE project (2022-2025), where new co-creation and co-development methods in research and innovation are laying the foundation for a successful Stage 1.

The Institute also helps coordinate other Lighthouses-related EU projects in the Mediterranean basin, the Atlantic-Arctic basin, and the Baltic-North Sea basin. IFREMER is a partner on CLIMAREST, which explores possibilities for restoring marine ecosystems at five demonstration sites in the Atlantic-Arctic basin. The project takes a holistic, interdisciplinary approach and seeks involvement from many different stakeholders, including individual citizens. IFREMER does work at the French demonstration site, focusing on oyster reefs in the Bay of Brest and Quiberon Bay.

* Mission "Restore Our Ocean and Waters" is one of five related Missions initiated by the European Commission.

Researchers, decision-makers, investors, individuals—protecting and restoring marine ecosystems is a job for everyone. Pictured here: reefs of flat oysters in Quiberon Bay.
Photo: Stéphane Pouvreau / IFREMER (CC BY)

Flat oyster resilience: A year of experiments in the public eye at Océanopolis

Working in front of an audience to analyze flat oysters from an experiment performed at Océanolab, a research laboratory at the heart of the Océanopolis ocean discovery park in Brest. © Stéphane Lesbats / IFREMER. Océanolab by Océanopolis & UBO

Flat oysters are on the decline, but they're good at resisting the combined effects of ocean warming, acidification, and plastic pollution. That was the result found by MicroCO2sme, a joint project of IFREMER and the National Centre for Scientific Research (CNRS) that offered a special twist: At Océanolab, the public could come watch scientists in action. The new facility sits at the heart of the Océanopolis ocean discovery center in Brest, and has attracted more than 22,000 visitors.

Climate change, plastic pollution, and the deterioration of marine life pose threats to more than just coral reefs in far-off tropical waters. Biodiversity on the coasts of mainland France is also being affected. To learn more about how marine biodiversity responds to the combined effects of these pressures, IFREMER and the CNRS joined forces to conduct an experiment on flat oysters. Overfishing and disease have caused a sharp decline in the species, native to European coastal areas. Scientists spent a year testing the oysters to see how vulnerable they are when exposed to the kinds of environmental conditions that ecological predictions say could plausibly exist in the year 2100: higher temperatures (+2 °C compared to Bay of Brest average daily water temperature calculated over the period 1991-2020), acidification (0.3 pH unit decrease compared to current average daily pH in the Bay of Brest), and greater concentrations of microplastics (fifty times higher than current concentrations in the Bay of Brest). These variables were tested both separately and in combination inside twelve 300-liter tanks installed in Océanolab's experimental facilities.

After several months of exposure, initial results on mortality and growth had the flat oysters proving themselves highly resilient in the face of disruptions, despite effects on their reproduction and feeding habits. The oysters subjected to cumulatively stressful conditions (warmer water, acidification and exposure to plastics) spawned a full month earlier than those in the control group. Their feeding habits (filtration rate) also appeared to be negatively affected by the presence of plastics, which could have long-term consequences for their physiology. That effect was exacerbated with the addition of higher temperatures and ocean acidification. Such interactions highlight the importance of conducting impact studies that take into account environmental complexity and long-term effects. Further analysis will solidify and add to these initial observations, and help provide a more detailed assessment of metabolic effects.

Sharing the scientific process with the public

MicroCO2sme is the first research project to take place in Océanolab, a laboratory designed by Océanopolis and University of Western Brittany to share science with the general public "as it's happening." With this first-ever open-audience lab, scientists have a dedicated space to showcase their work in real time while engaging in dialogue with members of the public. It represents a whole new way to help people understand the process of scientific research and develop critical thinking skills.

MicroCO2sme project coordinators: Carole Di Poi, Ika Paul Pont and Arnaud Huvet, Marine Organism Ecophysiology and Life Cycle Traits unit, LEMAR joint research unit

Phenomer: Citizen monitoring of marine water discolorations goes national

IFREMER has reiterated its call for reports of marine water discolorations as part of citizen science program Phenomer. Citizen participation plays a crucial role in helping scientists identify the species that cause such events, and will eventually help limit potential impacts on marine biodiversity and human health. Now, in 2023, the program has expanded countrywide.

Seawater sometimes takes on an unusual appearance visible to the naked eye: shades of green, brown, red, or gold. These water discolorations and colored surface scums are often the result of a rapid, massive proliferation of microalgae. These algal blooms normally show up in spring, when sunlight and water temperatures are just right to encourage the organisms to grow. But in early February 2023, satellite imagery detected a slick of wine-red in South Brittany. Some of the microalgae responsible for that event then broke off and drifted toward the South Brittany coast, where green discolorations were observed and reported to IFREMER in mid-February. Never before have algal blooms occurred this early in the year. That particular bloom had no health effects—the species in question, *Mesodinium rubrum*, isn't toxic when consumed. But seasonal blooms of microalgae could have negative consequences for marine biodiversity as well as human health and activities, so it's crucial to study and monitor these organisms. And the blooms are becoming more and more unpredictable with climate change.

An appeal for citizen aid

IFREMER's citizen science program Phenomer lets the general public help keep an eye out for water discolorations. How? By encouraging individuals to locate seawater discolorations and report them on the program's website or app. Every reporter has to include a photo—and, ideally, take a water sample and get it to the nearest IFREMER site or relay structure as quickly as possible. (Relayers include water recreation centers, environmental education associations, oceanography professionals, harbormasters, boaters, and others.)

Phenomer began ten years ago on the coast of Brittany and Pays de la Loire. Today, with the creation of additional relay points, and the involvement of all IFREMER's coastal laboratories, it has expanded to cover the whole mainland France coastline. Fifty-two water discoloration phenomena were reported in 2023, bringing the total number of reports over the past decade to 409. The submitted samples are analyzed so that scientists can identify the species responsible for the bloom and set up research projects.

Phenomer project coordinator:
Anne Doner, Western Brittany Environment and Resources Laboratory, IFREMER

For more information (in French):
https:/www.phenomer.org/

IFREMER has expanded its Phenomer citizen science program. Participants nationwide can now monitor water discolorations that may be linked to harmful algal blooms.
Photo: Stéphane Lesbats / IFREMER (CC BY)

Experts from across the academic spectrum join together to advance Arctic research

The Arctic is a bellwether for world climate issues. Ocean physicist Camille Lique coordinates CLIMArcTIC, a multidisciplinary project deciphering the causes and consequences of climate change in this region.
Photo: Stéphane Lesbats / IFREMER (CC BY)

Camille Lique has been studying the far reaches of the Earth for fifteen years. She arrived at IFREMER in 2015 after completing doctoral and post-doctoral research on Arctic issues, and is now a researcher at the Laboratory for Ocean Physics and Satellite remote sensing. She launched CLIMArcTIC at the end of 2022. Now a massively interdisciplinary project takes center stage.

What makes the Arctic different from other parts of the world as an observation site?

It's the place that's experiencing the most striking changes, in terms of climate. Everything that happens up there is faster and more intense than in, for example, Antarctica. The numbers reflect that: Atmosphere and surface warming are happening four times more quickly than elsewhere, and half the sea ice has disappeared in the past forty years. It's estimated that the Arctic will experience its first ice-free summer within the next twenty years.

All of that information comes from previous research on the subject. How does CLIMArcTIC differ from what's already been done?

All of the models used in the latest report from the Intergovernmental Panel on Climate Change predict physical and biogeochemical upheavals. But none of those models agree on exactly how intense the changes will be or how quickly they'll happen. That hinders our ability to examine the effects of these changes on both a local and a global level. To understand the Arctic as a whole, we need to take a more regionalized approach. I'm thinking especially about water salinity, which tends to fluctuate so that it's higher in one spot and lower in another. CLIMArcTIC adds value by improving our ability to predict future changes and recognize how they'll impact an often mobile population.

How exactly will it provide these benefits?

ClIMArcTIC's primary goal is to bring together a wide variety of disciplines and get them to interact so that they can take inspiration from one another. That includes experts in applied mathematics, ocean and sea ice physicists, and biogeochemists and biologists who understand polar processes, but it also means specialists in humanities, social sciences, and even fields like law. The project is funded by the "Ocean and Climate" priority research program, directed by IFREMER and the National Centre for Scientific Research. This allows us to work toward that goal, because the six doctoral candidates and twelve postdocs we plan to hire will have their work overseen by two advisors from different fields. For my part, I'm working closely with some anthropologists, and we hope to eventually use the insights and models we produce to adapt our approach to local populations. Another innovation is that we're hoping to use artificial intelligence to come up with novel assay formats.

Another of CLIMArcTIC's priorities is to spread information and share expertise with as many people as possible. Tell us about that.

The project includes a pop-science outreach program with us at the forefront. As part of that, we're going to create an exhibit for Océanopolis, in Brest, as part of France's "Year of the Ocean" (2025). There will be a series of panels explaining the problems the Arctic is facing due to climate change. We'll also make use of virtual reality—users will be able to scan a QR code to see a scientist giving explanations. On top of that, ClIMArcTIC is sponsoring an edition of the Sea-Education summer school at the University of Western Brittany.. The course will help high school instructors turn information about polar issues into pedagogical content that they can teach in class.

The first few months of CLIMArcTIC focused heavily on administrative issues, recruitment, and discussions about how to proceed. If we spoke again six years from now, when the project is over, what sort of feedback would you hope to be able to give us?

What I want most is for us to achieve some real synergies. Beyond the findings the project will generate—of that, I have no doubt—I hope to be able to say that we managed to bring a broad community together to sit at the same table and talk to one another, and that we've ensured we're all moving in the same direction. If we can orchestrate all that, and make every individual involved feel like they're really a part of the project, I think we'll have accomplished what we set out to do.

Learn more at the CLIMAacTIC Project website:
https://climarctic.cnrs.fr/about/

CLIMArcTIC is funded as part of the "Ocean and Climate" priority research program, directed by IFREMER and the National Centre for Scientific Research for the benefit of the entire French scientific community.
The six-year program was launched in 2021. It has been certified by the UN Decade of Ocean Science for Sustainable Development, and forms part of the France 2030 investment plan, with a budget of €40 million. The program aims to structure France's research forces around seven major scientific challenges in order to better understand and protect the ocean. For more information (in French): https://www.ocean-climat.fr/Les-actions-et-projets/Les-projets-de-recherche/CLIMARCTIC

Extreme weather events: Better prediction through better description

During her dissertation work at the Laboratory for Ocean Physics and Satellite remote sensing, Coline Poppeschi sought to understand and describe extreme events in coastal areas, with the goal of defining new indicators that could make it easier to predict such events. Photo: Olivier Dugornay / IFREMER (CC BY)

“Toward an understanding of coastal environmental responses to extreme events in a context of climate change”: That was the subject of Coline Poppeschi’s dissertation, completed between 2020 and 2023 at IFREMER’s Laboratory for Ocean Physics and Satellite remote sensing. Now a researcher at France Energies Marines, she looks back at a piece of work that may go down in science history.

A topic that hits close to home, personally and professionally

Climate change provokes a lot of anxiety, but the better we understand it, the better we can tackle it. I'm an oceanographer by training, and I'm familiar with the kinds of extreme events (floods, heat waves, etc.) that have been happening more and more often all over our planet in recent years. It's a tangible subject that really speaks to me. It was important to me that my work deal with something that directly concerns us, and I based my work on high-frequency data that hadn't yet been utilized. No one had done anything like that yet, which was very exciting.

Key topics out in the field

Autonomous buoys float in the waters from the English Channel to the Atlantic Ocean and the Mediterranean Sea. Every twenty minutes, these buoys take measurements across more than a dozen different parameters. Salinity was the first one I took an interest in. Heavy precipitation causes extreme freshening—meaning the seawater gets less salty—because of the massive amounts of fresh water flowing from riverbeds into the ocean. That can cause changes in ocean currents, and some species don't always have enough time to migrate. I also studied water temperature, specifically marine heat waves and cold waves, which can have biological effects like causing coral bleaching or leading invasive species to appear in certain areas. In Baie de Seine we looked into the specifics of how storms stir up sediments in order to figure out the size and concentration of the resulting turbidity plume. And then in addition to all that, I wondered whether generally rising water temperatures could be causing algal blooms to occur earlier in the year. In short, my work covered all parts of the ocean—that was what made it interesting. I basically wrote a dissertation made up of a lot of mini-dissertations.

Inspired methodology...

I used an internationally recognized technique where you define thresholds above which an event qualifies as "extreme." Then my colleagues and I took major characteristics of each extreme event (duration, spatial extent, and intensity) and combined them into a single indicator. It was the first time anyone had done anything like that.

...and inspiring results

We determined that the marine heat waves aren't intensifying in the same way everywhere on the French coastline. For salinity, we saw that the extreme freshening is particularly surging off the coast of Brest. Turbidity is a more complicated topic to analyze, but it seems as if it's not so intrinsically linked to extreme events. And the phytoplankton variations observed in the Bay of Brest and the Vilaine estuary don't seem to show any particular patterns at the moment. Nevertheless, the blooms are a sign of major multi-year environmental changes across multiple parameters. But beyond identifying a rise in extreme events, my dissertation improved our ability to detect, understand, and describe these occurrences, so that later we can set up metrics that will let us predict and prepare for them. The foundation has been laid; now we need to push further, and give the scientific community what they need to build other projects. At least that's what they said at my dissertation defense, when they told me my work might end up changing the whole landscape.

Fiber optics, the latest trend in underwater seismic monitoring

Shane Murphy, a researcher at the Marine Hazards Laboratory, is developing a new technology to monitor underwater seismic activity using fiber-optic cables. Photo: Stéphane Lesbats / IFREMER (CC BY)

Development of submarine earthquake monitoring is lagging behind its terrestrial cousin, but major strides have been made since 2020. That momentum is evident with the launch of the first phase of FOCUS (Fiber Optic Cable Use for Seafloor studies), a European Research Council project coordinated by researcher Marc André Gutscher of the GéoOcéan* joint research unit at the National Centre for Scientific Research. Shane Murphy is a researcher at the Marine Hazards Laboratory (one of six labs in GéoOcéan). Here he takes a look at how the project opens up new possibilities.

FOCUS uses a technology originally developed for telecommunications to transform a single standard fiber-optic cable into multiple sensors. What is this project trying to accomplish? And how does the technology work?

With FOCUS, one of our main goals is to find out whether fiber-optic cables can help monitor dangerous submarine faults in a cheaper, more permanent way. Our test site sits off the coast of Catania, in Sicily, and it's crossed by the North Alfeo active submarine fault. There's a lot of seismic activity in the region, so it would be really useful to be able to better identify the potential dangers an earthquake could pose to the large surrounding population. Our technique uses an optical interrogator, which sends out a laser beam. Analyzing the backscatter (how much light returns back to the interrogator) provides information on the conditions the cable is being exposed to—temperature, strain, and speed of strain. In other words, we can measure vibrations (acoustic and seismic waves) as well as the displacement and temperature of the oceanic plate. Why is it groundbreaking? Because we only need to access one end of the cable to turn dozens of kilometers of fiber into an extremely sensitive multi-sensor instrument. This technology also has the advantage of working with standard telecommunication cables, meaning we can make use of infrastructure that's already in place. It's a little detail that's not so little at all—it's usually very expensive to set up scientific instruments at the bottom of the ocean for continuous monitoring.

The project's first cruise (FOCUS X1) aboard R/V *Pourquoi pas?* laid a six-kilometer cable at a depth of two kilometers. What were you aiming to do with FOCUS X2 in January 2022? And what about FOCUS X3?

All of these cruises are trying to calibrate the information we get from the FOCUS cable by deploying more conventional seismic monitoring systems in parallel. On the second cruise, we set up twenty ocean-bottom seismometers (OBS). We also retrieved no fewer than seventeen sediment cores and performed several microbathymetric surveys on the test site. On FOCUS X3, in February 2023, the OBS installed the previous year were collected and nine new ones were put in place. Two additional geodetic networks were also established, to mark the terrain with a set of reference points whose coordinates have been determined with a high degree of precision. Other cruises took place to gather the data from the geodetic stations, as well as to study the cable and place 25-kilogram sacks of sand and pellets on top of it to help it stay right where it's supposed to be in the seabed. The data gathered during FOCUS X3 is currently being analyzed. It should detect any earthquakes that have happened near the fault over the past few years. The plan for 2024 is to retrieve the OBS placed during FOCUS X3.

What insights has FOCUS offered so far?

We've detected daily and annual temperature changes in shallow waters on the order of one degree Celsius. At depths greater than 1.5 kilometers, we've been able to locate to within one meter the places where the FOCUS cable is experiencing strain from the sand and pellet sacks that have been laid on top of it by a remotely operated underwater vehicle. A huge number of different signals—earthquakes, passing ships, the Mount Etna eruption—have been observed along the full length of the fiber-optic cables, at distances of 50 to 100 kilometers. One memory that stands out is a November 2023 earthquake that the terrestrial stations didn't even register! It's a real game changer for oceanographers to have access to such critical data covering long time periods at super high spatial and temporal resolution. The data obtained through the fiber-optic cables will help us improve earthquake and tsunami alert systems and better understand the physics behind these catastrophic events. And FOCUS could absolutely be replicated to assess other active submarine faults, like the ones in the Sea of Marmara near Istanbul, or in subduction zones like the Japan Trench.

What's next for the project?

FOCUS will continue through October 2025. We'll keep working in the lab and in the field to use the measurements we gather to help us analyze results from the cable. A huge amount of data was collected in 2023, enough to constitute a "big data" project. Right now we're in the process of transferring that data to Datarmor, IFREMER's high-performance computing center, so that we can develop large-scale automatic data processing programs. In 2024 IFREMER will help launch three projects under Objective 10 ("The deep seabed") of the France 2030 program. All three will investigate how fiber optics can help us learn about the Earth system. That goes to show what we're aiming for, and how involved we are in developing the next generation of optical interrogators and new means of analyzing marine data. But it also shows how interest in fiber-optic detectors has skyrocketed among earth scientists in recent years. More generally, there's still a lot of work ahead of us. That will include improving our understanding of what we're measuring, as well as integrating the new data with the conventional measurements. This new approach is a great opportunity to bolster our knowledge and enhance our monitoring of the ocean and the marine environment.

* The GéoOcéan joint research unit is France's largest hub for marine geoscience studies. It pools expertise from IFREMER, University of Western Brittany, and University of Southern Brittany.

Ocean health assessments to enhance preservation efforts

Up and down the French coastline, IFREMER gives the marine environment a "check-up," monitoring marine ecosystems and the pressures affecting them. These evaluations inform public policy on the preservation and restoration of marine areas. The July 2023 assessment reviewed decades of monitoring by Institute scientists.

Chemical contamination, industrial and agricultural discharge, municipal waste, etc. Human activity puts enormous strain on marine habitats and species, causing them damage. Coastal environments are particularly vulnerable because they're home to so many kinds of activities (fishing, aquaculture, recreation) on top of having to deal with chemicals and waste flowing through rivers and streams from inland out to the sea. At the same time, coastal marine ecosystems play a crucial role in providing many species with the resources they need to feed, grow, and reproduce.

Shaping ecosystem preservation policy

IFREMER scientists collect data regularly over long periods of time to monitor and assess the health of the marine environment. At the local level, the Institute works with local water agencies; at the national and international level, its efforts are part of the EU's Water Framework Directive and Marine Strategy Framework Directive. IFREMER's insights and data are used by French government services to guide adoption of anti-pollution measures intended to conserve marine ecosystems or restore them to good health. Significant strides have been made: Enforcement of regulations governing the use of certain chemical contaminants has led to improvement in some areas of the marine environment over the past thirty years. However, newly identified pollutants are adding to existing stresses, with dire consequences for coastal areas. These new threats include persistent risk of algal blooms, strandings of green algae on beaches in northern Brittany, new contaminants, and ongoing pollution by marine litter (plastics) that has touched even submarine canyons.

In addition to running diagnostics on marine health, IFREMER scientists also conduct research to enhance tools and methods for monitoring and assessment, so as to better describe pressures and their impacts. All of these actions are helping to shape future policies.

To evaluate marine environmental health and inform public policy, IFREMER monitors ecosystem stressors (algal blooms, fishing, chemical contamination, marine litter, etc.). Photo: Olivier Dugornay / IFREMER (CC BY

IFREMER's first Blue Research Chair: Spotlight on the microbiome of the Pacific oyster

Microbiome has received little scrutiny until recently, but it's key to keeping organisms functioning and healthy, concludes research conducted by IFREMER's Blue Research Chair.
© Anthony Bertucci — IFREMER

Molecular biologist and ecotoxicologist Anthony Bertucci is IFREMER's first Blue Research Chair* in "Contaminants, Seas, and Health" at the Atlantic Center in Nantes. Since September 2022, he's been exploring the microbiome of the Pacific oyster and how it responds to contaminants in its environment. Six different IFREMER units participate in this major multi-disciplinary project.

Microbiome refers to the entire collection of microbes (bacteria, viruses, unicellular eukaryotes) that exists in symbiosis with all living organisms. If something upsets the balance of the microbiome, or prevents the microbiome from functioning properly, it's the host's life that could be endangered. Recent studies have revealed that the microbiome could be considered a whole separate organ within a creature's system. In humans, that organ would weigh about 200 grams, roughly the same as a kidney (120 grams) or heart (330 grams). Microbiome is also an impressive genetic reservoir, holding 100 times more bacterial genes than human genes.

Anthony Bertucci is IFREMER's first Blue Research Chair and leader of the "Contaminants, Seas, and Health" project. He studies microbiome to identify links between environmental contamination, ecosystem functioning, and the health of humans and other organisms. His work as Blue Research Chair has two goals: to augment existing projects at the Atlantic Center by adding a "contamination" dimension, and to create connections between labs to ensure greater visibility for their future projects. As part of PESTO, a French National Research Agency project coordinated by functional genomics researcher Rossana Sussarellu, IFREMER scientists studied the effects of a cocktail of pesticides on Pacific oyster larvae. Bertucci now wants to find out whether such exposure could alter microbiome in adult oysters. Another example: When the annual French Marine Chemical Observation and Monitoring Network cruise gathered its samples, Bertucci collected additional Pacific oysters from the same sites on the same days. Then he described the communities of microorganisms present in the oysters to try to determine whether there was any link to the types and amounts of detected pollutants.

Microbiome might be another way for contaminants to affect organisms and impact their health. But with its vast genetic reservoir, it could also enable speedy adaptation to environmental disturbances.

* The Blue Research Chair program was launched in May 2021 and is funded by IFREMER's exceptional science investment plan. Over a period of five years, the Blue Chairs will bolster interdisciplinary collaboration at the Institute by blending many different domains in pursuit of insights on innovative topics.

Bertucci A. 2023. Symbiotoxicity: The Ability of Environmental Stressors to Damage Healthy Microbiome Structure and Interactions with the Host. *Environmental Toxicology and Chemistry*, 42(5), 979. https://doi.org/10.1002/etc.5592

SURIMI, a sensor with big potential

Catherine Dreanno (researcher) and Morgan Tardivel (technician) of the Detection, Measurement, and Sensors Laboratory, are developing an optical sensor that uses ion-imprinted polymers to specifically identify which metals are present in water. Photo: Stéphane Lesbats / IFREMER (CC BY)

Metals are present in fresh water, oceans, and living organisms. Now IFREMER is measuring them in whole new ways with the SURIMI* project. In the spotlight: research directed by Catherine Dreanno, researcher at the Detection, Measurement, and Sensors Laboratory in IFREMER's Research and Technological Development unit.

Is the presence of metals always "anthropic"—linked to human activity—or are we talking about totally natural sources?

We have to be clear up front that for the most part, metals are naturally present in the environment and are essential to the life and functioning of aquatic systems. They're part of the global carbon cycle. However, when certain heavy metals like lead, cadmium, or nickel are present in the environment, that can be the result of anthropic pollution from, e.g., industrialization and urbanization. So the presence of metals doesn't inherently qualify as pollution. Why measure them, then? To gain insight into how ecosystems work, yes, but also to describe water quality, be it salt water, fresh water, or groundwater. The next generation of multiparameter optical sensors developed by SURIMI will be usable for environmental monitoring, and will be able to act as an autonomous alert system for anthropic pollution.

What makes your approach different?

To put it in concrete terms, the traditional approach to analyzing these metal traces involves repeatedly sampling the water and sending it off to a lab to be analyzed in ways that are very powerful, but very costly. And that strategy can only deliver results after the fact. Field tools designed to measure *in situ* will not only improve our descriptions of the chemical dynamics of water masses, but also enable rapid, appropriate management of pollution accidents. Our goal was to develop sensors that could measure in real time, without prior sample preparation, detecting and quantifying multiple metallic elements at the same time in a single analysis.

What is this project trying to accomplish?

First and foremost, we were trying to create polymer technology that could identify these metals specifically. The ion-imprinted polymers are the key to the chip and active surface of the Surface Plasmon Resonance Imaging sensor. They're what allow the device to capture metallic ions. The capture is detected and translated into a measurable signal that's proportional to the quantity of metals present in the water. The second goal was to develop a chip that was both robust and reproducible. The SURIMI sensor was successfully tested in lab conditions using multiple water types: fresh water, groundwater, coastal water, "transition" water (in between fresh water and salt water), and mineral water. All these waters have various physicochemical features: different levels of salt, particles, and organic matter, among other things.

What comes next?

We have proof of concept, and vast potential for diverse applications. It'll be a research and development project that we could offer to any number of interested parties. What comes next depends on the outcome of that process and whether or not financial backers take an interest. And before we get to that handoff, SURIMI has to be adapted to ocean conditions so it can be tested in the field—meaning harsher environments like the abyssal zone and polar seas. That step is necessary to demonstrate that the sensor offers definitively higher performance than traditional sensors and methods. We are, of course, keeping an eye out for potential development opportunities.

It seems as if collaboration was vital to making this project work.

Definitely! If you ask me, that's always a crucial aspect of any attempt at research and innovation. If we hadn't brought all the stakeholders to the table (see sidebar), each with their own specialty and expertise, then we wouldn't have been able to create the SURIMI prototype.

* SUrface plasmon Resonance for In situ Metallic Ions detection

Cao P., Pichon V., Dreanno C., Boukerma K., Delaunay N. 2023. Development of ion-imprinted polymers for the selective extraction of Cu(II) ions in environmental waters, *Talanta*, 256,124295. https://doi.org/10.1016/j.talanta.2023.124295

Working hand in hand

Ifremer joined a vast array of partners and research programs to help develop the SURIMI optical sensor for measuring metal content in water:

- Institut d'Optique (Université Paris-Saclay)
- École Supérieure de Physique et de Chimie Industrielles
- Bureau de Recherches Géologiques et Minières
- Laboratoire Nanotechnologies et Nanosystèmes, a bilateral research unit involving France's National Centre for Scientific Research and Canada's Université de Sherbrooke
- Université Laval's Takuvik program (Canada)
- Klearia, a Nice-based company specializing in microfluidics for analytic and synthetic chemistry

Two doctoral candidates also aligned their dissertation work with this project.

Sustainably manage marine resources for the well-being of human societies

An ocean of solutions

IFREMER conducts research, innovates and advises to propose sustainable solutions that will nourish, nurture, or produce energy and materials for the soon to be nine billion people on our planet, while preserving marine biodiversity and protecting marine ecosystems.

Fish catch in 2022: Results for mainland France and overseas

Sorting great scallops dredged in Saint-Brieuc Bay on the COSB 2022 cruise. Photo: Stéphane Lesbats / IFREMER (CC BY)

IFREMER reviewed the 2022 fish catch in mainland France and, for the first time, assessed its five overseas departments as well. About half of the catch volume on the mainland comes from sustainably harvested fish populations; not so in overseas France, where results varied wildly between departments. The new report underlines the need to continue sustainability efforts in the fishing industry.

Mainland France takes on the challenge of sustainable fishing

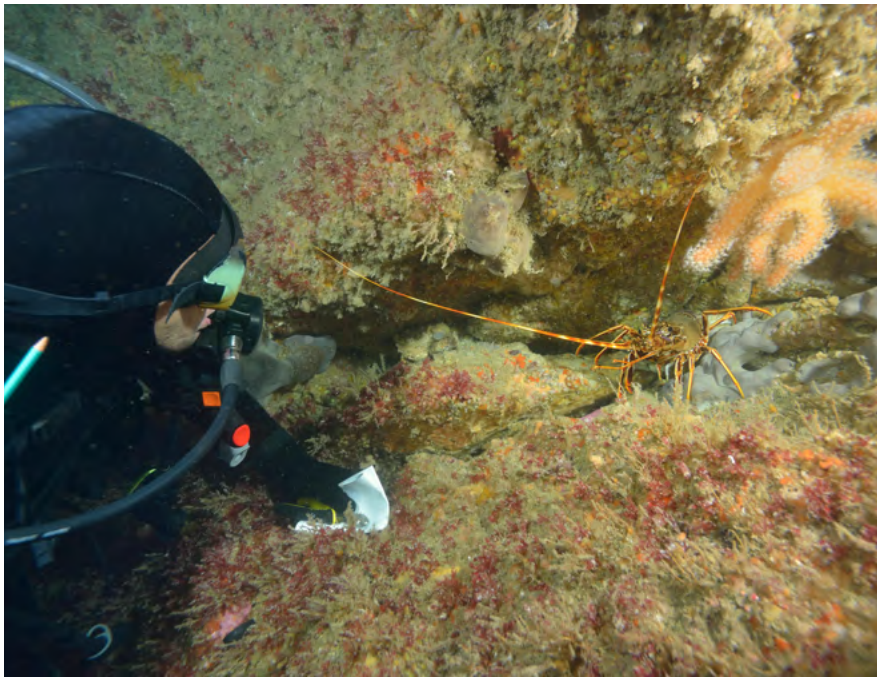
According to IFREMER's 2022 report, 51% of fish unloaded in mainland France in 2021 came from sustainably harvested fish populations, up from 48% in 2020. Nearly one quarter (23%) of the catch came from overfished populations, and 2% from fish populations deemed "collapsed." Harvested fish populations are in much better condition now than they were twenty years ago, but the 2022 report indicates that harvest volumes from fish populations in good condition have stagnated over the past five years. That means the goal of 100% sustainably harvested fish will be difficult to achieve in the near future. Nonetheless, IFREMER scientists are working hard to assess the condition of fish populations and investigate factors contributing to the current stagnation. That includes taking an "ecosystemic" approach to fishing, grounded in a thorough understanding of how populations interact with one another and with their environment. This approach also accounts for the impact of anthropic pressures and climate change on fish population dynamics.

Insufficient data on overseas France

IFREMER's first assessment of the five overseas departments indicates wide disparities. In 2021, the share of catch species considered to be "in good condition" was 51% in Réunion, 40% in French Guiana, 30% in Martinique, 20% in Guadeloupe, and 11% in Mayotte. The report was completed at the request of the French government, which expects to receive EU funding to modernize fishing fleets in these departments. However, the ecological status of a significant part of the fish populations remains unknown. That's because 43% of species in the catch, on average, still haven't been evaluated because not enough is known about them. More data is needed.

Access the assessment report (in French): https://www.ifremer.fr/fr/commentvontlespoissons2023

Studying fish and lobster movements with FISH INTEL



Common spiny lobsters stick close to their rocks in fall and winter, according to initial results from acoustic telemetry monitoring of fifty males on the English Channel. Photo: Olivier Dugornay / IFREMER (CC BY)

FISH INTEL was set up to track fish and lobsters in the English Channel using acoustic telemetry. Now, the EU-funded project has shared its initial results: Male lobsters are more sedentary, while European seabass are travelers. This valuable information will help scientists identify critical habitats for catch species and design more sustainable harvesting practices in the English Channel.

FISH INTEL (2021–2023) was an EU joint project featuring teams from France, Belgium, and the United Kingdom. They used acoustic telemetry to track five commercially important marine species in the English Channel: European seabass, European pollock, common spiny lobsters, bluefin tuna, and black seabream. French teams focused on the European seabass, European pollock, and common spiny lobsters, while their counterparts in Belgium and the UK tracked the bluefin tuna and black seabream. Between May and September 2022, French scientists worked with fishermen and fisheries committees to fit fish and lobsters with acoustic-trackers that emitted sound waves whenever they passed near one of the receivers set up by IFREMER and France Energies Marine. The receivers were located along France's Channel coastline, including zones marked for future wind farm development (Saint-Brieuc, Courseulles-sur-Mer, and Saint-Nazaire). With the data from the trackers, scientists were able to reconstruct some movements. The seabass, for example, would wander hundreds of kilometers along the French coast. Full results aren't in yet, but what's been revealed so far confirms the hypothesis IFREMER formed during previous geolocation experiments: Seabass from the eastern Channel migrate west to reproduce, while seabass from northern Brittany migrate to the Bay of Biscay. Meanwhile, pollock seem to be fairly sedentary, as are spiny lobsters (especially the males).

FISH INTEL has wrapped up, but acoustic tracking of Channel species will continue for years to come, providing richer insight into the spatial ecology of these creatures. That information will improve ecosystemic management of harvested species and help marine space planners in the English Channel create balance between human activities and ecosystem health concerns.

This project received funding from the European Regional Development Fund via the Interreg France (Channel) England Program.

IFREMER FISH INTEL project lead: Mathieu Woillez, Fisheries Biology Laboratory, DECOD joint research unit
Check out the project website, run by the University of Plymouth: https://www.plymouth.ac.uk/research/marine-conservation-research-group/fish-intel-interreg

IFREMER oyster farming expertise hailed by global science community in Australia

In late May 2023, scientists from IFREMER's Marine Resources unit in French Polynesia participated in two international events in Darwin, Australia: The World Aquaculture Conference and the International Tropical Rock Oyster Workshop. IFREMER's Pacific Center experts had the chance to present their pioneering research on rock oysters, currently ongoing in Vairao.

Scientists from IFREMER's Pacific Center spent two days presenting on development strategies in rock oysters (Saccostrea *cucullata* and *Saccostrea echinata*) and the future of sustainable aquaculture in French Polynesia for these species. They demonstrated a thorough grasp of the rock oyster development cycle, from broodstock conditioning to culture of larvae to the pre-growing phase.

To alleviate infestations of parasitic *Polydora* worms disturbing the oysters' growth phase, the team set up a system of exposure tables to bring the oysters out of the water on a regular basis. The system was developed in partnership with Ostrea Tahiti and Occitanie company Medithau. Recent years have seen striking results, with an 85% success rate and 90% attachment rate in one cycle. Outcomes like this have made IFREMER a world leader in oyster farming.

Greater visibility

IFREMER's visit to Darwin presented a unique opportunity to raise awareness of the Institute's research efforts, as well as to meet with international partners like Australia's Darwin Aquaculture Center, James Cook University, and University of the Sunshine Coast, and New Zealand's Cawthron Institute. It also provided a chance for discussions with experts from other South Pacific countries like Fiji and New Caledonia.

"Presenting our projects at a global event like the World Aquaculture Conference is crucial for getting our work recognized, spreading awareness of our research, and raising the profile of the Institute," explains Manaarii Sham Koua, a livestock agriculture technician with the rock oyster hatchery at the IFREMER Pacific Center.

Members of the Marine Resources unit in French Polynesia at the World Aquaculture Conference: Guillaume Mitta, unit chief; Manaarii Sham Koua, livestock agriculture technician; Cristian Monaco, ecophysiology researcher

Manaarii Sham Koua at the IFREMER Pacific Center rock oyster hatchery.
© Heivini Le Gléau / IFREMER

Fifteen years of commitment under the Marine Strategy Framework Directive

IFREMER's contribution to the national implementation of the Marine Strategy Framework Directive has led to major scientific progress in the monitoring and understanding of the marine environment. Photo: Olivier Dugornay / IFREMER (CC BY)

For more than fifteen years, IFREMER has been working with the ministry in charge of the environment and the French Biodiversity Agency (OFB) to implement both the environmental and socioeconomic elements of the Marine Strategy Framework Directive (MSFD) in France. Major scientific progress has been made in the monitoring and understanding of the marine environment.

The MSFD, adopted in 2008, aims to maintain or restore good functioning for marine ecosystems while preserving future generations' ability to make use of the ocean. From the beginning, IFREMER has been collaborating with the OFB to support the ministry in charge of the environment as it implements the directive. Indeed, IFREMER is the lead coordinator on the specific theme of pressures affecting the marine environment, their impact, and the status of biodiversity. Ten scientific and technical organizations are working on this theme in France. Furthermore, IFREMER was the evaluator or co-evaluator for half of the topics under this theme: benthic habitats, fish, cephalopods, commercially exploited species, eutrophication, contaminants, and marine litter. Alongside the University of Western Brittany, IFREMER was the co-evaluator of the socioeconomic analysis element.

This directive, which is meant to take an ecosystemic approach, involved IFREMER teams from a variety of departments: Oceanography and Ecosystem Dynamics, Biological Resources and Environment, and Research Infrastructures and Information Systems.

IFREMER's investment over many years has enabled major scientific progress in the monitoring and understanding of the marine environment: data acquisition at sea; improvement of monitoring networks; more exhaustive quantitative evaluation (more habitats, more species); and development of new indicators, methods for integrating data, and proposals for evaluation. Considerable efforts were undertaken to harmonize similar directives' efforts (the Maritime Spatial Planning Directive; Water Framework Directive; Fauna, Flora and Habitats Directive; Common Fisheries Policy; etc.) and regional sea conventions, for both elements of the MSFD.

In 2024, the coordination and implementation of the environmental element of the directive will be handed over to the OFB. IFREMER will remain in charge of the socioeconomic theme.

The MSFD by the numbers

- Ecological assessment of the environment on **4** metropolitan French seafronts
- Nearly **10** scientific and technical organizations involved
- Almost **20** IFREMER scientists working on scientific leadership, evaluations, and coordination of monitoring activities
- Close to **70** environmental indicators calculated, all themes included
- **130** social and economic analysis reporting sheets created
- **60** themed environmental summaries produced

National coordination for IFREMER: Lucile Delmas, Information Valuation Service for Integrated Management and Monitoring

What if genetics could halt the spread of nodavirosis in European sea bass farms?

After years of research on nodavirosis, a viral disease that affects offshore European sea bass farms, scientists at IFREMER and the National Research Institute for Agriculture, Food and the Environment (INRAE) have discovered two genes involved in better resistance to viral infection. These advancements mark an important step forward for European sea bass farming in the Mediterranean, and even beyond.

Nodavirosis is the most widespread disease in offshore European sea bass farms. It is typically found in the Mediterranean, particularly in Greece, Italy, and Turkey, which host the largest sea bass farms in Europe. By replicating within the infected organism, the virus causes brain damage, which changes swimming behavior and usually leads to lethal cerebral hemorrhage. Naturally, this is extremely destructive to sea bass farms.

Since 2013, IFREMER and INRAE scientists have been working to understand why some sea bass resist the disease better than others. In collaboration with the National Agency for Food, Environmental and Occupational Health and Safety, the French Poultry and Aquaculture Breeders Technical Center, and commercial sea bass hatcheries, they combed through the genomes of 7,000 sea bass to find the difference that might explain better resistance. After several years of research, they identified two key genes that could reduce virus replication in sea bass: ZDHHC14 and IFI6.

Survival rates for populations exposed to the virus varied as follows: 80% for sea bass populations that were "double-resistant" (homozygous carriers of two "resistant" alleles); 60% for heterozygous sea bass populations carrying one "resistant" allele and one "vulnerable" allele; and 40% for "double-vulnerable" populations.

After their findings were published in the journal *Genetics Selection Evolution*, the scientists and French sea bass hatchery professionals continued their research in the hope of using these marker genes to identify more resistant individuals and contribute to more sustainable aquaculture. The stakes are high—though the virus is currently limited to the warm waters of the Mediterranean Sea, it could spread across European coasts as climate warming progresses.

These results were obtained as part of the GeneSea and MedMax projects, which were supported by the European Maritime and Fisheries Fund.
Coordination for IFREMER: François Allal, Animals and Systems Adaptation and Adaptability Laboratory, MARBEC joint research unit

Delpuech, E., Vandeputte, M., Morvezen, R. et al. 2023. Whole-genome sequencing identifies interferon-induced protein IFI6/IFI27-like as a strong candidate gene for VNN resistance in European sea bass. *Genetics Selection Evolution*, 55, 30. https://doi.org/10.1186/s12711-023-00805-2

Each year, the Mediterranean produces around 200,000 tons of sea bass from fish farms like this one for sea bass and sea bream in Greece.
© Tsuguliev / Shutterstock.com

LIFEDEEPER: Measuring the impacts of potential seabed uses

Many projects have been conducted over the years to better understand deep-sea ecosystems. LIFEDEEPER goes a step further with a new approach that combines experimental, social, and political sciences. Its goal is to measure the potential ecosystemic impacts of mining operations performed on the seabed.

Manganese, iron, copper, nickel, cobalt, lead, zinc, molybdenum, lithium, titanium, niobium, silver, gold … All can be found in highly concentrated pockets dotted along the ocean floor. Land-based mineral deposits are becoming less and less profitable to exploit, so these marine resources hold tantalizing potential given the needs of the Earth's growing population. But what would be the consequences of exploiting seafloor resources? To protect ecosystems and ensure the sustainable protection and management of these resources, we must improve scientific knowledge of the deep sea.

Greater familiarity with the seabed for enhanced protection

From 2022 until 2028, IFREMER is piloting the LIFEDEEPER project (LIving together in the Future: vulnErability of DEEP-sea Ecosystems facing potential mineral Resources exploitation), funded by the "Ocean and Climate" priority research program. LIFEDEEPER seeks to propose a strategy for preserving resources near hydrothermal vents, whose environments are poorly known and potentially threatened by future mining operations. The project shares similarities with previous efforts by IFREMER to describe and understand deep-sea ecosystems.

LIFEDEEPER is being conducted in a specific area of the Mid-Atlantic Ridge 3,600 meters underwater. The TAG and Snake Pit hydrothermal fields are at this level, 300 kilometers away. With a multidisciplinary team of scientists, IFREMER is aiming to understand the geological, geochemical, and biological functioning of the ecosystems in this area. This knowledge would make it possible to obtain new markers or determinants to track in order to verify the environment's good environmental status and, eventually, propose solutions for the sustainable management and protection of the deep seabed.

Going beyond scientific data

LIFEDEEPER includes legal, political and sociological analyses of potential exploitation of these mineral resources in the seabed. The project also includes an outreach element to showcase the scientific results and raise awareness among the public (academics, students, citizens, decisionmakers) through educational actions, participatory science, and artistic projects.

LIFEDEEPER project coordinator: Marie-Anne Cambon, Microbiology of Extreme Environments Laboratory, IFREMER

LIFEDEEPER is funded as part of the "Ocean and Climate" priority research program, directed by IFREMER and the National Centre for Scientific Research for the benefit of the entire French scientific community. The six-year program was launched in 2021. It has been certified by the UN Decade of Ocean Science for Sustainable Development, and forms part of the France 2030 investment plan, with a budget of €40 million. The program aims to structure France's research forces around seven major scientific challenges in order to better understand and protect the ocean. For more information: https://lifedeeper.ifremer.fr/

The seafloor isn't just rich in mineral resources —it is also the largest habitat in the world. To protect and manage the deep seabed sustainably, it is essential to improve our knowledge of its ecosystems. © IFREMER

IFREMER keeps an eye on seafloor mineral resources for the French government

Sébastien Ybert, France 2030 coordinator for deep-sea studies in the Physical Resources and Deep-Sea Ecosystems department at IFREMER. Photo: Stéphane Lesbats / IFREMER (CC BY)

Twice a year, IFREMER sends the French government a watchdog report on mineral resources in the deep seabed. The report covers not only the scientific point of view, but also all news relevant to this topic, including the latest work done by different actors in the field and updates to the constantly changing regulatory environment. As the France 2030 coordinator for deep-sea studies in the Physical Resources and Deep-sea Ecosystems department at IFREMER, Sébastien Ybert explains the importance of this report and its context.

What kinds of mineral resources can be found at the bottom of the ocean?

There are three kinds. First, there are polymetallic nodules formed by the accumulation of mineral precipitations around a piece of debris such as a pebble. They can be as small as new potatoes or as large as tennis balls. Composed of manganese, copper, cobalt and nickel, these nodules can be found in the abyssal plains, rather far from coasts. Another type of resource is polymetallic sulfides. These are found in more tumultuous areas such as mid-ocean ridges, where the oceanic crust is created. These deposits form when seawater permeates rocks and becomes enriched with minerals, heats up, and rises to the surface of the oceanic crust in plumes that precipitate in the form of chimneys. Polymetallic sulfides may be made of copper, zinc, and sometimes silver and gold. The third type of resource is cobalt-rich deposits or crusts. These deposits, which are commonly found in the Pacific, are created in a similar way to polymetallic nodules but are located atop seamounts. Crusts as thick as twenty centimeters form here on the rocky substrate. Besides cobalt, they may contain manganese, copper, nickel, and elements from the platinum group.

Aside from knowing how these resources form, why is it important for the government to be informed about this subject?

The time is now for energy transition technology, which is intensifying interest in certain metals. Terrestrial mining is getting more complicated for some of them (environmental and societal consequences, diminishing yields, etc.) and industry actors want to move into offshore exploitation to continue to meet growing needs. The European Academy of Sciences does not see the same urgency in the situation, predicting an increase in the quantities consumed along with technological progress and better recycling, while also pointing out that deep-sea mining can destroy fragile, unexplored ecosystems whose role in environmental cycles is not yet understood. There are geopolitical stakes as well; each country's position varies. Our work as a watchdog does not entail giving our own point of view, but instead surveying the latest information and knowledge available and communicating it to the Ministry for the Ecological Transition.

Over the last three decades, we've seen an increase in the number of contractors with the International Seabed Authority who have received the green light to conduct exploration missions in various parts of the world's seas. IFREMER is one of them. These missions must help scientists characterize certain underwater zones. How else do they feed into your reports?

The exploratory activities led by IFREMER, other contractors and other scientists working in the same environments improve our knowledge and understanding of geoscientific phenomena and other environmental matters. For example, we have learned how hydrothermal vents contribute to metal cycles, and we know more about the role of deep-sea ecosystems in the carbon cycle. These missions and research give fodder for scientific publications, press releases, and other media that we collect using tools from the La Pérouse library. Since 2015, we have produced a report on the state of affairs of mineral resources every six months for the Water and Biodiversity division of the Ministry for the Ecological Transition, which then sends the reports to other ministries (Foreign Affairs, Overseas France, the General Secretariat for the Sea) and public and private actors such as the Bureau de Recherches Géologiques et Minières (BRGM, the French geological survey) and the French Maritime Cluster. The purpose is clear: to provide a summary of the public information available on the sector, especially related to scientific activities, countries' exploration missions, interest in resource exploitation, and changes in the regulatory environment. Our simple report, both quantitative and qualitative, mentions recent scientific publications too. One thing we have noticed is that the subject of seabed mining in international waters—which is prohibited—has been coming up more and more. The economic aspects of mineral resources do not fall within our scope and are covered broadly by the BRGM. Our biannual report focuses on the marine environment.

Who collects and analyzes the information?

These reports are produced entirely in-house at IFREMER by a skilled team of five people: a librarian from the Scientific and Technical Information department at the La Pérouse library, a member of the European and International Affairs division, a lead researcher who handles everything to do with science and environment, and a geologist-engineer who takes care of geoscience topics and with whom we also share work related to exploration and exploitation. This last person collaborates with me on the coordination of our monitoring efforts too. Regulatory matters fall under my scope. Depending on the report, we might add other specialists to this core team.

DIKWE, a breakwater that transforms wave energy into electricity

DIKWE will be the first electricity-producing breakwater. It uses wave energy. Prototype tested in the Bay of Brest. Photo: Olivier Dugornay / IFREMER (CC BY)

After several successful test phases, the first breakwater that produces renewable energy from waves should be installed along French coasts in 2025. Initiated in 2020 by Legendre Group, this R&D project represents a collaborative effort with GEPS Techno and IFREMER, which conducted tests in tanks and then at sea.

Protecting ports and coasts while producing energy from waves, a renewable marine resource: This is the DIKWE project. It was launched in 2020 by Legendre Group in partnership with GEPS Techno, which created the prototype with support from IFREMER scientists. DIKWE will be the first "positive-energy breakwater" in the world. It is based on a tidal power system with oscillating flaps and can turn wave energy into sustainable, locally produced electricity. And it can do all this while fulfilling the main function of a breakwater: protecting the coast.

From digital simulation to prototype

After an initial digital model was created by GEPS Techno, a 1/15 scale model of DIKWE was tested in 2021 in IFREMER's wave tank in Brest. Then a 1/4 scale prototype was placed in the sea in March 2022 at IFREMER's test site in Sainte-Anne du Portzic, near Brest. During these tests in real-life conditions, the prototype could be evaluated in all kinds of sea conditions, including strong waves. The results were promising for the prototype's structural integrity and its energy yield. In fact, DIKWE has an average yield of 40% "from wave to electron" in favorable conditions, which is very good for a wave energy system.

These results confirmed those obtained during the tank tests and supported the continuation of the project through its final phase of research and development starting in 2023. A full-size demonstration version could be installed in 2025 at a yet-to-be-named site along the French coast. The technical studies and construction of the breakwater, which started in 2023, will continue in 2024. These studies are bolstered by measurements and models of wave fields in coastal areas, which are key data for the project's success.

Project lead for IFREMER: Marc Le Boulluec, Marine Hydrodynamics Laboratory
Project lead for Legendre Group: Quentin Henry
Chairman of GEPS Techno: Jean-Luc Longeroche

INSTITUT CARNOT MERS

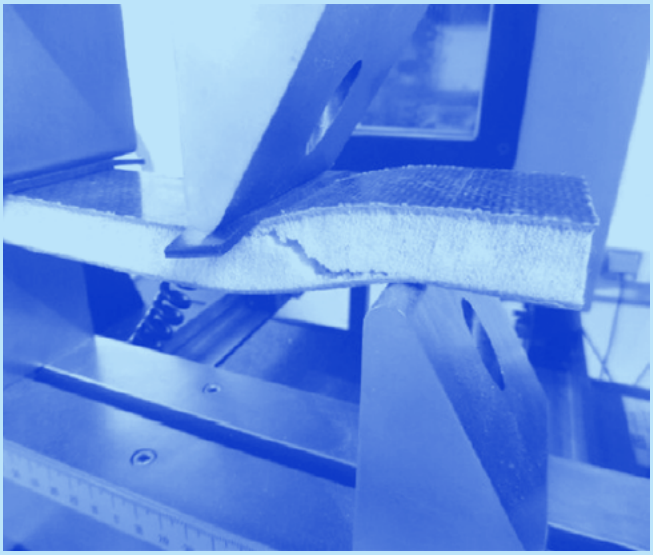
Innovations for successful transitions

Making electricity from waves

Since October 2023, the start-up Seaturns has been testing a prototype wave energy device in partnership with IFREMER at IFREMER's Sainte-Anne du Portzic test site. For ten months, the Seaturns and IFREMER teams have been observing the prototype's behavior in order to determine its potential in real-world conditions. Other tests will be necessary before deploying multi-float clusters of this new technology at a grander scale. Sales of these very low-carbon electricity production units should begin in 2025.
The prototype has received funding from the French government's France 2030 plan and from the European Union's France Relance plan. It was designed as part of the IAS-WEC project, which won the French government's innovation competition, i-Nov, in July 2023.

Project lead for IFREMER: Martin Träsch,
Marine Hydrodynamics Laboratory
CEO and founder of Seaturns: Vincent Tournerie

Ten-month test in the Bay of Brest of the prototype of a new tidal energy system designed by the start-up Seaturns (Bordeaux).
Photo: Olivier Dugornay / IFREMER (CC BY)



More environmentally friendly racing boats

Can racing boat hulls be made with more environmentally friendly materials? Innovation Laboratory MerConcept, founded by skipper François Gabart, is betting on it. The lab reached out to IFREMER to assess the resistance of two innovative composite materials (recycled foam combined with linen or bamboo fibers) compared to the typical fiberglass and PVC foam. IFREMER made some testing equipment available so the lab could determine the amount of physical shock it took to damage or break the materials. The initial results have been very encouraging. The linen composite is sufficiently resistant, barely heavier, and capable of reducing CO_2 equivalents by 20–25%!

Project lead for IFREMER: Peter Davies, Advanced Materials Structures and Hyperbaric Stress Laboratory

Evaluation of the resistance of innovative composite materials for boat hulls. Stress test of a composite material based on bamboo fibers.
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Using artificial intelligence to optimize wayfinding at sea

Cargo ship in a storm in the Mediterranean.
Photo: Olivier Dugornay / IFREMER (CC BY)

The start-up Marine Weather Intelligence (MWI) won the 2023 edition of IFREMER's Octo'pousse innovation competition. Using artificial intelligence, it aims to create a better wave prediction model that makes navigation both safer and less energy-intensive.

To find the best route at sea, a ship's crew uses weather forecasts produced by models that ingest an enormous amount of data on atmospheric and oceanic conditions: wind, currents, waves, etc. However, the parameters characterizing waves (force, height, direction, period) generally attract less interest because they have no climate impact. On the other hand, sea conditions do have consequences for a ship's speed, trajectory, and fuel consumption. Sea swell is also important to account for to ensure that rescue operations at sea and maintenance on submerged equipment can be performed safely. MWI—founded by Christian Dumard, a legendary navigator in high seas racing—is taking up this challenge.

Optimizing routing calculations with artificial intelligence

To do so, the young start-up can count on scientific support from IFREMER, which picked it as the winner of the third edition of the Octo'pousse innovation competition. MWI relies on artificial intelligence to automate routing calculations for pleasure boats and maritime transport and therefore to reduce the uncertainty of the predicted conditions. Not only does this lucky winner receive a budget of about €250,000 over eighteen months to bring their project to life, but they also benefit from IFREMER's experience modeling atmospheric physics and wave physics, key elements of weather-based wayfinding.

A data scientist has joined IFREMER's teams in Brest for eighteen months to examine and select the data that will feed into the predictive models.

Once the training phase is over, the finalized model will be able to quickly produce predictions of sea conditions. Later, the tool created by MWI will take the form of an online platform that navigators can use to check weather information and route recommendations in real time. They will also be able to adapt their speed to current sea conditions and thus reduce their fuel consumption, all while ensuring safer navigation.

Project leads for IFREMER:
Nicolas Raillard (Marine Hydrodynamics Laboratory) and Mickaël Accensi (Space and Air-Sea Interfaces Laboratory)
Co-founders of Marine Weather Intelligence:
Christian Dumard and Basile Rochut

Marine bacteria: A promising solution for improving the quality and safety of seafood products

Spraying marine bacteria strains onto smoked salmon prevents the pathogen *Listeria monocytogenes* from developing while limiting the food's organoleptic degradation (appearance, taste, smell, texture). Photo: Françoise Leroi / IFREMER (CC BY)

Scientists from IFREMER's MASAE unit (Microbiology, Food, Health, Environment) are studying salmon microbiota to understand their effects on the quality and safety of salmon food products.

Due to the composition of their flesh and the absence of additives and heat-based decontamination treatments, semi-preserved seafood products such as smoked salmon are very vulnerable to microbial development. When they leave the processing facility, these products contain microbes influenced by the fish's microbiome and the ambient microbiome of each facility. Preservation at refrigerator temperatures allows some bacteria, including those harmful to humans (mainly *Listeria monocytogenes*), to multiply. Their growth depends on abiotic factors such as salt level, smoking, pH, and preservation temperature, but also on interactions between different species of bacteria. This bacterial development can impact the enjoyment and safety of these foods.

By adding marine bacteria strains selected for their antimicrobial properties (biopreservation), the Microbial Ecosystems and Marine Molecules for Biotechnologies Laboratory (laboratory head: Françoise Leroi; MASAE unit) is attempting to understand and control the microbiome of semi-preserved seafood products. Thanks to EU H2020 project MASTER (Microbiome Applications for Sustainable food systems through novel TEchnologies and EnterRprise, 2019–2023), encouraging results have been found.* Three strains of lactic acid bacteria (property of IFREMER/Oniris) that have been studied in laboratories for a long time were tested. Produced and freeze-dried by an industry manufacturer, one strain has had very good results against *Listeria* in slices of smoked salmon while limiting the development of bacteria that change and degrade the food's organoleptic qualities (appearance, taste, smell, texture). This work has pushed biopreservation technology to a new level for smoked salmon, and the strain has been licensed to the manufacturer that co-financed the research.

The secondary objective was to explore the probiotic potential of marine bacteria in salmon farming and induced biopreservation. The probiotic activity of one bacterial strain was confirmed in vivo with juvenile salmonids (Arctic char), showing an improvement in growth. Furthermore, bathing the fish in water containing the experimental strain just before slaughter showed that the bacteria naturally spread throughout the flesh of the filets and prevented the development of the pathogen *Listeria monocytogenes*. This opens up new possibilities for IFREMER's bioprotective bacterial strains, which have so far mainly been used for processed products. Research will continue as part of new EU projects on biopreservation.

* Begrem S., Ivaniuk F., Gigout-Chevalier F., Kolypczuk K., Bonnetot B., Leroi F., Grovel O., Delbarre-Ladrat D., Passerini D. 2020. *Microorganisms*, 8(7), 1093. https://doi.org/10.3390/microorganisms8071093

Jérôme M., Passerini D., Chevalier F., Marchand L., Leroi F. and Macé S. 2022., *International Journal of Food Microbiology*, 363, 109504. https://doi.org/10.1016/j.ijfoodmicro.2021.109504

Knobloch S., Skírnisdóttir S., Dubois M., Kolypczuk L., Leroi F., Leeper A., Passerini D. and Thór Marteinsson V. 2022., *Frontiers in Microbiology*, 13, 912473 (14p.). https://doi.org/10.3389/fmicb.2022.912473

New cancer-fighting molecules from marine bacteria

Sylvia Colliec-Jouault, a researcher at the Microbial Ecosystems and Marine Molecules for Biotechnology Laboratory, aims to use molecules from marine bacteria for cancer-fighting treatments. Photo: Faustine Verger / IFREMER (CC BY)

Codename: MAPACA, for MArine PolysAccharides and CAncer. Conducted in close collaboration with Ouest Valorisation, a SATT (company accelerating technology transfer), this project, which represents the culmination of years of research, is a shining example of the healing properties of the ocean's resources. Sylvia Colliec-Jouault, a researcher at the Microbial Ecosystems and Marine Molecules for Biotechnology Laboratory at IFREMER, told us about her hopes for the future of this work.

In April 2020, Ouest Valorisation's investment committee announced a cofinancing agreement for a program using marine polysaccharides—polymers from the carbohydrate family—to fight cancer. What steps took place before this announcement?

The origins of MAPACA go back around twenty years to the beginning of a collaboration with Dominique Heymann, a professor at Nantes Université. Thanks to dissertations, research, oceanographic expeditions, experiments, and more, we discovered that deep-sea areas harbored bacteria that could produce polysaccharide derivatives that resemble the ones found in human tissues and that are beneficial for restoring cellular function. These molecules are very desirable in fields as varied as cosmetics, agriculture and food, and health. In 2015, we were able to apply for a patent and then decide to study these molecules' potential in even greater detail with the SATT Ouest Valorisation.

And your goal is to see whether these molecules can help combat several different types of cancer?

Yes, that was the idea. When the first tests for MAPACA were performed in September 2021, we wanted to verify the effect that several derivatives had on cancer cells of different origins *in vitro*. From 2022 onward, we were able to show that some of our products inhibited the proliferation of osteosarcoma cells (malignant bone tumors found in teenagers and young adults). The year 2023 marked the beginning of our first *in vivo* studies, on mice. Here again, the results were positive. The compounds worked as well as doxorubicin, a medicine used in chemotherapy, and reduced the growth of other cancerous tumors (such as lung cancer) in mice. We submitted another patent application. Beyond these specific advancements, the results show why IFREMER's work is so valuable. Its oceanographic cruises have featured bacteria sampling in the deep sea for around thirty years, which means that the institute has been able to build up a library of strains that is nearly unique in the world. And there are fermenters, reactors, and so on—the team has excellent equipment not only for cultivating bacteria, but also for producing, isolating, and characterizing polysaccharides, and modifying these compounds through depolymerization and resulfation for oncology activities. It's a real advantage for us to know how to manipulate marine bacteria to produce biotechnological molecules in a controlled environment.

This pre-clinical approach marks the end of MAPACA. What's next?

What's next will depend on what investors are willing to put on the table in order to move our work into clinical trials. We need a few million euros to prepare for that. The SATT does currently have the ability to contact structures that might be interested in the patents that we have filed. There's still a lot to do, but you have to have faith. We have faith.

During your career as a researcher, you filed fourteen patents, mostly related to cellular repair. What makes MAPACA different from the others?

We need to give this molecule a chance. It's unbelievable that this research could help heal sick people, if we took advantage of the results! And there might be no side effects to this molecule that repairs tissues that chemotherapy destroys. We don't consider molecules of marine origin often enough when making medications. This one may help in cancer treatment, so imagine what others could do!

Create and share a digital ocean

An ocean of data and services

As in all fields, the digital transition is the key to continued success for maritime activities as well as our professional practices. Managing growing volumes of data and turning them into services for businesses, the scientific community, and the general population has become a crucial step in sharing knowledge about the ocean and promoting environmentally friendly economic growth. These masses of available data also feed into models that test hypotheses, recreate the past, and imagine the future.

Datarmor, a lightning-fast supercomputer dedicated to marine science

The Datarmor supercomputer (IFREMER: Plouzané, Finistère), which is freely accessible, provides researchers with high-performance computing and ocean observation data collected everywhere from the deep sea to space. Photo: Olivier Dugornay / IFREMER (CC BY)

Given the ever-increasing amount of scientific data on the ocean, IFREMER is modernizing the infrastructures of its supercomputer Datarmor, which is hosted at IFREMER's Brittany center in Plouzané. It is the only data center in France fully dedicated to the ocean, and its storage capacity will be multiplied sixfold without a change in energy consumption.

Since 2017, IFREMER has opened up the use of its supercomputer Datarmor to the French oceanographic community so scientists can better gather, store, and analyze huge volumes of data on the ocean. Valuable information is collected every day about the ocean, in different forms and from different sources: observations by satellite, seafloor mapping by research vessels, and data from instrumented buoys and floats.

426 teraflops of computing power for Datarmor

Datarmor currently has 426 teraflops of computing power (the equivalent of 3,000 personal computers), ten petabytes of storage (ten million gigabytes), and four supercomputers dedicated to using artificial intelligence. Its incredible computing and storage power can be used free of charge, enabling researchers to perform very complex calculations and make advanced digital simulations to better study the ocean and climate change. To help them make the most out of Datarmor's capacities, researchers are supported by a special group of engineers from IFREMER's computing hub. This group serves as an intermediary for the major national research centers.

Greater performance and resilience

As technologies progress, scientific data from measurement tools and digital simulations becomes more precise—but it also demands more computing time and storage space. To keep apace with evolving technical capacities, IFREMER began to modernize Datarmor's infrastructures in 2023. The platform has new high-capacity, high-efficiency storage solutions that will multiply its storage capacity sixfold without increasing its energy use.

Datarmor fits neatly into the European and national strategies for scientific data analysis and adds to the Brittany region's contributions to science. Its modernization program is funded by the French government and the Brittany region under the 2021–2027 State-Region Contract Plan (€4.5 million) and by the EquipEx+ GAIA Data project, which is supported by the national research infrastructure Data Terra (€1.2 million). Both of these have been integrated into France 2030.

Head of the Datarmor platform: Benoît Morin, Computing Resources and Communications, IFREMER

JERICO and ILICO research infrastructures create synergies for integrated littoral and coastal observation

From left to right: Laurent Delauney, coordinator of EU project JERICO, and Alain Lefebvre, co-director of ILICO. Photo: Stéphane Lesbats / IFREMER (CC BY

Joining forces to better observe and understand littoral and coastal environments and ecosystems within France and Europe: Research infrastructures JERICO (Joint European Research Infrastructure of Coastal Observatories) and ILICO (Infrastructure for LIttoral and COastal research) federate the scientific community around shared ambitions. Laurent Delauney, coordinator of the JERICO project, and Alain Lefebvre, co-director of ILICO, talk about the role and value of these infrastructures in which IFREMER is involved.

JERICO and ILICO have now been around for a few years. What led to their creation?

Alain Lefebvre: For ILICO, the story starts in the early 2000s, when it became necessary to harmonize ways of working and formalize the observation services of the National Institute for Earth Sciences and Astronomy at the National Centre for Scientific Research (CNRS). The French government decided to pursue the federation of all systems for littoral and coastal observation and their operating entities, including in overseas France. This is of course a complex environment with multiple interactions under many pressures that require multidisciplinary cooperation (physical oceanography, hydrology, biogeochemistry, marine biology, coastal geomorphology, and meteorology). To approach it properly, IFREMER, the CNRS, and the other signatories and partners all pitched in for ILICO's development. ILICO received its quality label in 2016 and was added to the French government's national strategy for research infrastructures.

Laurent Delauney: JERICO was created for similar reasons, but at the European level. Seventeen countries with no fewer than 600 coastal observation systems were involved. The harmonization measures that Alain mentioned were both crucial and ripe with promise. JERICO debuted through projects whose funding began in 2010. Today, nine countries have research infrastructures like ILICO that we rely on while trying to bring other nations up to the same level. We hope to serve as a catalyst so that we can then offer activities and services to bolster public policy; that way, we could help promote the blue economy and marine renewable energies. After JERICO-FP7 (2011–2014) and JERICO-NEXT (2015–2019), the project is currently in its third and final phase, JERICO-DS (Design Study), which should allow us to apply for European Research Infrastructure Consortium (ERIC) status (as a legal entity created by a European Parliament decision) and, in parallel, JERICO-S3 (the third edition of the JERICO project).

At this stage, it will be possible to assess the concept's effectiveness at pilot sites around Europe, right?

L.D.: Exactly. We have targeted five sites where we want to improve the connections between different scientific teams, countries, disciplines, and systems focused on societal needs. And JERICO-S3 has another important goal: developing a Virtual Research Environment based on best practices and providing services that make life easier for researchers and other stakeholders.

What is ILICO's role in these advancements?

A.L.: We draw on national observation services and scientific projects throughout the country, whether they are ILICO projects or not. I'd like to reiterate that building strong national systems is what will help give rise to a strong European scientific community that works together to better observe and understand the functioning of our littoral and coastal environments, and also to improve predictions of what could happen in the future.

L.D.: ILICO could live without JERICO, but knowledge acquisition would be slower if it were limited to France only. Opening up to Europe makes everything more efficient.

What achievements can we expect to see in the future thanks to these two research infrastructures?

A.L.: We've already gleaned important information on the long-term evolution of littoral and coastal environments from data acquired through ILICO. I could mention the description of the evolution of phytoplankton dynamics and biodiversity—since phytoplankton are a key part of the food chain—and high-temporal-resolution monitoring, via instrumented buoys, of the physical, chemical, and biological characteristics of water masses in response to human pressures. With our wide variety of observation systems, we can even track rare or extreme phenomena that affect this environment, such as marine heat waves. The same goes for the impacts that storms and climate change have on sea level rise, coastal erosion, and the dynamics and diversity of organisms that live in the open sea or on the seafloor.

L.D.: In 2019, JERICO-NEXT showed for the first time that there are traces of human activity (antibiotics, herbicides, hydrocarbons, food additives) in coastal waters and farther out at sea. This is a concrete example of the way in which JERICO's integrated approach over large European regions and its connections with other observation infrastructures contribute to the pantheon of marine observation. Becoming an ERIC would give us the ability to deploy a long-term strategy, collaborate more efficiently within Europe, and ultimately save time. It would help us keep moving forward. We really want to optimize scientific research on coastal and littoral marine environments through streamlined and harmonized marine observation in Europe. Our ultimate goal is to change this paradigm.

Learn more (in French): "Observing and understanding coastal and littoral areas: Ocean observation infrastructures" https://www.ifremer.fr/fr/infrastructures-de-recherche/observer-et-comprendre-les-zones-cotieres-et-littorales
JERICO website: https://www.jerico-ri.eu
ILICO website: https://www.ir-ilico.fr/?PagePrincipale&lang=en

A Franco-Japanese observatory for studying seamounts in New Caledonia

IFREMER and the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) have established a new submarine observatory to study the biodiversity and environment of seamounts in the Natural Park of the Coral Sea, one of the largest protected marine areas in the world. This presents the opportunity to test a latest-generation multidisciplinary observatory before reproducing the model around the world.

In early May 2023, scientists from IFREMER, JAMSTEC, and the National Research Institute for Sustainable Development went to southern New Caledonia to set up the first elements of a submarine observatory between 500 and 1,100 meters underwater on the flanks and summit of the Stylaster seamount. From R/V *Antéa*, a research vessel in the French Oceanographic Fleet, they deployed an experimental mooring line fitted with sensors and sampling equipment and a seafloor observation station with high-definition cameras. With the data that these instruments will collect over twelve months, the scientists will study the environment and functioning of these ecosystems, which are poorly known yet rich in biodiversity.

This new observatory is both modular and movable. It will ensure very high frequency monitoring of a plethora of physical and biological parameters. Measurements of the currents, temperature, salinity, and carbon flows will yield valuable information on the role of seamounts and the ocean depths in climate change, as well as the impact of currents on the concentration of food sources on these seamounts. The cameras and environmental DNA sensors developed by JAMSTEC will be used to study biodiversity dynamics at the same time.

Deployment, from R/V *Antéa*, of an experimental mooring line fitted with sensors and sampling equipment to observe the little-known and biodiversity-rich ecosystems of Coral Sea seamounts near New Caledonia.
© Julien Legrand / IFREMER

What's next?

In 2028, a profiling float will be added on a new mooring line to measure the same parameters at every depth in the water column. An autonomous seafloor measuring station will be installed on the seamount's summit as well. The whole system will then be placed on a second seamount to gather comparative data. This mobile observatory will provide valuable data for the study and protection of seamounts in the Natural Park of the Coral Sea.

Innovation for enhanced deep-sea observation in the South Pacific

As part of IFREMER's ScInObs project (Science, Innovation and submarine Observatories), this observatory is another illustration of the Institute's capacity to leverage technological innovation to optimize the work of submarine observatories in the ocean depths. With this type of system, IFREMER aims to limit observatories' ecological and economic impacts through energy sobriety and heightened autonomy of their measurement instruments, which reduces the need for maintenance operations. These advancements should facilitate their adoption in other Pacific island states.

Lead scientists on the KASEAOPE 1 expedition: Karine Olu, Deep-sea environment Laboratory, IFREMER, and Clément Vic, Open Water and Ocean-Scale Interactions Laboratory, IFREMER

MEDIATION project: Toward a digital coastal ocean

Romaric Verney, a researcher in hydro-sedimentary dynamics, is working to develop an interactive high-resolution digital model of the coastal ocean's evolution through 2050. Photo: Stéphane Lesbats / IFREMER (CC BY)

Romaric Verney has been contributing to the MEDIATION project, which aims to create a digital twin of the coastal ocean, since 2022. The hydro-sedimentary dynamics researcher from the Oceanography and Ecosystem Dynamics department explains the purpose and different stages of this project focused on the decades to come.

Your field of research has to do with sediment movement caused by tides, storms, and rivers. What influences this movement?

Along coasts and in estuaries, waves and currents interact with sediments like sand and mud. What we want to know is how these sediments are transported around these systems. Where do they go? What direction do they travel? Do they form deposits or spread over larger areas depending on tides, floods, and storms? These are our questions. Not only are these studies useful for hydro-sedimentary dynamics, they help us understand and predict how coastal and estuary systems might change under anthropic pressures such as those related to maritime traffic (since we're studying maritime waterways). Biodiversity is abundant along the coasts as well, and it is important to understand how sedimentary habitats evolve in order to learn how they work and anticipate their future.

Do you need a multi-pronged approach to tackle all of these subjects?

We certainly do. Our approach has three phases: first, measurements on site. Then, experiments in the lab to observe and understand hydro-sedimentary processes. The third phase is for digital modeling. During this phase, we reproduce the spatial and temporal dynamics of an estuary or a coastal sea, which enables us to anticipate how these environments could change in the future due to climate change or human activity.

So, this is where MEDIATION has a role to play.

As we've learned, coastal environments are very dynamic. Water, sediments, nutrients (which organisms like phytoplankton need in order to grow and contribute to the food chain)—all are in constant movement. With MEDIATION, we want to provide a digital solution to describe what the coastal ocean could look like in 2050. This knowledge could then be shared with other actors, those in charge of the environment, to help them make decisions with a view to preserving the marine environment.

What added value does MEDIATION bring compared to other modeling tools used previously?

Other tools offer only basic representations of the coastal ocean, and carry their share of uncertainties in their results. The way they represent interactions between physical and biological elements of the environment is often too simplistic. We want to create simulations with greater precision and robustness. We're working on two test areas at the moment, in the Bay of Biscay and in the northwest Mediterranean.

The project is currently underway. Aside from providing information to decision-makers, what other purposes might it serve once it has reached maturity?

An ecosystem is an interconnected web of interactions and processes. In an oversimplified way, fish feed on plankton, which need light, which depends on sediments and water transparency, which is affected by the presence or absence of suspended sediments. At the end of the project, MEDIATION will enable us to sketch out the future of the coastal environment and all of its components. We may be able to anticipate that if a given societal scenario X occurs, an ecosystem will evolve in Y ways. This is why we need to master the interactions between all of these processes.

In your opinion, what one thing would make MEDIATION a success?

This is an immensely exciting project for many reasons, particularly because it brings together a large community of French scientists with complementary profiles. Everything we need is in place so that, in the future, it will be possible to anticipate changes in the coastal ocean via digital models.

Next steps of the project

2025: Prepare a coupled modelling chain for testing
2026: Run the first simulations of the future of the coastal environment
2027: Extract useful information from the anticipated scenarios in order to inform decision-making processes

Learn more at the MEDIATION Project website: https://mediation-ocean.org/

MEDIATION is funded as part of the "Ocean and Climate" priority research program, directed by IFREMER and the National Centre for Scientific Research for the benefit of the entire French scientific community. The six-year program was launched in 2021. It has been certified by the UN Decade of Ocean Science for Sustainable Development, and forms part of the France 2030 investment plan, with a budget of €40 million. The program aims to structure France's research forces around seven major scientific challenges in order to better understand and protect the ocean.
For more information (in French): https://www.ocean-climat.fr/Les-actions-et-projets/Les-projets-de-recherche/MEDIATION

SHOM and IFREMER follow in the footsteps of SWOT satellite

Two teams from the French Naval Hydrographic and Oceanographic Service (SHOM) and IFREMER explored the Mediterranean to check the precision of observations produced by the satellite SWOT, which was undergoing final validations before its operational launch in summer 2023. The results were very promising. They revealed, with unparalleled precision, oceanic structures that had never before been detected by ordinary satellite altimetry. It was a great leap forward for understanding of the ocean and climate change.

Scientists from SHOM and IFREMER spent a month aboard two research vessels from the French Oceanographic Fleet, *L'Atalante* and *Téthys II*, to study medium-sized oceanic structures between Toulon and Minorca. These structures are whirlpools, filaments, and fronts that are visible on the surface of the ocean due to "hollows" and "humps" that can vary sea level by several centimeters and up to several dozen centimeters. They play a key role in climate mechanics because they have significant influence over water exchanges between the surface and the deep ocean and therefore over transfers of heat, carbon, and nutrients.

The satellite SWOT is being developed jointly by NASA and the Centre national d'études spatiales (CNES) to provide the international scientific community with a myriad of new data at an exceptionally high resolution. Thanks to a new radar called KaRIn, which IFREMER teams helped design, SWOT can detect oceanic structures five to seven times smaller than other satellite observation instruments can.

Very precise satellite imagery

During these twin missions, scientists tracked and characterized, as granularly as possible, the oceanic structures situated in the two fifty-kilometer-wide bands that the satellite glides over each day between the Balearic Islands and the French coasts of Bouches-du-Rhône and the Var. They relied on many types of instruments (CTD probes, drifting buoys, acoustic sounders) and the joint navigation of their two vessels to detect rapidly evolving and sometimes ephemeral phenomena. The thirty-five drifting buoys that they deployed helped track changes in the currents along SWOT's path.

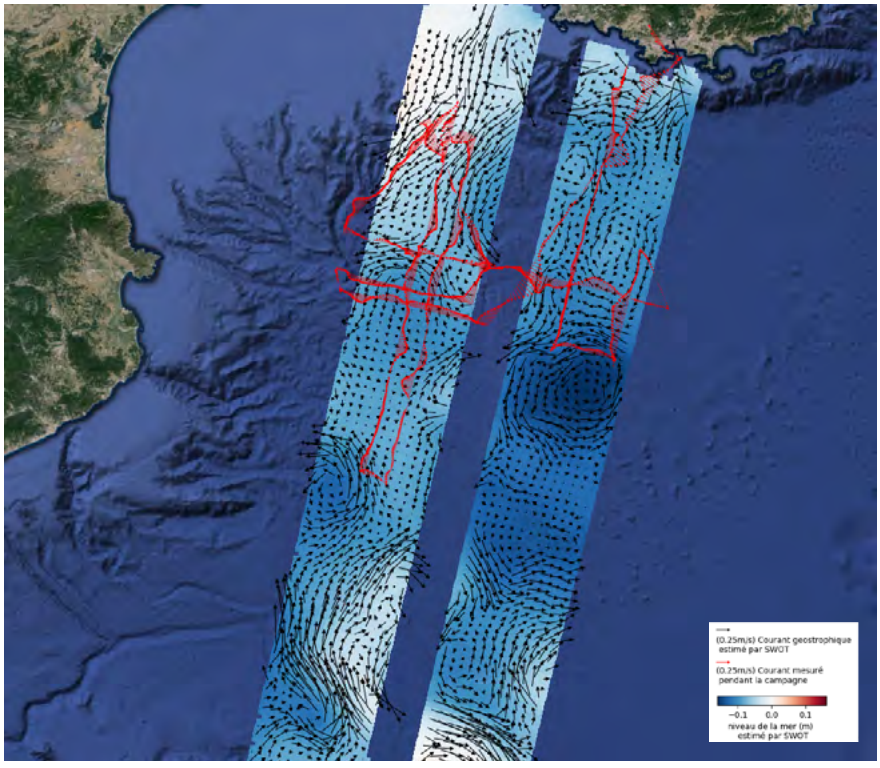
The researchers then compared the data collected at sea to the initial high-resolution satellite data provided by SWOT. They were impressed by the precision of the satellite imagery within the zone examined by IFREMER and SHOM. Structures around ten kilometers wide, which had been observed at sea but were not picked up by altimetric satellites with classic radars, were clearly visible in SWOT's images.

Other similar missions have been launched in other parts of the world. If it performs just as well there, SWOT will break ground for a new era of satellite oceanography, making it easier to understand the role these medium-sized oceanic structures play in climate mechanisms.

Lead scientist on the C-SWOT cruise on R/V *Téthys II*: Pierre Garreau, Coastal Ocean Laboratory, IFREMER

Lead scientist on the WEMSWOT cruise on R/V *L'Atalante*: Franck Dumas, SHOM

Comparison between on-site measurements by the C-SWOT cruise and satellite measurements. (Base map from Google Maps.)



RETROSCOPE: A closer look at fifty years of oyster farming history, and its future

The oyster farming industry has always recovered well from environmental and economic crises, as shown by a retrospective study covering three oyster farming basins from 1970 until the modern day. This is promising given the new challenges posed by climate change. Photo: Olivier Dugornay / IFREMER (CC BY)

Forty scientific partners, including IFREMER, worked with professional shellfish farmers and local management entities to examine close to fifty years of history (1970–2018) at three oyster farming basins: the Thau lagoon in the Mediterranean, the Marennes-Oléron basin in Charente-Maritime, and the Bay of Veys in Normandy. The RETROSCOPE project (2020–2023) weaves together scientific expertise and social sciences to shed new light on these social-ecological systems to help their actors better prepare for the future.

The review of these three oyster farming sites revealed moments of ecological and social upheaval. These ecosystems have changed greatly since IFREMER-operated monitoring and observation networks were established in 1979: Nutrient density has decreased, phytoplankton communities have changed, mortality has increased for Pacific cupped oyster spat and juveniles, chemical contaminant content has dropped, and microbiological contaminants have also dropped, although less significantly, in farmed oysters. On the social science side, other profound changes have occurred. Coastal areas where oysters are farmed have had to meet other ecosystem services needs and extend their scope to biodiversity conservation, water quality, and cultural and leisure activities.

Resilience in the face of environmental and economic crises

Drought, human pressures, disease, changes in environmental protection regulations, evolving commercial practices … Oyster farmers have always been able to adapt when crisis has struck. European flat oysters, which used to be the main species cultivated in France, were affected by overexploitation and disease and were replaced in the 1920s by Portuguese oysters, which were themselves replaced by Japanese oysters in the early 1970s. Since 2008, oyster farmers have successfully managed episodes of mass mortality among Japanese oysters. They skillfully implemented new methods to protect their farms, using oysters collected from natural environments, spat from hatcheries, and triploid oysters. They have changed their business strategy as well, turning toward greater mechanization and direct shipping and sales.

What does the future of oyster farming look like?

Aside from climate change, whose effects are already noticeable in the most southerly ecosystems, the oyster farming industry must also contend with the redefinition of its identity. Caught between the traditional labor of humble “sea farmers,” anchored in the natural environment, and an industrialized activity that mirrors modern agriculture, oyster farmers are questioning their identity and the societal role of their profession. They remain optimistic about the future, however, and they know that the diversity of their aquaculture practices and the representations of their industry will guide them through ecological and economic turbulence.

RETROSCOPE project leads:
Valérie Dérolez, Languedoc Roussillon Environment and Resources Laboratory, MARBEC joint research unit, IFREMER
Audrey Bruneau, Pertuis Charentais Environment and Resources Laboratory, IFREMER
Aline Gangnery, Coastal Benthic Ecology Laboratory, IFREMER
Rémi Mongruel, Maritime Economy unit, AMURE joint research unit, IFREMER

Learn more at the RETROSCOPE project website (in French): https://retroscope.ifremer.fr/index.html

Citizen science – science by and for the people

Ocean Spy: When citizens lend researchers a hand...

With its app Ocean Spy, IFREMER invites children and adults alike to contribute to its research on marine ecosystems. How so? They can examine photos of the deep sea uploaded to a participatory science platform and help scientists perform the meticulous work of identifying marine species. Their comments on these images are used to train artificial intelligence algorithms to better recognize species. Aside from advancing research, this project has another advantage: familiarizing the public with little-known ecosystems such as those in submarine canyons and on abyssal plains. This app is the second in the series. Deep Sea Spy works in the same way, but for hydrothermal vents on the seabed.

Learn more (English available): Ocean Spy platform, https://ocean-spy.ifremer.fr/

The participatory science platform Ocean Spy teaches the wider public how to identify species populating a variety of ecosystems in the Atlantic and the Pacific to help scientists inventory marine biodiversity.

Fish & Click: Combating pollution generated by fishing equipment

For three years, IFREMER has been inviting the greater public to use the Fish & Click site or app to report abandoned fishing gear found at sea or washed up on the beach. Ropes, lines, nets ... 27,000 pieces of trash have already been reported at sea and along the coasts of Normandy, Brittany, and Hauts-de-France since this participatory science project was launched. These reports feed IFREMER's efforts to map out this waste so that it can be managed better. The stakes are high, because abandoned pieces of equipment can damage the seafloor, trap marine animals, and degrade into microplastics under the effects of waves and UV light. IFREMER displayed some photos showing the diversity of the fishing waste items observed at the Marinarium in Concarneau.

Learn more (English available): Fish & Click platform, https://fishandclick.ifremer.fr/

In three years, fishermen, beach strollers, and leisure boaters have reported 27,000 pieces of abandoned fishing gear at sea and along the coasts of Brittany, Normandy, and Hauts-de-France. Photo: Emina Mamaca / IFREMER (CC BY)

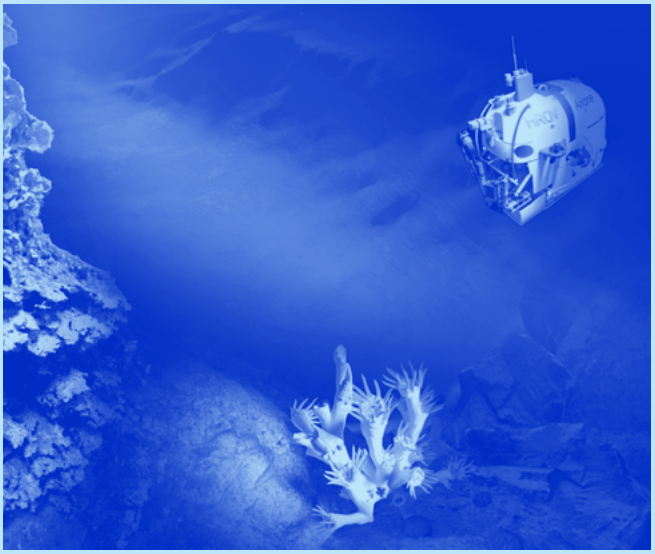
An educational Art and Science kit on underwater landscapes

After two years of tests, the *Initium Maris Civis* educational kit is now available for schools to teach children aged 6–12 about the diversity and importance of marine ecosystems. It mixes artistic activities with scientific investigations to explore these hidden landscapes from an aesthetic and scientific point of view. The kit contains eight lessons for a total of twenty-five teaching hours. It was designed by IFREMER and photographer Nicolas Floc'h, who has taken many pictures of underwater landscapes along the Brittany coast from his sailboat and during IFREMER's scientific cruise ChEReef. The kit was developed in partnership with artconnexion, the Passerelle Contemporary Art Center and Cap vers la nature.

Learn more (in French): https://www.ifremer.fr/fr/la-mediation-scientifique-l-ifremer/nos-offres-pedagogiques/initiummariscivis

This project received support from the European Regional Development Fund, the Brittany Region, and the Ministry of Culture-Brittany Region Cultural Affairs Division.

Students present photos of underwater landscapes taken by Nicolas Floc'h, from the *Initium Maris Civis* Art and Science kit. © Aurélien Mole



Virtual immersion among cold-water corals

With a new 360° film, IFREMER is offering a one-of-a-kind immersive experience: a visit to the hidden treasures of a submarine canyon between 200 and 600 meters deep! Thanks to virtual reality headsets, spectators are invited to dive into the Mediterranean and swim through a forest of cold-water corals. The highlight of the virtual dive is an inside look at these fascinating life forms through 3D X-ray microtomography. The film sequences were captured in the Lacaze-Duthiers canyon during the CALADU 2019 cruise. On that cruise, IFREMER collected bathymetric data and took pictures and samples of corals to learn more about their habitat, the form and structure of their skeletons, and the distribution of their colonies.

Learn more (in French): https://www.youtube.com/watch?v=59O0lVDI28A

Image from the 360° film *Dive among cold-water corals in the Mediterranean.*
Photo: IFREMER CALADU cruise (CC BY)

Guidance and support

Social and societal responsibility: Significant progress in response to the transition

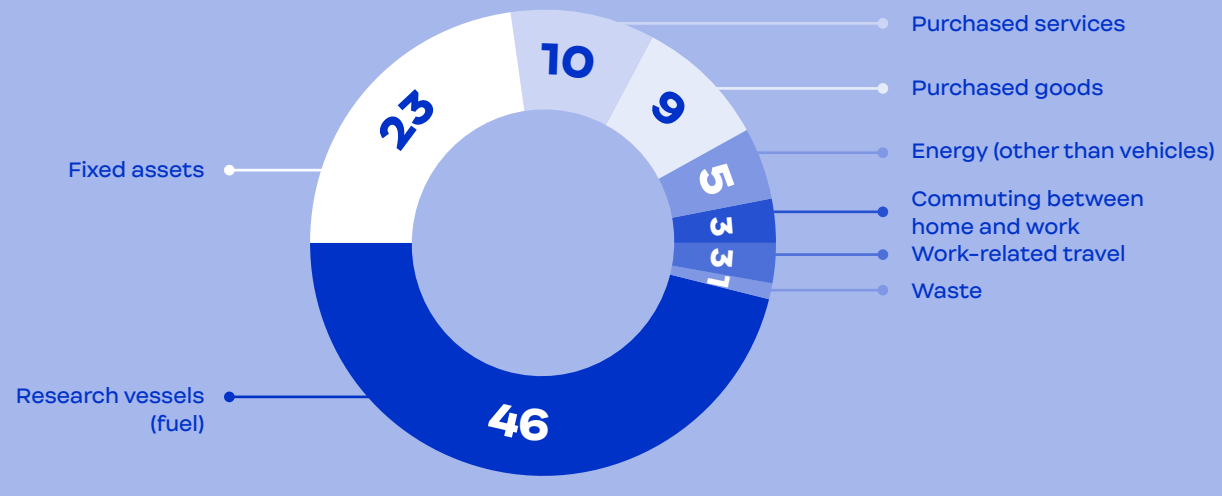
Spearheaded by upper management and formalized in the Institute's Statement of Objectives (2019–2023 COP), IFREMER's CSR policy has led to a multitude of projects involving different stakeholders (the Board of Directors, the Central Social and Economic Committee, the Labos 1point5 collective). With sixteen goals divided up into five broader objectives, the CSR policy will become IFREMER's next set of Guidelines for Sustainable Development and Social Responsibility, and these guidelines will be sent to the Ministry for Higher Education and Research as part of the Climate and Biodiversity plan for National Research Organizations.

In 2023, many projects were conducted with the different divisions of the Institute to meet internal and external social and societal needs.

The projects' broad themes (decarbonization, sobriety, mobility, circular economy, responsible use of technology, eco-friendly public services) demonstrate the Institute's commitment to the 2030 Agenda for Sustainable Development set by the UN.

- A major first step: **The creation of an exhaustive Carbon Emissions Report** (or greenhouse gas emissions report) broken down by source has revealed the respective footprints of different IFREMER activities. Specific work was done with the French Oceanographic Fleet to forecast what the fleet will look like in 2035.
- **Creation of a sustainable mobility subsidy** following the signature of a national agreement. This act shows upper management's desire to support employees who use alternative means of transport to get to work, such as cycling or carpooling.
- **Deployment of the governmental energy sobriety plan** involving all employees of the Institute. This sobriety plan was underpinned by an internal communication campaign focusing on five priority themes: energy, mobility, digital technology, water, and the circular economy. The preliminary results show that the Institute is on track to meet its goal of a 10% reduction in energy usage. In the same vein, IFREMER launched **a call for internal projects** at the end of the year so that employees could share innovative ideas for energy sobriety (related to real estate, the scientific process, and other things).
- Along with the creation of the 2024–2028 Statement of Objectives, Means, and Performance,

IFREMER's 2022 carbon emissions: 59,200 metric tons of CO_2 equivalent



Contribution by activity (in %)

a **national CSR survey was conducted among employees** to delve into their expectations and needs. The survey revealed employees' desire to take action, as well as their expectations: communication, decarbonization of the fleet's activities, more action related to alternative forms of transportation, and more.

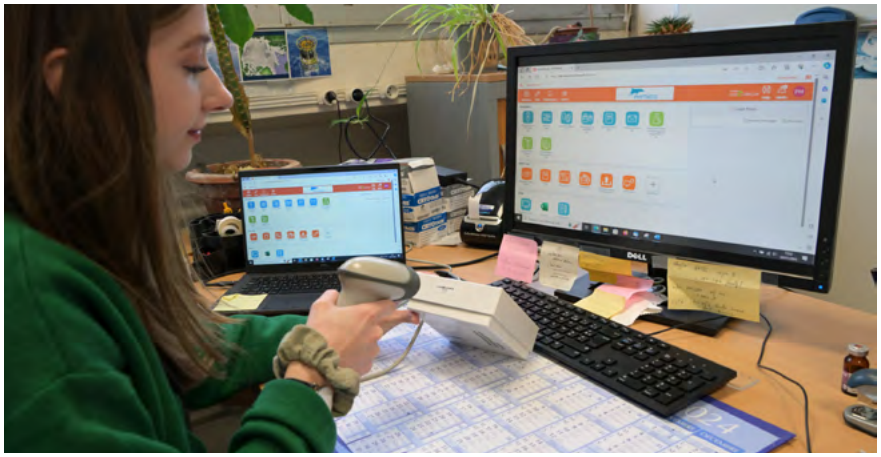
- Creation of a **training course** to help employees adopt more responsible digital technology habits in their scientific activities.
- Rollout of a **service promoting the transfer of scientific and technical materials not in use to other parts of the Institute**, so that employees can give their equipment a second life elsewhere at IFREMER.

IFREMER's five CSR objectives:

1. Strengthen citizen engagement for and through the ocean
2. Support the maritime ecosystem's transition with green innovation
3. Eco-design ocean observation
4. Reduce IFREMER's environmental footprint
5. Be a responsible employer

Poster from the internal campaign about eco-friendly habits that support the energy sobriety plan and echo the French government's national "Every little thing matters" campaign

Quality management: A continuous improvement system to build trust



The new laboratory information management system facilitates the inventory of equipment and samples throughout the entire Institute. Photo: Stéphane Lesbats / IFREMER (CC BY)

The trust of our external and internal stakeholders depends above all on our ability to understand and respond to their needs. Trust is cultivated through an approach consisting of listening and adapting where necessary. This is the main thrust of our quality management system, whose structured and cross-cutting approach feeds into our processes for continuous improvement.

SISMER, one of five French data centers with CoreTrustSeal certification

In 2023, the IFREMER-SISMER marine data center renewed its CoreTrustSeal certification. This recognition by an independent international authority guarantees that researchers' data will be optimally protected and managed in order to preserve the efforts that it took to acquire or produce them. The certification also reassures project funders that the data produced by these projects is accessible. In the context of the "open science" and "open data" movements led internationally by the Research Data Alliance and relayed in France by the Ministry of Higher Education, Research, and Innovation, the IFREMER-SISMER marine data center is one of the five French scientific data centers that has reached this level of certification.

Optimized management of our laboratory equipment

In 2023, IFREMER finished rolling out its new system for the digital management of its research laboratory equipment. Teams of lab users collaborated with the IT System Engineering service and the Technology Research and Development unit, as the quality process for measurement and experimental technology dictates. Their remarkable efforts yielded the new system for laboratory equipment management, which now contains more than 11,000 instruments. This tool will make it easier to keep track of equipment maintenance and verifications, and our teams can also use it to find out exactly what equipment is available at any given moment throughout the whole Institute. The project is a perfect illustration of a successful internal improvement process designed to make life easier for as many people as possible.

ISO 9001 certification renewed for six audited sites

In 2023, the follow-up audit for IFREMER's ISO 9001 certification occupied teams at six sites (Dinard, Martinique, La Tremblade, Nantes, Lorient, and Plouzané) for more than four days. Ultimately, the auditors evaluated the Institute's quality management system favorably once again, praising its "robust partnerships" and the "diversity of expertise and skills that are renowned and solicited at the national and international levels." Aside from these points of pride, areas for improvement were also mentioned and will receive special attention. No vulnerabilities or instances of non-compliance were identified. The audit's conclusions confirm the contributions made by quality management to IFREMER's guidance.

COFRAC accreditations maintained and extended

The year 2023 saw the continuation of our ISO 17025 and ISO 17043 accreditations. The accreditation scope was extended for the Marine Invertebrate Adaptation and Health unit at La Tremblade, with the detection of regulated endemic pathogenic agents (*Bonamia ostreae, B. exitiosa* and *Marteilia refringens*) by PCR in real time.

List of accredited laboratories
(see www.cofrac.fr/en for accreditation scopes)

- Environment and Resources Laboratory in Normandy: test accreditation no. 1-2048
- Detection, Sensors, and Measurements Laboratory: calibration accreditations no. 2-1192 and no. 2-1212
- Health, Environment, and Microbiology Laboratory: test accreditation no. 1-5451
- Environment and Resources Laboratory in Morbihan-Pays de la Loire: test accreditation no. 1-2349
- Marine Invertebrate Adaptation and Health: test accreditation no. 1-2160 and inter-laboratory comparison accreditation no. 1-6907
- Environment and Resources Laboratory in Arcachon: test accreditation no. 1-2062
- Environment and Resources Laboratory in Languedoc Roussillon: test accreditation no. 1-1655

Human resources and social dialogue

Welcome aboard: Sixty new employees gathered in Brest in October for an orientation seminar
Photo: Léa Lemée / IFREMER (CC BY)

In 2023, IFREMER added fifty-six new employees on permanent full-time contracts, bringing the total workforce up to 1,572 employees as of December 31, 2023.

This same year, HR and the Institute in general continued to prioritize skill development. IFREMER dedicated 3.21% of payroll to continuing professional development, which represented a budget of €2,194,953. As such, 887 employees were able to take at least one training course as part of the 2023 Skills Development plan. (1,510 training courses were started.)

Furthermore, the improvements made to training course offerings for managers led to the creation of a module on "hybrid management" (remote work and remote management) with seventy managers trained over nine sessions. IFREMER's skills-strengthening efforts will continue in 2024.

The HR department also spearheaded the creation of a "Practical HR Guide for Managers" for all employees in managerial roles and uploaded it to the Institute's intranet in September 2023, to provide further support.

Still on the HR and development side, a second "Life After Dissertation?" seminar was organized for doctoral candidates at IFREMER, two years after the first edition garnered overwhelmingly positive feedback from participants. The two-day seminar was produced jointly by the Science Division, the Innovation Division, and HR. Its workshops, discussions, and meetings were intended to help doctoral candidates plan their professional future, give them the tools they need, and introduce them to career options outside academic research. Participants rated their satisfaction with the 2023 edition at 4.75 out of 5.

Also in 2023, the Institute took action to improve support for annual evaluations. Members of HR collaborated with managers and employees from different departments and units to design a new model. In March, this model and the changes it represented (both in form and content) were presented during two videoconferences attended by nearly 580 Institute employees.

As part of our corporate social responsibility policy, a three-year agreement on sustainable mobility subsidies was signed. All employees on permanent contracts and short-term contracts, as well as interim workers, can take advantage of it. Thirty percent of IFREMER's workforce benefited from this subsidy in 2023.

In the realm of CSR once again, IFREMER joined AFDESRI this year to strive for better gender equality in research and innovation. This French association contributes to the promotion of women to leadership positions in higher education, research, and innovation. Its network offers seminars, conferences, training sessions, and mentorship on themes such as leadership and breaking the glass ceiling. AFDESRI works with other women's associations in higher education, research, and innovation, and with other French government ministries as well.

What's more, for International Women's Day (and the whole week of March 8, 2023), an awareness-raising quiz on women's rights and gender inequality was sent to all Institute employees. This action engaged 474 people.

The Institute continued to raise awareness about disabilities this year by participating in DuoDay 2023. The event took place on November 23, the national day for disability awareness. It consisted of inviting people living with disabilities to come to work with IFREMER volunteers so that they could meet each other, have conversations, and move past stereotypes together.

DuoDay offered thirteen people with disabilities the opportunity to learn more about IFREMER's working environment, narrow down their ideas for a career path, plan out their integration into the workforce, or decide which academic subjects interested them the most. Both the participants and the teams hosting the people with disabilities shared very positive feedback after the event.

During the first half of 2023, upper management and union representatives held regular meetings to work on updating the employment agreement. Seven of the eleven themes identified in the process agreement were successfully negotiated.

Since the employee representatives' terms were coming to an end, Social and Economic Committee elections were organized within the IFREMER-Genavir social and economic committee (UES) in spring 2023. Five Social and Economic Committees for five establishments were elected within the UES.

Finally, and for several years now, IFREMER has been dedicated to protecting health, quality of life, and working conditions (QWL) for all of its staff. For the second consecutive year, HR and the members of the QWL observatory have set up a benchmarking tool. It is a recurring survey that aims to measure employees' level of satisfaction with the Institute as a workplace. The survey establishes annual baselines that indicate whether it may be necessary to develop cross-cutting or local programs to improve well-being at work.

The 2023 edition helped determine an action plan, including the following elements:

- Continue the information and discussion sessions offered by upper management
- Develop actions that improve staff knowledge about the different jobs at the Institute
- Establish a mandatory training course for managers on the prevention of psychosocial hazards
- Continue our regular communication about the various options and mechanisms at the Institute for well-being at work.

Budgetary and financial data

BALANCE SHEET – ASSETS (euros)	2023 gross	Amortizations & depreciations	2023 Net	2022 Net
FIXED ASSET				
Intangible assets	59,945,583.66	45,573,030.39	14,372,553.27	15,173,162.65
Tangible assets	669,005,734.61	465,852,689.23	203,153,045.38	198,064,475.03
Land	6,916,387.90	2,190,920.84	4,725,467.06	4,703,432.06
Buildings	123,093,381.26	80,667,124.26	42,426,257.00	40,298,189.00
Technical facilities, equipment, and tools	434,938,387.47	345,845,021.66	89,093,365.81	87,680,323.00
Collections	861,392.32	0.00	861,392.32	861,392.32
Historical and cultural property	0.00	0.00	0.00	0.00
Other tangible fixed assets	45,426,503.15	37,149,622.47	8,276,880.68	9,198,450.00
Tangible fixed assets under concession	0.00	0.00	0.00	0.00
Tangible fixed assets in progress	630,805.68	0.00	630,805.68	630,956.92
Advances and deposits on orders	57,138,876.83	0.00	57,138,876.83	54,691,731.73
Fixed assets subject to rights	0.00	0.00	0.00	0.00
Tangible fixed assets (living assets)	0.00	0.00	0.00	0.00
Financial assets	20,134,958.61	1,408,325.93	18,726,632.68	20,393,668.43
TOTAL FIXED ASSETS	**749,086,276.88**	**512,834,045.55**	**236,252,231.33**	**233,631,306.11**
CURRENT ASSETS				
Stocks	0.00	0.00	0.00	0.00
Accounts receivable	74,696,597.45	5,974,683.60	68,721,913.85	72,013,603.15
Accounts receivables on public entities (national government, other public entities), international bodies and the European Commission	52,072,471.59	0.00	52,072,471.59	51,088,508.65
Customer receivable and related accounts	7,415,732.47	5,974,683.60	1,441,048.87	6,753,562.24
Accounts receivables on tax owed (income from earmarked taxation)	0.00	0.00	0.00	0.00
Advances and deposits on orders	12,880,589.79	0.00	12,880,589.79	2,085,519.70
Accounts receivables corresponding to operations on behalf of third parties (intervention plans)	0.00	0.00	0.00	0.00
Créances sur les autres débiteurs	2,327,803.60	0.00	2,327,803.60	12,086,012.56
Accounts receivables on other debtors	117,000.00	0.00	117,000.00	0.00
TOTAL CURRENT ASSETS	**74,813,597.45**	**5,974,683.60**	**68,838,913.85**	**72,013,603.15**
CASH FLOW				
Marketable securities	0.00	0.00	0.00	0.00
Cash and cash equivalents	159,769,593.18	0.00	159,769,593.18	153,915,058.91
Other	0.00	0.00	0.00	0.00
TOTAL CASH FLOW	**159,769,593.18**	**0.00**	**159,769,593.18**	**153,915,058.91**
Adjustment accounts	0.00	0.00	0.00	0.00
Unrealized foreign exchange losses	0.00	0.00	0.00	0.00
OVERALL TOTAL (euros)	**983,669,467.51**	**518,808,729.15**	**464,860,738.36**	**459,559,968.17**

BALANCE SHEET – LIABILITIES (euros)	2023	2022
LIABLE EQUITY CAPITAL		
Funding received	144,932,116.89	142,344,675.51
Assets funding by the State	102,169,851.81	97,358,065.30
Assets funding by third parties	35,319,669.08	37,141,736.21
Equity capital from foundations	0.00	0.00
Revaluation differences	7,442,596.00	7,844,874.00
Reserves	131,989,658.57	131,587,380.57
Retained earnings	27,829,516.07	14,602,098.69
Financial year results	-3,668,656.02	14,819,017.81
Regulated provisions	0.00	0.00
TOTAL LIABLE EQUITY CAPITAL	**301,082,635.51**	**303,353,172.58**
PROVISIONS FOR CONTINGENCIES AND EXPENSES		
Provisions for contingencies	333,363.12	2,635,902.03
Provisions for expenses	35,533,101.00	37,683,384.00
TOTAL PROVISIONS FOR CONTINGENCIES AND EXPENSES	**35,866,464.12**	**40,319,286.03**
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 payables and related accounts	17,396,715.25	18,405,761.55
Tax and social security payable	35,508,195.01	36,751,314.51
Advances and prepayment received	71,918,696.24	56,189,353.60
Accounts payable corresponding to operations on behalf of third parties (intervention plans)	0.00	0.00
Other non financial liabilities	1,718,058.17	3,468,006.61
Deferred income	1,369,826.00	992,094.16
TOTAL DETTES NON FINANCIÈRES	**127,911,490.67**	**115,806,530.43**
CASH FLOW		
Other elements of passive cash flow	148.06	80,979.13
TOTAL CASH FLOW	**148.06**	**80,979.13**
Adjustment accounts	0.00	0.00
Unrealized foreign exchange gains	0.00	0.00
OVERALL TOTAL (euros)	**464,860,738.36**	**459,559,968.17**

Income statement

EXPENSES (euros)	2023	2022
OPERATING COSTS		
Purchases	0.00	0.00
Consumption of goods and supplies, performance of work and direct consumption of services by the Institute for its activities as well as expenses related to change in stocks	111,387,147.53	112,042,385.99
Salaries and benefits	105,484,963.38	102,317,923.17
Salaries, appointments and misc. payments	73,051,371.09	69,985,802.91
Social contributions	26,874,819.06	26,686,071.47
Profit sharing and participation	0.00	0.00
Other staff expenses	5,558,773.23	5,646,048.79
Other operating costs	12,903,076.30	12,945,038.37
Amortization, depreciation, provisions and net book value of assets sold	32,610,201.60	33,198,715.50
TOTAL OPERATING COSTS	262,385,388.81	260,504,063.03
CHARGES D'INTERVENTION		
For intervention on own behalf	8,481.57	38,036.43
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	8,481.57	38,036.43
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	8,481.57	38,036.43
TOTAL OPERATING AND INTERVENTION COSTS	262,393,870.38	260,542,099.46
FINANCIAL EXPENSES		
Interest fees	0.00	0.00
Net loss from sale of securities	0.00	0.00
Exchange losses	13,404.76	11,271.11
Other financial charges	0.00	0.00
Amortization, depreciation and financial provisions	1,189,781.88	2,422.00
TOTAL FINANCIAL EXPENSES	1,203,186.64	13,693.11
Corporate income tax	-36,926.00	626,200.00
ACTIVITY RESULT (PROFIT)	0.00	14,819,017.81
TOTAL EXPENSES (euros)	**263,560,131.02**	**276,001,010.38**

INCOME (euros)	2022	2021
OPERATING INCOME		
Income without direct consideration (or subsidies, grantsand similar income)	223,717,107.57	221,264,699.39
Subsidies for public service responsibilities	186,324,000.00	181,040,100.00
Operating subsidies from the State and other public entities	37,393,107.57	40,224,599.39
Subsidies from the State and other public entities specifically earmarked to cover certain intervention costs	0.00	0.00
Donations and bequests	0.00	0.00
Income from earmarked taxes	0.00	0.00
Income with direct consideration (or direct income from activity)	16,063,006.28	37,391,328.17
Sale of goods or services	14,982,400.92	14,547,484.68
Gains from sales of assets	66,848.33	21,586,452.59
Other management income	1,013,757.03	1,257,390.90
Inventories and capitalized production	0.00	0.00
Other income	19,947,112.06	16,964,281.22
Write-off of amortizations, depreciations and provisions (operating income)	6,298,174.94	1,409,847.52
Write-off of financing related to an asset	13,648,937.12	15,554,433.70
TOTAL OPERATING INCOME	259,727,225.91	275,620,308.78
FINANCIAL INCOME		
Income from shares and loans	12,634.19	20,795.88
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	13,793.22	16,195.73
Other financial income	0.00	0.00
Write-off of amortizations, depreciations and financial provisions	137,821.68	343,709.99
TOTAL FINANCIAL INCOME	164,249.09	380,701.60
ACTIVITY RESULT (LOSS)	3,668,656.02	0.00
TOTAL INCOME (euros)	**263,560,131.02**	**276,001, 010.38**

Governance and organization

Board of Directors

Composition as of December 31, 2023

Chair
François HOULLIER
Chief Executive Officer

Members representing the State
Ministry of Higher Education and Research
Anne PUECH (incumbent)
Cyril MOULIN (alternate)

Ministry for the Ecological Transition and Territorial Cohesion
Thierry COURTINE (incumbent)
Anaïs MELARD (alternate)

Secretary of State for the Sea and Biodiversity
Aurélie DARPEIX-VAN TONGEREN (incumbent)
Hélène RENAULT (alternate)

Ministry for the Armed Forces
Cédric CHETAILLE (incumbent)
Alain THOMAS (alternate)

Ministry of the Economy, Finance and Industrial and digital Sovereignty
Agathe ROLLAND (incumbent)

Ministry of the Economy, Finance and Industrial and Digital Sovereignty
Michel PASCAL (incumbent)

Ministry for Europe and Foreign Affairs
Mathieu PERROT (incumbent)
Leila CHABANE (alternate)

Ministry for the Ecological Transition and Territorial Cohesion
Fabienne RICARD (incumbent)
Magali NAVINER (alternate)

For their expertise in the Institute's fields of study
Julien LAMOTHE
Françoise GAILL
Frédéric MONCANY DE SAINT-AIGNAN

For living resources
Elsa CORTIJO
Valérie VERDIER

Members elected by IFREMER personnel
CFDT
Abdellah BENABDELMOUNA
Jean-François PEPIN
Marie-Anne CAMBON
Cathy TREGUIER

CGT
Carla SCALABRIN
Éric ABADIE
Jean-Michel SCHRAMM

Members voting in advisory capacity
Government Commissioner
Laurence PINSON

Secretary General for the Sea
Didier LALLEMENT
Benoit DE GUIBERT

General Comptroller for Finance and Economy
Jean BEMOL

Representative of the Minister delegate for overseas France
Élodie SEZNEC

Chair of IFREMER's Scientific Committee
Patrick LANDAIS

Head Accountant of IFREMER
Didier JAOUEN

Stakeholders Committee: A unique space where science and society meet

The members of IFREMER's Stakeholders Committee at the Argenton experimentation site. Photo: Olivier Dugornay / IFREMER (CC BY)

IFREMER's Stakeholders Committee, created in 2021, brings together a variety of actors from civil society and the private sector. The co-chairs of this structure bridging science and society are Geneviève Pons, the director general and vice president of Europe – Jacques Delors, and Sébastien Treyer, the director general of IDDRI (a French think tank for sustainable development and international relations). Both gave us their point of view on the committee and its unique role in the research world.

Why did you want to join IFREMER's Stakeholders Committee?

Sébastien Treyer: Many different actors have high expectations for IFREMER and its scientific and technical expertise. We strive to identify and distill the questions occupying society at large in case they could become future subjects of research. We play an intermediary role to get the dialogue started. On a daily basis, I work on international negotiations, especially those pertaining to the future of the ocean. Being part of this adventure gives me another perspective and a better understanding of how scientific cooperation works. It's really an innovative experience.

Geneviève Pons: It's compelling that no committee like this exists elsewhere. Even in the United States or Germany, countries that also have renowned ocean research organizations, there is no equivalent to IFREMER's Stakeholders Committee. And it's a pity, because in our context of climate change, diminishing biodiversity, and the need to develop a sustainable blue economy, creating and maintaining a connection between science and society—in a participatory way—strikes me as essential. Personally, I've been based in Brussels for thirty-four years. It's exciting, but sometimes too far removed from reality "in the field," and I wanted to get closer to that. My love for the ocean was another factor that motivated me to join IFREMER.

What do you think of the Stakeholders Committee and how it functions?

G.P.: First, I want to say that I really like the idea of having co-chairs. Sébastien and I work together in a very complementary way. Thanks to the other members' strong engagement, and the teams helping us produce and polish our work, everyone is on the same wavelength. After the fact-finding missions on citizens' engagement and then on European directives governing the marine environment, the 2023 investigation *La recherche pour une aquaculture durable et innovante* (Research for sustainable, innovative marine aquaculture) was, I think, very high-quality. The resulting report was presented to IFREMER's Board of Directors in March 2024. It included important subjects such as the need to make the research strategy understandable for the aquaculture industry, to help industry professionals adapt to climate change, and to reduce the harmful effects of some types of aquaculture by developing (for example) research on nutrition sources other than feeder fish* for fish farms. We also pointed out the value of promoting research on promising economic activities such as multi-trophic aquaculture and seaweed farming. Finally, we reiterated the importance of maintaining a dialogue with the industry's entire value chain, all the way down to the consumer.

S.T.: Our report will of course lead to discussion, starting with IFREMER's response to our work. In the months to come, we would also like to reflect on lessons learned halfway through our term, and share them with other French and international scientific institutions to demonstrate the utility of a structure like the Stakeholders Committee. We will also confirm the details of our next fact-finding mission, whose focus will be the seabed.

A bit more than two years after its launch, what do you think of your participation in the Stakeholders Committee?

S.T.: Personally, I'm very proud to be part of such an innovative, experimental structure! In a more and more polarized society, it's really exciting to be at the forefront of this effort for collective deliberation—even more so since the different sectors it draws in have historically been at odds. The Stakeholders Committee is a space for democracy. I'm always amazed at how science knows no borders when it comes to creating opportunities for collaboration.

G.P.: I'm very proud, too! IFREMER is a place where you interact with people whose professional and personal lives are intimately tied to the ocean. I really prize this collaboration.

* Feeder fish are small pelagic fish caught to produce fishmeal and fish oil.

Check out the website and the Committee's activities (in French):
http://www.ifremer.fr/fr/un-dialogue-regulier-avec-la-societe

Composition of the stakeholders Committee (as of December 31, 2023)

Co-chairs
- Geneviève PONS
- Sébastien TREYER

Panel of associations and NGOs
- Laurent DEBAS
- Raphaëla LE GOUVELLO
- Céline LIRET
- Jean-Yves PIRIOU
- Christophe SIRUGUE

Panel of businesses and artisans in the maritime sector
- Laurent CASTAING
- Anne GUILLAUMIN GAUTHIER
- Sarah LELONG
- Alexandre LUCZKIEWICZ
- Stéphane Alain RIOU

Panel of maritime workers
- Thierry LE GUEVEL
- Marie-Noëlle TINE DYEVRE

Panel of local elected officials and representatives
- Gil BERNARDI
- François GATEL
- Michel GOURTAY
- Stéphane HAUSSOULIER
- Gaël LE MEUR
- Patricia TELLE

Panel of citizens
- Marion BOURHIS
- David GUILLERME
- Simon RONDEAU

Scientific Committee

Two sessions with the Scientific Committee were arranged on May 4, 2023 and October 6, 2023. These sessions provide occasions to talk about strategic subjects for the Institute and obtain the Committee's opinion on research programs, particularly their scientific aspects. Furthermore, they serve as the jumping-off point for work groups that provide support for the Institute's internal reflections.

In 2023, IFREMER employees, scientific departments and support functions participated in workshops to define the priority themes for the 2024-2028 Statement of Objectives, leading to the creation of a summary that was presented to and discussed with the Scientific Committee. The Committee assisted the Institute with the complex task of drafting the Statement of Objectives while accounting for the directives given by the supervising ministries.

The Committee brought its expertise to bear on the priority theme of "How and why the ocean can contribute to the energy transition?" and on the marine renewable energies'roadmap. It issued recommendations to clarify the Institute's internal positioning as well as its position within the scientific community, all while seeking to improve its consistency and strengthen the interactions between research and expertise that informs public policy.

The "Ocean and Climate" priority research program, funded by the France 2030 program and bearing the UN Decade of Ocean Science for Sustainable Development label, is headed jointly by IFREMER and the National Centre for Scientific Research. This PRP strives to develop integrative and interdisciplinary research into solutions for the ocean's challenges, and share ocean discoveries and related issues with society at large. In this context, two projects led by IFREMER were retained (LIFEDEEPER and CLIMArcTIC); they gave rise to fruitful discussion between their lead scientists and the Scientific Committee.

The Committee was solicited again in 2023 regarding the creation of a new multi-site unit called COAST (Observation and restoration ecology of coastal ecosystems) and its roadmap. This unit will carry out national-level missions in different areas thanks to its network of nine Environment and Resources laboratories. The Scientific Committee issued several recommendations to ensure adequate strategic positioning and visibility with regard to IFREMER's other units and the outside world, while also establishing a robust organizational structure.

Composition of the Scientific Committee (as of December 31, 2023)

Chair
- Patrick LANDAIS

Members appointed by decree
- Denis ALLEMAND
- Laurence LE COQ
- 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
- Ricardo DA SILVA JACINTO
- Philippe MOGUEDET
- Caroline MONTAGNANI

Permanent guest members
- Didier GASCUEL
- Nicolas ARNAUD
- François LALLIER
- Frédéric MENARD

Scientific integrity, ethics, and deontology: Toward responsible research

In 2023, IFREMER continued and redoubled its efforts to strengthen staff understanding and compliance with the principles of scientific integrity through an online training course. The 35-minute course, offered in French and English, was entitled Scientific Integrity, Ethics, and Deontology: The Fundamentals of Research Work.[1] This module was designed for all staff, both scientific and administrative. With this online training course and the fact that the overwhelming majority of its researchers have taken an in-depth, in-person course on the subject, IFREMER thus meets the requirement of Decree no. 2021-1572 of December 3, 2021, and specifically the first line of Article 2, which states that "public institutions and foundations with recognized public utility … must ensure that their staff, and students whose training involves learning through or performing research, are made aware of and trained on the requirements for scientific integrity." Moreover, IFREMER's head of scientific integrity, Marianne Alunno-Bruscia, and its deputy science director, Philippe Goulletquer, participated in the collective creation of a pedagogical work entitled *Une recherche responsible : l'intégrité scientifique*[2] (Responsible research: scientific integrity) published in the Les Mémos collection at Quae.

In terms of ethics, IFREMER relies on the reflections and work of the Ethics in Common Committee for the French Agricultural Research Centre for International Development, the National Research Institute for Sustainable Development, IFREMER, and the National Research Institute for Agriculture, Food and the Environment.* Four new members joined this committee in 2023: Mr. Bernard Bret, Ms. Paula Martinho Da Silva, Mr. Ricardo Serrao Santos, and Mr. Laurent Thévenot. In 2023, the Ethics in Common Committee focused on two priority subjects:

- An investigation that it initiated itself, entitled "What are the rights and duties of scientists and their institutions in the face of environmental emergency?" which was discussed by the staff of all four organizations at IFREMER's Atlantic Center in Nantes in May 2023. This investigation and discussion resulted in the publication of Opinion Report no. 15[3] in October 2023.
- An investigation called "Exploration, exploitation, and preservation of unknown environments minimally affected by human activity," on which the committee will finalize its report during the first half of 2024.

Ethics in Common Committee Members (as of December 31, 2023)

Michel BADRÉ, chair
Bernadette BENSAUDE-VINCENT, vice-chair
Madeleine AKRICH
Catherine BOYEN
Bernard BRET
Denis COUVET
Mark HUNYADI
Paula MARTINHO DA SILVA
Marie-Geneviève PINSART
Pere PUIGDOMENECH
Ricardo SERRÃO SANTOS
Youba SOKONA
Laurent THÉVENOT

* Check out the website and the committee's activities: https://www.ethique-en-commun.org/en

1 — IFREMER (2023). Scientific Integrity, Ethics, and Deontology: The Fundamentals of Research Work. E-learning module, Callimedia, 35 minutes.

2 – M. Alunno-Bruscia, C. Duquennoi, P. Goulletquer, E. Jaligot, A. Kremer, F. Simon-Plas. 2023. *Une recherche responsable: l'intégrité scientifique.* Editions Quae, Collection: Les Mémos de Quae, 63 p.

3 — (In French) https://www.ethique-en-commun.org/content/download/7968/file/Avis15-Comite-Ethique-en-Commun.pdf

Central Social and Economic Committee (CSE-C)

Composition as of December 31, 2023

Office members

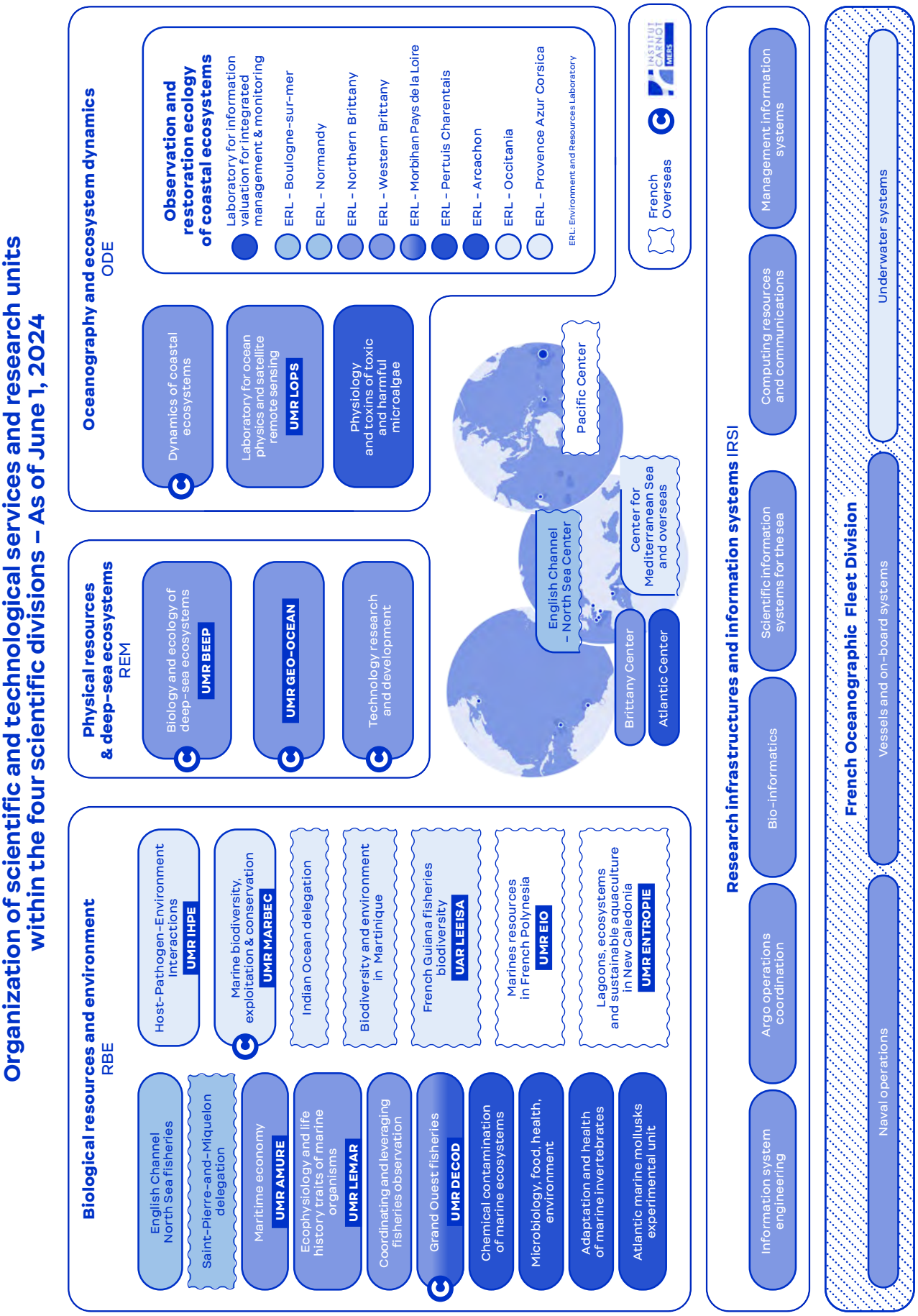
Secretary	Anne BOISSEAUX
Treasurer	Marine SALAÜN GRALL
Assistant Secretary	Jean-Bernard DONOU
Assistant Treasurer	Fabrice GUÉGAN

Elected representatives

Brittany		
Incumbents	Philippe HERVÉOU	CFDT
	Jean-Bernard DONOU	CFDT
	Fabrice GUÉGAN	CFDT
	Olivier MÉRAL	CGT
	Emmanuel RINNERT	CFDT
	Marine SALAÜN-GRALL	CFDT
	Olivier DUGORNAY	CGT
Alternates	Christine DUBREUIL	CFDT
	Alison CHALM	CFDT
	Stéphane GUIOMAR	CFDT
	Mickaël GELEBART	CGT
	Gilles CAVAREC	CFDT
	Lucile DURAND	CFDT
	Guillaume CLODIC	CGT
Atlantic		
Incumbents	Anne BOISSEAUX	CFDT
	Bruno SAINT JEAN	CFDT
	Stéphane GUESDON	CGT
Alternates	Clarisse HUBERT	CFDT
	Muriel LISSARDY	CFDT
	Maud LEMOINE	CGT
Mediterranean		
Incumbents	Emmanuel MANSUY	CFDT
	Aurélien ARNAUBEC	CFDT
	Maxime FERRERA	CFDT
Alternates	Maxime MONFRET	CFDT
	Romain PIASCO	CFDT
	Patrice LUBIN	CFDT
English Channel – North Sea		
Incumbents	Geoffrey BLED-DEFRUIT	CGT
	Carolina GIRALDO	Libre
Alternates	Josselin CABOCHE	CGT
	Grégory GERMAIN	Libre
New Caledonia		
Incumbent	José HERLIN	Usoenc/CFDT
Alternate	Eugénie AKARO	Usoenc/CFDT
Genavir sailors		
Incumbents	Philippe SCHNEIDER	CGT
	José REBELO	CGT
	Antoine BERLEMONT	CGT
Alternates	Pascal DELPIERRE	CGT
	Madjid BOUAYAD-AGHA	CGT
	Vincent ROUSSELOT	CGT

Organization of research and research support units

Organization of scientific and technological services and research units within the four scientific divisions – As of June 1, 2024



General organization
As of June 1, 2024

François Houllier
Chairman and chief executive officer

Laurent Couret
Deputy chief executive officer
in charge of resources

Jean-Marc Daniel
Deputy chief executive officer
in charge of strategy

Didier Jaouen
Head of accounting

Genavir
Éric Derrien (CEO)

INSTITUT CARNOT MERS
Jean-Marc Daniel (director)

Chantal Compère
Science division

Olivier Le Pivert
Coordination for expertise in support of public policy

Jean-Marc Daniel
(Acting)
European & international affairs division

Romain Charraudeau
Division for partnerships and transfer for innovation

Tristan Renault
Department of biological resources and environment

Nabil Sultan
Department of physical resources and deep-sea ecosystems

Philippe Riou
Department of oceanography and ecosystem dynamics

Olivier Lefort: French Oceanographic Fleet division

Gilbert Maudire: Department of research infrastructures and information systems

Géraldine Guillevic
Communications and institutional relations division

Elisabeth Etcheverry
Human resources division

Maureen Jacolot
Administrative, legal and financial division

Xavier Harlay
Direction of the English Channel-North Sea Center

Valérie Mazauric
Direction of the Brittany Center

Yvan Guiton
Direction of the Atlantic Center

Vincent Rigaud
Direction of the Center for Mediterranean Sea and overseas

Philippe Moal
Direction of the Pacific center

Vincent Rigaud
Security and defense official

Marianne Alunno-Bruscia
Delegate for professional conduct and scientific integrity

Jean-Marc Sinquin
Delegate for data protection and corporate social responsability

Nolwenn Coat
National anti-corruption, access and benefit sharing coordinator

Marie-Laure Chao
National quality and safety coordinator

IFREMER's operations span the globe

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#AllOnBoard

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Fraternité

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