



EUROPEAN
INSTITUTE
FOR MARINE
STUDIES

The ocean and its coasts, at the heart of crucial stakes and resource issues, are now the focus of humanity's attention. The 21st century is already the century of the ocean. Here in Brest, at the tip of Europe, IUEM provides a fertile environment where the University and national organisations combine their research forces to push back the frontiers of knowledge.

Over the years, the commitment of IUEM's staff and students have put IUEM at the forefront of the international marine science community. Its research, which is profoundly multi- and interdisciplinary, aims to help us understand processes spanning from the gene to the ecosystem and from the distant past to the present, taking into account the central role of humankind in the evolution of the ocean system, from the coasts to the open sea.

IUEM is also a truly exceptional place for university training in Marine and Coastal Sciences and an Observatory of a changing blue planet.

Situated at the crossroads of different disciplines, institutions and generations, IUEM is an extraordinary scientific and human adventure!

Fred Jean - Director

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Coast and ocean, challenges for humankind

◀ Living and mineral resources, climate change, biodiversity, renewable energies... Humans are at the centre of all these issues. IUEM's cross-disciplinary approach enables it to address them holistically.

Returning from shellfish harvesting in a pirogue in the Sine Saloum, Senegal.

With 1.3 billion km³ of water and a surface area that represents over two-thirds of the earth's interface with its atmosphere, the ocean is a key player in a global climate undergoing major changes. It is a highly complex environment in which physical, chemical and biological processes are constantly interacting on all time and space scales. Climate, circulation of water masses, photosynthetic production, transfer of matter through marine food chains or between the Earth's spheres, feedback from living organisms on the system as a whole... One by one, the secrets of the «ocean machine» are gradually being uncovered. Humankind has also become a full-fledged part of this system, which integrates both living and non-living components. Here, as on continental surfaces, we have a significant impact on complex and fragile ecosystems.

More than ever, the fate of the ocean and that of humanity appear to be inseparable. Both the ocean and coasts have been sources of food and routes for trade since the dawn of time and the sites of numerous economic activities for the extraction, industrial, transport and service sectors. With a rapidly growing world population, half of which already lives within 100 km of the coast, and an increasing number of issues at stake, the resulting conflicts and need for sustainable development are a challenge for the management and governance of these areas.

Some of the solutions to the ecological challenges that humanity must now face will undoubtedly come from the ocean, a source of renewable resources, many of which have yet to be discovered and/or harnessed, such as marine energies and active molecules. The development of a sustainable blue economy - around fields such as health, renewable energies, fishing, the seaweed industry, maritime transport or the use of marine spaces - is a major issue for the future of our societies.

In order to meet all these major knowledge challenges, the European Institute for Marine Studies (IUEM) has built its specificity on interdisciplinarity and the synergy of expertise among its research units. To make this possible, its scientific community mobilises new approaches able to take complexity into account instead of trying to reduce it.

IUEM, an overview

With the scope of its multidisciplinary research ranging from Human and Social Sciences to Universe and Life Sciences, a specific teaching field and observation missions, the European Institute for Marine Studies is a melting pot of marine sciences unique in France.

Its mission is to study the ocean and coastline as well as related human activities through observation, experimentation and modelling, and to transmit this knowledge through teaching and communication in order to achieve the objectives of sustainable development of maritime activities and the preservation of marine and coastal ecosystems.

To achieve these objectives, its activities are based on three complementary missions:

- **Research:** IUEM has seven laboratories (joint research units involving UBO, UBS, CNRS, IRD and Ifremer*) where more than 500 researchers, teacher-researchers, engineers, technicians and administrative staff work;
- **Training:** as a school of UBO, IUEM offers eight Master's degrees that are very closely linked to its research laboratories. That offer is unique in France. The average number of students enrolled in the master's programme is 270 per year. IUEM also hosts the Doctoral School of Marine and Coastal Sciences (EDSML), a multidisciplinary doctoral school associating 42 host laboratories, both within and outside IUEM. The EDSML has an average of 260 doctoral students each year, 25% of whom are newcomers in the Brest area;
- **Observation:** IUEM leads and contributes to national observation missions (CNRS), hosts the coordination of the coastal research infrastructure (IR ILICO) and also carries out its own observation series. IUEM brings together long-term observations of all the ocean's spatial components, from coastal areas to the open sea and ocean depths. It addresses global issues, from the living ocean to the physical ocean, as well as its use and management by humankind.

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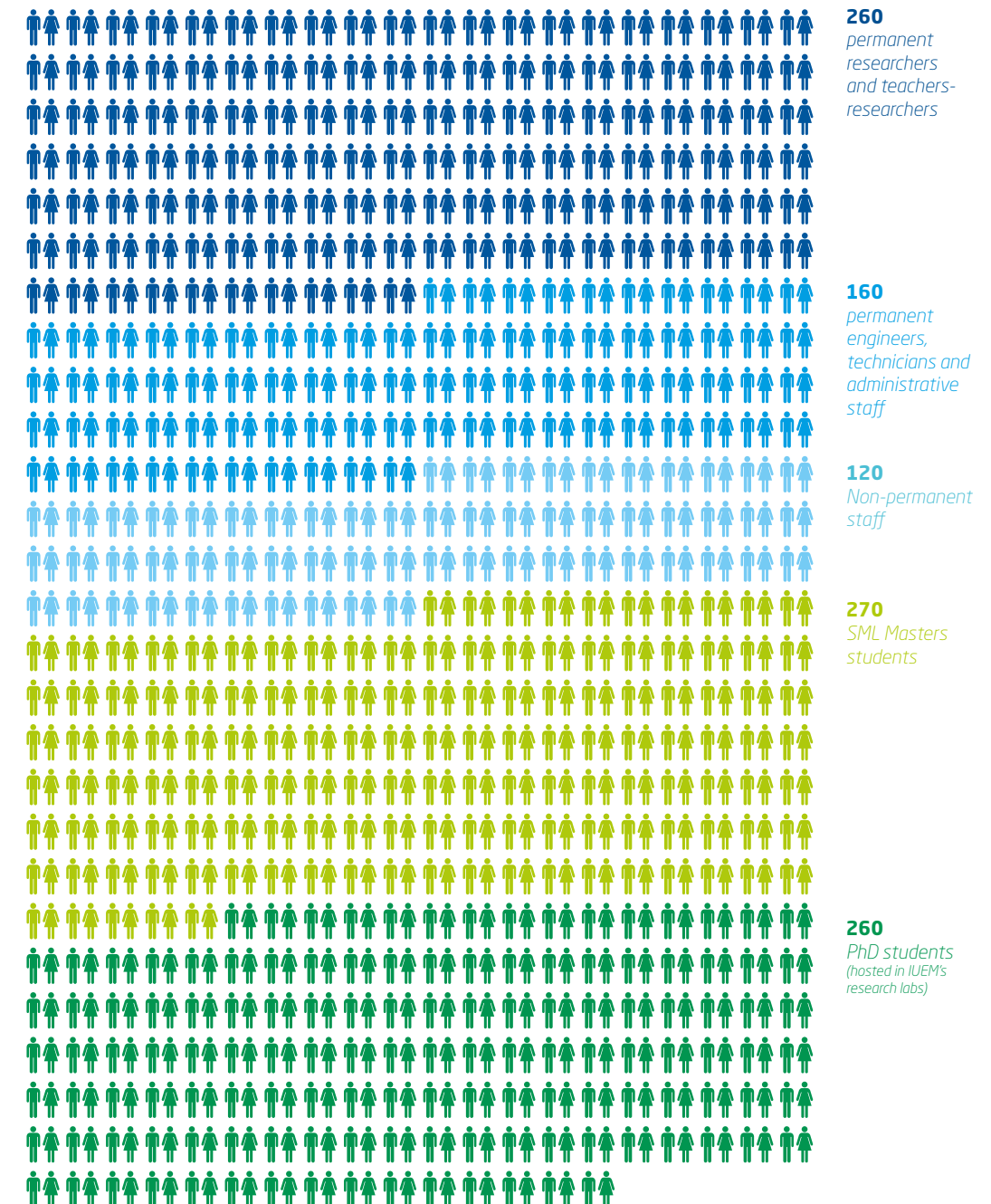
UBO: University of Western Brittany

UBS: University of Southern Brittany

CNRS: National Centre for Scientific Research

IRD : French National Research Institute for Sustainable Development

Ifremer: French Research Institute for Exploitation of the Sea



Distribution of IUEM staff and students (2022 data)

The means to an ambition



◀ The institute's teams benefit from access to a range of top-level services and technical resources.

The Albert Lucas, the institute's oceanographic vessel, is an exceptional resource for all coastal missions.

To carry out its scientific missions and objectives, the OSU-IUEM federative structure brings together the shared human and technical resources made available to IUEM's community by University of Western Brittany and national research organisms CNRS & IRD:

- common services: general administration and finance, IT and data management (SIMI), communication and multimedia production, international relations and partnerships, training activities relating to master's degrees in Marine and Coastal Sciences (schooling, educational engineering);
- technical support services for observation and research activities at sea;
- clusters and shared technical platforms.

Technical resources are shared and structured into the following analytical platforms and operational services:

- the Image and Instrumentation Cluster (P2I): scientific equipment and services in imaging and instrumentation;
- the seagoing facilities, which include diving activities and maritime transport, including the *Albert Lucas* oceanographic vessel commissioned in 2010;
- the PACHIDERM technical platform, dedicated to the analysis of basic parameters of the marine environment;
- the LIPIDOCEAN platform specialised in the detailed analysis of marine lipids.

IUEM is also involved in several multi-organisation platforms and contributes to their continuing development:

- the «Microsonde Ouest», platform for *in situ* elemental microanalysis of solids;
- the Ocean Spectrometry Centre (PSO), which brings together a range of innovative mass spectrometry equipment for the analysis of trace chemical elements and isotopes in marine samples of geological and biological origin, pooled by UBO, CNRS, Ifremer and IRD;
- the Computing and Data Center for the Sea for the benefit of the oceanographic scientific community;
- a marine science documentation centre, jointly managed by Ifremer and UBO;
- the BIODIMAR®/LEMAR/UBO Platform, specialised in the extraction, purification and analysis of marine biomolecules and their biological activities.

Oceanography at the tip of Europe

◀ Brest, on France's northwest peninsula where it extends into the Atlantic, is at the heart of French marine research and IUEM has a key role there.

Aerial view of IUEM. Research, innovation and high technology are located together here at the western tip of the breathtaking Breton coastline.

Founded in 1997 by the University of Western Brittany (UBO) to support the international ambitions of its «sea axis», IUEM is the legacy of Brest's involvement in marine sciences dating back to the 18th century. It occupies a prime position in a region that has defined its strategic sector as «marine excellence» and has been able, with the support of the Europôle-Mer Scientific Interest Group (2007-2017), to develop major «Investissements d'Avenir» projects such as LabexMER and the ISblue interdisciplinary graduate school for the blue planet, and to ensure the international influence of its marine research.

Located on the outstanding site of the Pointe du Diable, in the heart of the Brest-Iroise Technopole, IUEM has 15,000 m² of laboratories, offices and classrooms. IUEM is an actor in the «Campus mondial de la Mer» together with Ifremer Brest and some Grandes Écoles, national public establishments located in the area and socioeconomic partners. One third of the country's marine science and technology resources are thus located at the tip of Brittany.

IUEM brings together a group of laboratories whose research is related to the sea and that were built in partnership with national research institutes (CNRS, IRD and Ifremer). IUEM, within UBO, is one of the actors in the SEA-EU alliance, which brings together nine multidisciplinary European universities that all have a territory and cultural heritage open to the sea and are working together to train the next generation of Europeans in the issues and challenges relating to the ocean and coastal sustainability.

As a place for initiatives beyond the national framework, IUEM has led French universities involved in marine sciences to form a «Marine Universities» network and, organised in this way, to contribute to the construction of a European Research Area by sitting on the European Marine Board.

Directly involved in innovation and economic development, IUEM is a member of the Pôle Mer Bretagne Atlantique (Brittany-Atlantic Sea Cluster). A true melting pot of marine sciences, it is also a key player in the development of a regional marine policy and plays an important role in developing a vision for the future of marine sciences.

International perspectives



On the strength of its expertise in marine sciences, IUEM has implemented an ambitious international policy by engaging in numerous collaborations on a global scale (collaborative research projects, co-publications, thesis co-supervision, etc.). The actions carried out internationally have confirmed the Institute's positioning at European level and have contributed to its international influence. Since 2018, UBO has been included in the Shanghai ranking, and is in the top 15 world and European rankings for the field of oceanography.

◀ Since its creation, IUEM has built up an international reputation and gained recognition in the marine sciences.

The Institute's strategic partnerships

IUEM is involved in more than a hundred bilateral international research and training agreements, and belongs to numerous networks, including the Marine Biodiversity Hub (Australia), the European Marine Board and the Ocean Frontier Institute (Canada).

Since 2016, UBO via IUEM and University of Quebec at Rimouski (UQAR) have jointly led the France-Quebec Institute for Scientific Cooperation to Support the Maritime Sector (IFQM), which aims to facilitate research collaborations (such as the International Research Project (IRP) BeBEST) and the mobility of lecturers and doctoral students.

In Asia, the BEEP laboratory has been coordinating the MICROBSEA IRP with the Third Institute of Oceanography in Xiamen (China) since 2018 after 10 years of scientific cooperation activities focused on the microbiology and ecology of deep ocean hydrothermal vents.

The integration in 2019 of UBO as one of the nine partners of the SEA-EU European University has opened up many opportunities in research, training and observation on a European scale. In 2022, UBO joined the UArctic network of universities and institutes for the promotion of training and research in the Arctic region.

IUEM in global south

Supported by IRD and UBO, cooperation with global south countries is one of IUEM's main priorities. It promotes cross-disciplinary dynamics between its laboratories, through the development of more than sixty research and training projects involving more than 40 partner countries with emerging economies.

In addition to these collaborative research projects, IUEM is present in southern countries through its involvement in two Joint International Laboratories (LMI):

- Following LMI ECLAIRS created in 2012 at the Cheikh Anta Diop University in Dakar (Senegal), LOPS and LEMAR became members of LMI ECLAIRS-2, launched in 2018, which focuses on the study of climate and ocean in West Africa;
- Since 2019, LEMAR has been part of LMI TAPIOCA (Tropical Atlantic Interdisciplinary laboratory on physical, biogeochemical, ecological and human dynamics) in partnership with the Federal University of Pernambuco (UFPE) in Brazil.



◀ Since its inception, ISblue has been a catalyst for new projects in both research and education.

Demonstration of the ImmerSea LAB, an innovative educational project using immersive technologies applied to marine sciences.

ISblue, the Interdisciplinary graduate School for the Blue Planet

As an «Investissements d'Avenir» (French government's investment program for higher education and research) project coordinated by UBO/IUEM, ISblue is based on close collaboration between two universities, three research organisations and four engineering schools to develop synergies between training (master and PhD levels) and research in marine science and technology on the Brest site. ISblue has been granted €21 million over 10 years (2018-2028).

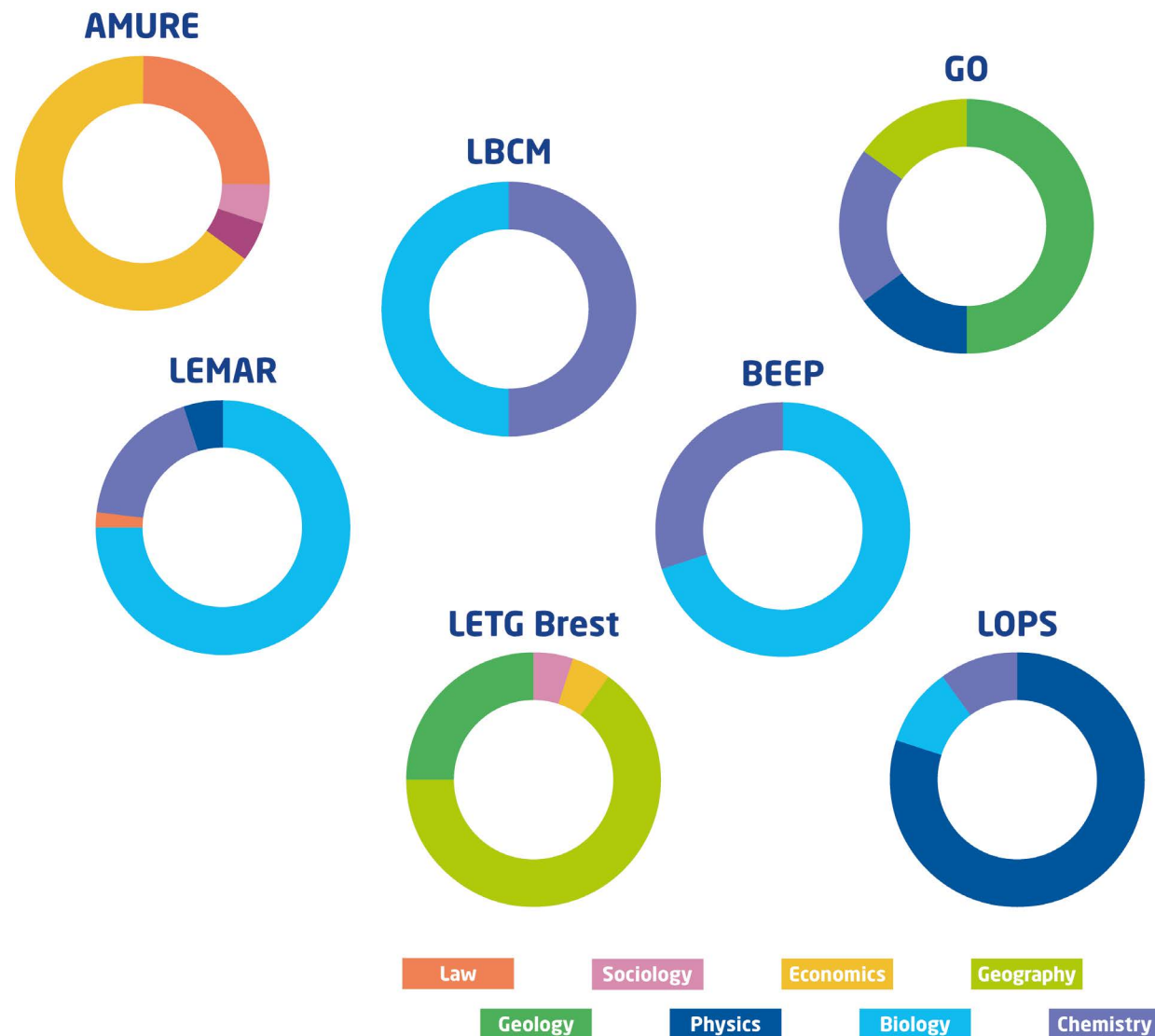
ISblue, a graduate school of international standing, brings into play the research strengths available on the site in an ambitious training scheme, in order to train future generations of researchers and professionals at the cutting edge of marine science and technology, who will have to meet the challenges of a world in transition. ISblue aims to increase the international visibility of the interdisciplinary and innovative curricula offered by its members, as well as the attractiveness of its research units, in particular for young researchers.

ISblue supports research projects in its five themes: ocean & climate regulation, Ocean-Earth interactions, sustainable coastal systems, the living ocean and ecosystem services, and long-term observing systems for ocean knowledge. The emergence of new projects at the interfaces of disciplines and laboratories is encouraged, as well as structuring flagships and research at sea. ISblue also runs an international post-doctoral fellowship programme and supports the international mobility of researchers and professors, doctoral students and masters students.

ISblue students benefit from new interdisciplinary training courses that are closer to the challenges and the societal and economic needs related to the oceans and coasts. ISblue allows the development of pedagogical innovation and project-based training, but also the promotion of original approaches such as virtual reality to enrich students' skills.

Wide-angle research

Research at IUEM is carried out in seven research units. Its research projects and programmes are mainly funded by the French National Research Agency (ANR) and the European Union.



Each laboratory defines its own scientific research strategies, which are part of the interdisciplinary dynamics directed and led by IUEM around five transversal themes:

Marine biotechnology

The research units have a range of multidisciplinary expertise which, added to the diversity of the models studied, gives IUEM a truly original position compared with other establishments working in marine biotechnology in the west of France.

New uses and renewable energy

IUEM is involved in partnerships with industrial developers of Marine Renewable Energy technologies (estimation of production, wind/sea-structure interactions, environmental and socio-ecosystem impacts and legal framework). These programs contribute to the development of sustainability sciences within IUEM, through technological innovation.

Polar research

The environmental consequences of the development and diversification of human activities in the polar regions are significant. The evolution of these activities requires more study, as do the associated risks. Based on the assessment of risks to human safety and environmental impacts, we should then focus on preventive measures.

Global South

In association with the international department, this theme supports cooperation of the various IUEM units with global south countries. It publicises and shares the tools to promote activities with researchers from these countries and encourages and supports the implementation of cooperation programmes.

Historical dynamics

This new interdisciplinary theme aims to understand the interactions between human groups and their environments during the Holocene in the broadest sense, regardless of the geographical sector studied. This theme builds close collaborations of geographers, geomorphologists, (paleo)ecologists, geologists, biologists and bio-geochemists of IUEM, with archaeologists and historians at local, regional and international levels.

AMURE

Management of uses, resources and marine and coastal areas

UBO, Ifremer, CNRS

The AMURE laboratory is a multidisciplinary research and training centre in human and social sciences applied to maritime and coastal activities. Its work focuses on the sustainable development of maritime activities, associated public policies and their impacts on the evolution of marine and coastal social-ecological systems.

The work carried out within the framework of the unit is divided into three thematic research areas supported by an observation, data and methods mission:

- Development and sustainability of maritime and coastal activities;
- Access regulation, accountability and equity;
- Management of social-ecological systems and public policy support;
- Cross-cutting theme: Observation, data and methods.

BEEP

Biology and Ecology of Deep Sea Ecosystems

UBO, CNRS, Ifremer

The ocean depths are the last frontier to be explored, an environment with potentially 1 million species to be discovered. They are the environments the least affected by humans and need to be protected. They are also a vast reservoir of biological, energy and mineral resources that could supply growing global demand. The deep sea has long suffered from a lack of knowledge due to its difficult accessibility, which has perpetuated the distorted image of a calm, quiet and almost desert-like abyssal plain, preserved from anthropic pressures. The scientific objectives of the new joint research unit BEEP are to describe and understand the composition, structure and functioning of different deep-sea ecosystems by coupling faunistic and microbial studies, from communities to molecules and vice versa, using integrated and multidisciplinary approaches. BEEP is one of the first multidisciplinary laboratories dedicated to the deep sea in France capable of integrating microbial and faunal compartments to understand the functioning of these ecosystems.

The laboratory is organised as a single team encompassing three scientific themes and a transversal action.

- Biodiversity of deep-sea ecosystems;
- Interactions in deep-sea ecosystems;
- Responses and adaptations of deep-sea organisms;
- Cross-cutting action: Methodological and technological developments for seabed study.



Geo-Ocean

UBO, CNRS, Ifremer, UBS

Geo-Ocean takes a multidisciplinary approach to the question of the genesis and evolution of oceanic domains (from continental rifts to oceanic ridges, from coastlines to deep basins via continental shelves, from hotspots to volcanic islands, and from passive to active margins). Research also includes chemical exchange between the earth's spheres, sedimentary archives that provide information on transport environments and processes, and coastal and littoral studies. The laboratory carries out innovative methodological and instrumental developments in the marine field and has a large pool of marine geophysical instruments and high-performance analytical resources in petrogeochemistry, sedimentology and palaeontology.

The unit comprises five research teams:

- ODYSC: Observation and dynamics of coastal systems;
- ASTRE: Sedimentary archives, transfers and paleo-environments;
- ALMA: Marine hazards;
- CYBER: Bio-geochemical cycles and resources at ocean Interfaces;
- GIPS: Geodynamics: deep/surface Interactions;

and a large technology and methodology team:

- ANTIPOD: Analysis, remote sensing, instrumentation, sampling, observations and data.



LBCM

Marine Biotechnology and Chemistry Laboratory

UBS, UBO, CNRS

The central theme of the research conducted at the LBCM is the understanding of the dynamics of microbial biofilm formation with a view to biocontrol, with three questions to answer:

- What is the link between the heterogeneity of a surface and its interactions with microbial cells during biofilm formation?
- How do chemical mediation and bioprotection take place in the holobiont?
- What is the link between biofilm and bacterial virulence?

As interdisciplinarity and innovation are two of the LBCM's strong points, a transverse axis of these three questions enables it to combine the different approaches with the objective of biotechnological valorisation.



LEMAR

Laboratory of Environmental Marine Sciences

UBO, CNRS, IRD, Ifremer



The central objective of this laboratory is to understand the interactions within the marine biosphere. Bringing together biologists, chemists, biogeochemists, physicists, but also legal specialists, LEMAR's research is carried out in a variety of areas, from the poles to the inter- and subtropical zones, and from coastal areas to the open ocean. Its tools are observation, modelling and experimentation in both the laboratory and field. LEMAR's research teams are structured around three themes:

- Integrative physiology and adaptation of marine organisms: from genes to population;
- Marine ecology: diversity, structure, dynamics and functioning of populations and communities;
- Marine chemistry, biogeochemical cycles and ocean dynamics.

LETG-Brest

Littoral, Environment, Remote sensing, Geomatics

UBO, CNRS



The LETG multi-site joint research unit of the CNRS has 3 sites, located in Brest (LETG-Brest), Nantes (LETG-Nantes), and Rennes (LETG-Rennes). Its research activities cover several fields of environmental geography: physical geography, human and social geography, remote sensing and geomatics. These are organised around three main themes:

- Coastline;
- Continental environments;
- Remote sensing-geomatics.

LETG-Brest carries out research mainly on the sea and coastline using geomatic methods and tools. The main themes are coastalisation-maritimisation, coastal risks, paleoenvironments, the use of geographic information and associated technologies.

LOPS

Laboratory for Ocean Physics and Satellite remote sensing

UBO, CNRS, Ifremer, IRD



The ocean is in constant motion and its movements are governed by complex mechanics, combining waves, jets and eddies of all sizes, from a few centimetres to the size of ocean basins, from the abyss to the coast. These movements transport heat, salt, carbon, oxygen and, small living organisms, but also pollutants and waste of all kinds. Ocean movements are connected to the atmosphere, cryosphere, solid earth, and continental surfaces. They play a major role in current climate change. The LOPS teams contribute to improving the knowledge, understanding and prediction of these ocean dynamics. This research involves the development of satellite and *in situ* observation programmes, campaigns at sea, and numerical simulations, in conjunction with theoretical analysis based on the equations of motion.

The four LOPS teams work on:

- Dynamics of coastal seas;
- Role of the ocean in climate change;
- coupled dynamics between small and large ocean scales;
- Air-sea interface, including in the presence of ice.

Ocean and global cycles



To understand the fundamental role of the ocean as a climate regulator, a large number of interactions must be taken into account, and research from many disciplines must be integrated.

Heard and MacDonald Islands, Australia, in a storm during the SWINGS oceanographic campaign.

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CNRS Photothèque

The ocean: a major player in the climate and biogeochemical cycles of our planet

Due to its mass, high thermal capacity and ability to absorb CO_2 , the ocean is a regulator of our planet's climate. According to the IPCC, 90% of the excess heat caused by greenhouse gases is stored in the ocean. Teams at IUEM are observing ocean warming, deoxygenation and acidification on a global scale, using a wide range of new instruments and platforms. One example is the international ARGO array of drifting floats that have been measuring vertical profiles of temperature and salinity since the early 2000s, as well as, more recently, fluorescence, dissolved oxygen, nutrient salts, irradiance and pH. A new generation of ARGO floats will measure changes in the deep ocean below 2000 m depth. With warming, sea level rises and the ocean becomes more stratified, leading to changes in ocean-atmosphere exchanges and the oceanic carbon sink. IUEM scientists are observing these changes and trying to predict them, using numerical simulations and new artificial intelligence methods.

The global ocean interacts with the continents and the biosphere, and the major biogeochemical cycles are addressed in all disciplines at IUEM: silica, nitrogen and trace metal (iron, copper, manganese, etc.) cycles in order to better understand their role in the biological carbon pump (sequestration of carbon by the biomass that settles at depth). The measurement

of trace elements requires the development of advanced laboratory methods, which are necessary for the success of the large international GEOTRACES campaigns and for a better understanding of the impact of marine pollution. Ecosystem dynamics and interactions between trophic levels are addressed through *in situ* observation (from acoustics to genomics), experimentation and numerical models.

Advances in satellite measurements and numerical simulations at increasingly high spatial and temporal resolution make it possible to address the continuity of scales in the marine environment, from coastal to global. Upwelling systems on the eastern edges of the oceans (South Africa, Mauritania, Peru) and in coastal bays are the site of remarkable biological productivity, often concentrated in fine-scale structures (filaments and eddies), with these physical phenomena favouring different planktonic species.

In the polar regions, which are subject to many of the most dramatic effects of climate change, our researchers are observing and modelling the melting of sea ice and its impact on stratification and heat exchange, changes in wave and mixing dynamics, as well as the evolution of the particularly fragile ecosystems of these regions.

Social-ecological systems and biodiversity

Objects of fascination and subjects of study, marine ecosystems offer an extraordinary diversity, but, due to multiple pressures, many are now threatened.

Polar marine fauna in Saint-Pierre and Miquelon.

© Erwan AMICE | CNRS

The ocean is home to some of the world's most diverse ecosystems and provides many ecosystem services. In the current context of climatic and environmental upheaval, the ocean is subject to numerous pressures whose cumulative effects are still poorly understood: the future of biodiversity and marine ecosystems are at the heart of the uncertainty.

These upheavals can impact ecosystems at the individual and population levels. Adaptive changes in certain species in response to anthropogenic pressures have already been observed, but we know little about population dynamics that depend on biotic interactions such as competition or predator-prey interactions. Major advances are expected through research on cell biology, ecophysiology and evolutionary processes. Statistical models of habitats and ecological niches attempt to predict future population dynamics. Understanding these types of phenomena will allow the formulation of theories on biological interactions and the links between populations and ecosystem functioning.

Paleoecology allows the reconstruction of past environmental changes. We conduct interdisciplinary studies on social-ecological systems exposed to strong anthropogenic pressures, based on sedimentary archives that allow us to reconstruct, over time, changes in biodiversity using fossil bioindicators combined with biomolecular tools. These analyses, discussed in parallel with landscape transformations, sedimentary flows, and the sources and impacts of pollution, provide a more detailed understanding of the land-sea *continuum* and the relationships between natural or anthropogenic forcing and environmental changes. These retrospective studies allow us to place current changes in a longer time frame and help us to simulate future trajectories, which are crucial in terms of the management of coastal social-ecological systems.

Ecosystems directly or indirectly benefit human societies, which in turn interact with ecological systems. While the importance of biodiversity is now widely recognised, some of the links with ecosystem functioning and the services they provide are still poorly understood. Yet this knowledge is essential for guiding public action and contributing to the desired changes in practices, both individual and collective. Social science research focuses on the complexity of the social processes at the heart of these transitions: norms and institutions, economic and power issues, representations and social movements. They provide a better understanding of the way in which social groups and public policy-makers address these issues. Research on the effectiveness of the protection of the marine environment is necessary to improve the regulatory mechanisms essential to the preservation of ecosystems. We are thus developing a framework to improve understanding of how biodiversity protection measures can influence the maintenance of ecosystem functions that benefit both ecosystems and human societies.

On this basis, we will be able to propose a new generation of complex mathematical models including biological communities and habitats, to characterise the impact of disturbances on the functioning of ecosystems at different temporal and spatial scales. Both numerical and qualitative models will also allow alternative management or conservation strategies to be explored on the basis of scenarios. Finally, companion modelling and living labs are innovative practices that transcend disciplinary boundaries and are in direct contact with stakeholders.

Marine ecosystems also represent a new field of opportunity for the agri-food, chemical and pharmaceutical sectors. Our research focuses primarily on sustainable and responsible resource exploitation, the development of innovative and environmentally friendly technologies and the design of new means of bioremediation.

Coastal dynamics and complexity



Coastlines are fragile and complex interfaces. IUEM scientists use their interdisciplinary expertise to understand and address coastal challenges.

Trebeurden beach in the Côtes-d'Armor.

© Manuelle PHILIPPE | UBO

The coastline cannot be reduced to solely the coast, a line that fluctuates in time and space, or even to the intertidal zone, a coastal strip defined daily by tide levels. It is a unique interface located between the lithosphere, hydrosphere, atmosphere and anthroposphere.

The coastline thus begins on the fore-coast, from the submarine depths of the near continental shelf, which can be reshaped by ocean waves. It then extends over the intertidal space subject to subaerial and marine processes that define ablation coasts (which can only retreat, such as cliffs) and accumulation coasts (which can advance and retreat, such as dune belts), as well as estuaries. Finally, it includes continental coastal areas whose evolution remains under the influence of coastal processes. It is therefore a place of complex interactions between geological, hydrological, oceanic, atmospheric and meteorological processes. The combination of these processes determines both the formation and the permanent mobility of the coastline on all spatial and temporal scales of. This environment remains dependent on both the climatic variability that has existed since the end of the last ice age and the geomorphological legacies of earlier periods.

At the same time, because of its many resources and diverse amenities, the coastline is particularly attractive to humans. Consequently, coastal zone have witnessed a growing concentration of the world's population and activities, particularly since the middle of the 19th century. The densification of populations, activities and developments in these areas

leads to competition between activities, actors and users, which must be managed by defining integrated coastal zone management (ICZM) strategies at the international or state level, which are then implemented regionally or locally. At sea, Maritime Spatial Planning (MSP) is required not only because of the growing need for space at sea to accommodate new activities but also because of the current challenges of preserving ecosystems.

Understanding these natural and anthropogenic dynamics requires a systemic analysis and a fundamentally interdisciplinary approach. From local to regional or larger spatial scales, and on overlapping time scales, it combines the methods and techniques of geosciences and geography. Geomorphology, geography, geophysics, hydrodynamics, physical and chemical measurements, short-, medium- and long-term observations, spatial analysis, remote sensing and geomatics are applied to the understanding of natural processes. Human and social sciences (geography, sociology, environmental psychology, economics and law) are applied to the analysis and understanding of anthropic dynamics, public policies and management strategies.

This integrated approach supports expertise and reflection on the management of the coastal strip in terms of human activities and the preservation of natural environments, as well as about development, vulnerability and coastal risks, by integrating hazards (what can happen), issues (what we risk losing), management (how to deal with risks) and social representations (what people think).

It relies on co-constructed observation and decision-making tools (e.g. OSIRISC coastal risk observatory) to support coastal managers and involve citizens in monitoring their coasts (CoastAppli citizen science application).

Deep sea and open ocean

The deep sea and the high seas are frontiers of knowledge, at the crossroads of major international issues.

Bathymetric map of the East Sicily - Calabria region, Ionian Sea

© Marc-André GUTSCHER | CNRS

The extent and importance of the deep ocean environment, in terms of its contribution to global biogeochemical balances and mineral and biological resources, is only beginning to be measured. Several IUEM units are interested in this environment, which represents a final frontier to be explored and preserved. The high seas also present unique conservation challenges, which are difficult to grasp due to the fragmentation of governance beyond national jurisdictions such as exclusive economic zones.

The study of the biology and ecology of deep marine ecosystems requires a multidisciplinary approach considering both microbial and faunal compartments. The biodiversity, functioning and connectivity of communities within deep-sea ecosystems need to be better understood in order to assess their potential resilience to different degrees of disturbance, to identify indicators of change and to characterise tipping points. The study of the diversity and biology of microorganisms in hydrothermal springs and their adaptation to extreme conditions aims to better understand the functioning of this unique ecosystem from the ecosystemic to the molecular scale. To this end, oceanographic campaigns and technological development in the field of *in situ* observation are essential tools for research.

The deep ocean is the interface between the geological processes of the Earth's crust and the physico-chemical dynamics of the deep ocean. Geosciences research is particularly interested in mechanical couplings, chemical exchanges, transfers between the interfaces of the solid Earth and the surface spheres, dynamic processes at the origin of telluric hazards as well as

the sedimentary archives of these different processes. To conduct cutting-edge research in these fields, new methods of observation, sampling, analysis and instrumentation are being implemented both at sea and in the laboratory.

Knowledge of deep currents is important for understanding biodiversity and material fluxes as they influence the distribution and functioning of ecosystems, marine sediments and the fate of substances migrating from the solid earth to the ocean. Research teams at IUEM study the mechanisms and variability of deep convection, the evolution of deep ocean properties on long time scales, bottom currents and small-scale topography-induced turbulence. Despite the technological challenges of accessing them, seamounts, volcanoes and hydrothermal vents are both special environments and ideal areas for setting up monitoring networks through the installation of deep-sea observatories.

Under the international law of the sea, the ocean floor beyond 200 nautical miles enjoys the status of common heritage of humankind. The growing need for mineral resources and the prospects that genetic resources offer for biotechnologies challenge the capacity of this international regulatory regime to arbitrate between conservation and exploitation. The question of international governance dedicated to the protection of the high seas, in the sense of the water column, has been at the heart of an ambitious treaty being negotiated at the UN in recent years. The conditions for an effective protection and exploitation of these ecosystems are the subject of multidisciplinary research combining natural and social sciences, in direct contact with the political negotiation spaces stakeholders. Projects focus on the legal, economic and social dimensions of the management of deep-sea and offshore ecosystems under anthropic pressure, as well as on the development of stakeholder training and public awareness.

Training the scientists of tomorrow



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IUEM offers a complete and varied range of training courses in Marine and Coastal Sciences starting from the master's level.

Eight master's degrees in Marine and Coastal Sciences

The Marine and Coastal Sciences training area is unique in France. It comprises eight master's degrees, each of which covers different aspects of marine and coastal sciences, according to their respective fields of study.

- Biotechnology
- Biology
- Marine Environmental Chemistry
- Law of Maritime Spaces and Activities
- Applied Economics
- Environmental Management
- Physics
- Earth, Planetary and Environmental Sciences

Backed by the research laboratories of IUEM and their partners, these master's offer the best learning conditions to train future professionals who are experts in their fields and capable of establishing collaborations between natural and social sciences. Our objective is to train researchers and managers capable of understanding current and future scientific issues in order to provide answers based on interdisciplinary approaches.

Doctoral School of Marine and Coastal Sciences

The Doctoral School of Marine and Coastal Sciences (EDSML) is a multidisciplinary thematic school that offers 22 doctoral specialities, covering the fields of Life Sciences, Earth Sciences, Humanities and Social Sciences and Engineering Sciences. Hosted at IUEM, it aims to federate the disciplines involved in the study of the marine environment and participates in the construction of a culture of marine sciences, which extends to the human and social sciences.

EDSML provides high-level doctoral supervision by hosting PhD students in leading research laboratories. Its ambition is to train the scientists and decision makers of tomorrow, capable of providing high-level expertise on an increasingly uncertain ocean and planet.

▲ Immersed in the research teams and trained in cutting-edge techniques, students at the institute benefit from a «tailored» learning environment.

Class of 2019. New EDSML PhD graduates at the UBO graduation ceremony.

New audiences, new practices



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◀ In addition to master's and doctoral courses, IUEM is strongly committed to the evolution of teaching practices and their opening to new audiences.

At the Mer et Education summer school, a researcher works with secondary school teachers to raise awareness of the various dimensions of marine science.

Continuing education

Continuing education is one of the missions of universities. It enables people to acquire new skills throughout their careers in order to return to or remain in employment and to optimise and secure their professional careers. In this context, the University Service for Continuing Education and Work-linked Training (SUFGA) of UBO offers a complete catalogue of short or degree courses in all of IUEM's fields of excellence to support both individual and group projects.

New pedagogies

To strengthen the professional integration of students, the educational engineering team accompanies the evolution of teaching, particularly through the support and training of teacher-researchers and doctoral students.

Within the Interdisciplinary Graduate School for the blue planet ISblue, IUEM develops innovative teaching practices through various formats: interdisciplinary project-based teaching, learning by doing, use of immersive environments. These innovations allow us to offer new learning tools to all audiences.

Internationalisation of training

IUEM encourages the international mobility of all of its undergraduate and post-graduate students and staff, notably through programmes such as the ISblue University Research School and the SEA-EU European alliance.

International opening of the Marine and Coastal Sciences training programme is a priority for IUEM. Both master's degrees in Marine Physics and Biotechnology are taught in English. IUEM participates in several training programmes at European and intercontinental levels:

- IMBRSea, International Master in Marine Biological Resources ;
- double degree programme with UQAR (Quebec) and dual certification with CIBNOR (Mexico) ;
- a short and intensive training course on the interconnected aquatic environments of the land-sea *continuum* in partnership with the University of Utrecht (Netherlands).

In addition, IUEM shares its know-how innovative and multidisciplinary training with its partners in southern countries, notably in Latin America and Africa.

Observing to understand

© Erwan Amice | CNRS

At the beginning of the 21st century, the sea is a subject of major scientific and societal focus. IUEM's mission of observation is to study it over the long term, so as to understand it and to predict its evolution in the context of climate change and local constraints. Since 2005, IUEM is one of the 25 national observation institutes supported by CNRS.

IUEM conducts its Observation mission in synergy with its Research and Training missions and considers this as a long-term federating axis of ideas, projects, achievements and expertise.

IUEM carries out its Observation mission by coordinating more than ten monitoring systems which, through regular and long-term measurements (over several decades), build up physical, chemical, biological, floristic or faunistic databases, available to the scientific community and the public.

The Observation mission combines measurements, experiments and modelling with regard to past and future trajectories. The sea and its evolution are approached from all disciplinary fields, including the national instrumented sites of the sciences of the universe (SNI OHASISBIO and REVOSIMA/MAHY), but above all by the national observation services (SNO) on the high seas (SNO-Argo) and coasts (SNO-Somlit/Coast-HF/Dynalit), on the life sciences (SNO-Phytobs/Benthobs) and on human and Social sciences through observation of the socio-ecosystem of the Brest-Iroise Workshop Area (ZABrI).

In particular, IUEM is in charge of:

- the quality and sustainability of the resources and skills mobilised;
- the optimal coordination of resources;
- the links between stakeholders (actors, services and organisations);
- the alignment of the national compliance strategies of the different schemes.

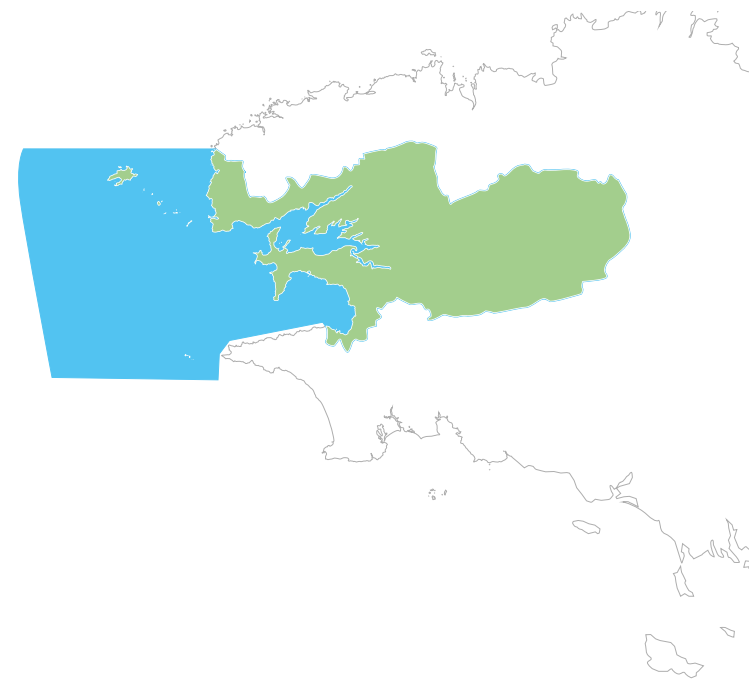
With several decades of experience, IUEM is a leading contributor to knowledge of the evolution of the sea system, and is a key player in federating, structuring and carrying out observation of the sea at regional, national and international levels. Today, in order to better respond to societal needs, IUEM is focusing its Observation mission on the Man-Earth-Sea *continuum* with a multidisciplinary and integrative approach.

To collect more data and make society aware of its role as an operator for the preservation of the environment, IUEM has included citizen participation in its observation approach, through systems such as CoastAppli (smartphone application for participatory monitoring of coastal hazards), Ecoflux-Bretagne (monitoring of water quality and biodiversity along the land-sea *continuum* by schoolchildren) and Objectif Plancton (collection of plankton by recreational boaters).

▲ From the Brittany coast to the warm seas of the tropics or the icy seas of the poles, IUEM plays an essential role in observing an environment that is undergoing radical changes.

An IUEM researcher explores an ice cave in Antarctica.

ZABri, the Brest-Iroise workshop area



The Brest-Iroise Workshop Area

The Workshop Areas (ZA) form a broad inter-agency network for interdisciplinary research on social-ecological systems in relation to societal issues of national interest.

The Brest-Iroise Workshop Zone (ZABri) is a scientific project supported by the CNRS Institute of Ecology and Environment (INEE) since 2012. It focuses on the coastal socio-ecosystem of the Iroise Sea, the Bay of Brest and its catchment areas. It is coordinated by three IUEM laboratories (LETG-Brest, LEMAR and AMURE) and brings together a group of researchers from different universities and institutes conducting environmental research in the context of integrated management, sustainable development and transformation along the land-sea *continuum*. The workshop area also involves a large number of non-academic partners: protected areas, local authorities, associations, professional groups, watershed managers and scientific outreach stakeholders.

The work combines environmental sciences and human and social sciences around four major issues:

- vulnerability to coastal hazards;
- water quality and biodiversity along the land-sea *continuum*;
- sustainability, between conservation, restoration, exploitation and uses;
- long-term trajectories of social-ecological systems.

▲ The ZABri extends from the Brest harbour to the Iroise sea, from the catchment areas to the islands. It represents approximately 6,690 km², of which 3,730 km² are at sea.

◀ Young grey seal in the kelp in the Iroise Sea.

Opening science to the world



◀ As an actor of a open and shared science, IUEM plays an essential role as an intermediary for a wide audience of schoolchildren, teachers and actors of the civil and associative world.

Produced in partnership with Océanopolis, the photographic exhibition Plastik Panic, presented in the busy Brest marina, warns of ocean pollution by plastic and shows the science being done at IUEM on this subject.

Since its inception, IUEM has been committed to an innovative and ambitious approach to decompartmentalise the world of research and the rest of civil society. From mediation actions towards the general public to projects at the interface between arts and sciences, including training for audiences traditionally far from the laboratories, IUEM innovates to bring its scientists into dialogue with a variety of audiences.

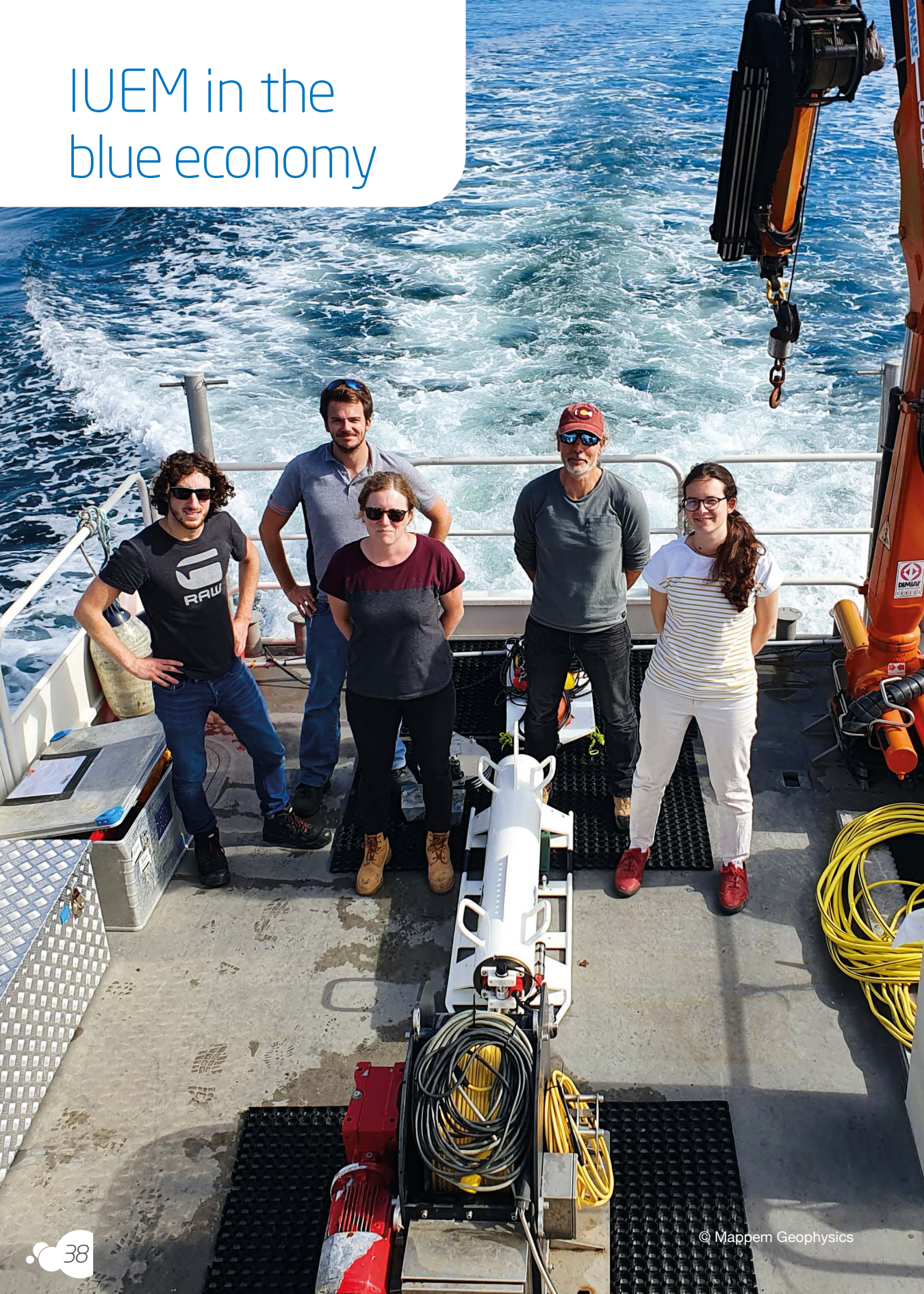
Enthusiasm for communication on the part of researchers from IUEM and research structures in Brest, combined with a strong partnership with the Brest aquarium and sea life center Océanopolis, has made the tip of Brittany a particularly dynamic region, rich in scientific culture events. Our teams are widely involved in national and European scientific communication events such as the Fête de la Science and European Researchers' Night and regularly come into schools to explain their work, show the pupils their tools and present their results through adapted equipment. IUEM regularly designs and produces exhibitions on its research themes for the general public.

OCEANOLAB, the result of a collaboration between Brest and Océanopolis, is a project unique in the world, bringing together scientists from IUEM and Ifremer with the aim of jointly and simultaneously carrying out research activities and sharing scientific knowledge. Experimental structures have been set up at Océanopolis, as has equipment for scientific communication, allowing the public to access science «in real time».

Our training courses, which are provided for a variety of audiences (journalists, secondary school teachers, managers of natural areas, industry representatives), include summer universities and thematic schools and can rely on a catalogue of online courses (MOOC and SPOC) developed at the Institute and made available on a dedicated platform.

IUEM is also a seedbed for pioneering and fruitful initiatives between the arts and sciences. Many visual artists, musicians and authors have collaborated with our research teams for more than ten years in order to sensitively express the subjects and work carried out at the Institute. These dialogues have given rise to exhibitions (Ocean and Climate, Arctic Blues, Myctophidae, Rhizaria) and are at the origin of the Ressac Festival of Arts and Sciences supported by UBO.

IUEM in the blue economy



◀ IUEM's involvement in the economic sphere is growing, through the business start-ups and research and developments projects.

MAPPEM Geophysics is an independent and, above all, innovative company that uses its unique expertise in marine site investigation to support various industrial offshore projects using electromagnetic techniques.

The research work of IUEM laboratories is the source of many innovations being valorised in the economic world: expertise, technology transfers, and the creation of innovative companies.

To achieve this, IUEM works on maritime themes in synergy with innovation partners: the Pôle de compétitivité Mer Bretagne-Atlantique (Brittany-Atlantic Sea Competitiveness Cluster), SATT Ouest Valorisation (Technology Transfer Acceleration Company), Technopôle Brest-Iroise, and business incubators and nurseries. Together with these partners, IUEM promotes the technological innovations resulting from its research, the know-how and skills of its scientists and the resources of its laboratories, and helps entrepreneurs to develop their products.

Thus, young innovative companies have been created as spin-offs from IUEM in the fields of:

- sea aquaculture and abalone farming: FRANCE HALIOTIS;
- 3D geophysical imaging: IMAGIR and MAPPEM GEOPHYSICS;
- geomatics applied to integrated coastal zone management: TERRAMARIS;
- analytical and expert services in elemental and isotopic geochemistry: SEDISOR.

The scientific and geographical proximity of IUEM to these young innovative companies ensures the development of strong links and multiple relationships. These take the form of support and commitment from the original laboratory to the start-up (hosting, research collaboration) and enable new research themes to be identified that can respond to problems encountered by the companies.

To go further



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