Marine Biotechnology in western France

This document was produced by the Europôle Mer Working Group on Marine Biotechnology set up in 2013. Composed of members from academia and innovation & technology transfer support structures in the French regions of Brittany and Pays de la Loire, this group met five times in 2013 and 2014 in Roscoff, Saint-Nazaire, Plouzané and Lorient. Sub-groups were formed to write the research, education & training and technology transfer sections of this document.

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EXECUTIVE SUMMARY

Marine (= blue) biotechnology, i.e. the utilisation of marine bioresources as targets or sources of biotechnology applications, is a field with massive potential for innovation and economic growth. In the context of rapid climate change and increasing pressure on natural resources, recent advances in methodology and technology, particularly in bioprocessing, and in the study of marine biodiversity in conjunction with the various omics fields have fostered renewed interest in marine biotechnology. Marine biological resources hold potential as sustainable raw materials for use in diverse fields, including nutrition, health, agriculture, aquaculture, energy, environment, and cosmetics. Marine biotechnology is now recognised as a strategically important field at European, national and regional levels.

The present document, compiled by the Marine Biotechnology Working Group of the “Europôle Mer” consortium, reviews the skills, actors and principal infrastructures in regard to marine biotechnology in the western French regions of Brittany and Pays de la Loire to identify their strengths and weaknesses and propose strategies to stimulate the development of this strategic domain.

Marine biotechnology is an integral part of the Smart Specialisation Strategies of both maritime regions, which have more than 3000 km of coast and numerous assets for becoming a hub of excellence for marine biotechnology. These include high-quality, internationally renowned research laboratories and university degree programmes in marine biology and engineering (bioprocessing), a strong inter-regional technology transfer ecosystem, and a dynamic and diversified network of private-sector companies.

However, marine biotechnology would benefit from greater inter-regional coherence and synergy between stakeholders, which call for undertaking specific actions in the following domains:

- communication: implementation of a shared and proactive communication strategy;
- research: provision of further support for fundamental research and research infrastructures; funding of proof-of-concept studies to bridge the gap between public-sector and private-sector research;
- education & training: development of multidisciplinarity in existing education & training programmes; identification of the skills needed at each level of the value chain and proposal of targeted vocational training courses to fill gaps; involvement of academic, technology transfer and industry actors in moulding the future education & training landscape;
- technology transfer: definition of a national strategy for the development of marine biotechnology activities, identify the Technology Readiness Level of projects and provide support accordingly; support for the creation of public-private laboratories, demonstrator facilities and science parks.

RÉSUMÉ

Les biotechnologies marines (ou biotechnologies bleues), c’est à dire l’utilisation des bioressources marines en tant que cibles ou sources d’applications biotechnologiques, constituent un domaine qui recèle un énorme potentiel pour l’innovation et la croissance économique. Dans un contexte de changement climatique et de pression croissante sur les ressources naturelles, les biotechnologies marines connaissent actuellement un regain d’intérêt grâce d’une part aux progrès méthodologiques dans le domaine des bioprocédés et d’autre part à l’avancée majeure des connaissances sur la biodiversité marine accompagnée de la révolution dite « omique ». Les ressources biologiques marines constituent en effet une matière première durable pour une exploitation dans divers domaines d’application tels que la nutrition, la santé, l’agriculture, l’aquaculture, l’énergie, l’environnement et les produits cosmétiques. Les biotechnologies marines sont désormais reconnues comme un domaine d’importance stratégique aux niveaux européen, national et régional.

Ce document, émanant du Groupe de travail sur les biotechnologies marines de l’Europôle Mer, vise à analyser les compétences, les acteurs et les principales infrastructures liées à la biotechnologie marine en Bretagne et dans les Pays de la Loire afin d’identifier les forces et les faiblesses du secteur et de proposer des stratégies pour stimuler le développement futur de ce domaine stratégique.

Les biotechnologies marines figurent parmi les domaines d’innovation stratégiques de la Stratégie Régionale de Soutien à l’Innovation (SRI-SI) des deux Régions Bretagne et Pays de la Loire, qui cumulent plus de 3000 km de côtes et disposent de nombreux atouts pour constituer un pôle de compétences majeur en biotechnologies marines. Le Grand Ouest bénéficie en effet de laboratoires de recherche et de formations universitaires en biologie marine et en ingénierie de grande qualité et reconnus au niveau international, d’une dynamique très forte de transfert technologique, ainsi que d’un tissu industriel dynamique et diversifié.

Néanmoins, les biotechnologies marines pourraient avantageusement bénéficier d’une meilleure mise en cohérence inter-régionale, d’une plus grande synergie des acteurs et de la mise en œuvre de mesures spécifiques dans les domaines suivants :

- communication : mettre en œuvre une stratégie de communication mutualisée et offensive ;
- recherche : soutenir des programmes de recherche inter-régionaux Bretagne et Pays de la Loire ; soutenir davantage les infrastructures de recherche et la recherche fondamentale ; financer des études de preuve de concept afin de combler le fossé entre le secteur de la recherche publique et le secteur privé.
- formation : développer l’interdisciplinarité dans l’offre de formation; identifier les compétences requises à chaque maillon de la chaîne de valeur « de l’idée aux marchés » pour proposer une offre de formation sur l’ensemble de cette chaîne de valeur, encourager l’implication des entrepreneurs dans l’orientation des cursus de formation ;
- transfert de technologie : élaborer une stratégie nationale de développement des activités de biotechnologies marines, identifier le niveau de maturation des projets (TRL) afin de les soutenir de façon adaptée; soutenir l’implantation de laboratoires public-privé ainsi que les installations de démonstrateurs et de parcs scientifiques.

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A BRIEF HISTORY

Kelp bed ©P. Potin, Roscoff Biological Station UPMC-CNRS

Marine biotechnology is an emerging field with promising potential in terms of innovation and economic impact. Although seemingly recent, this field began to gain momentum as early as the 1990s: visionary scientists were already convinced that marine organisms could be sources of new molecules and innovative solutions. In 1995, the European Society for Marine Biotechnology was founded in France and in 1999, it published the first issue of *Marine Biotechnology*, a journal that currently boasts an impact factor of 3.21 (the impact factor is an indirect measure of the prominence and the influence a scientific journal has). However, marine biotechnology actually began its success story in the 1970s-1980s with major discoveries in biochemistry and microbiology such as DNA polymerases, GFPs and innovative marine drugs. Nonetheless, at that time, this promising field did not receive much attention and neither researchers, public authorities nor the industrial sector showed much interest. The attractiveness of marine biotechnology has changed for the better over the last two decades, primarily due to progress in bioprocessing methods and advances in our knowledge of marine biodiversity with the development of omics studies and high-throughput sequencing. Today, the field of marine biotechnology enjoys renewed interest.

A prospective European study published in 2010 by the European Science Foundation [1] confirms that marine biotechnology will contribute significantly to providing solutions for the major societal challenges targeted in the Europe 2020 strategy. In particular, marine biotechnology will foster the transition from fossil fuels to renewable biofuels and produce food and feed without competing for arable land.

The world market for marine bioresources is estimated at €2.8bn and is growing by more than 10% annually [2]. The potential for growth is such that only 300,000 of the estimated several million living marine species (from the smallest microorganisms to the largest whales) have been inventoried [3]. Untapped marine biodiversity could well be the main source of new compounds of interest in the coming decades.

This rapid expansion of marine biotechnology coincides with the global issues of:

- increasing scarcity of raw materials and fossil energy,
- increasing scarcity of marine food resources,
- reducing energy consumption and greenhouse gases.

Marine biotechnology R&D embodies a sustainable development tool for economic stakeholders, offering two real advantages: better environmental protection and possible alternatives that comply with the ever-stricter regulations on chemical substances (REACH). The development of marine biotechnology also portends vast possibilities for the food, health and cosmetics sectors.

In addition, marine biotechnology has an environmental component: marine microalgae absorb CO_2 and have high potential for carbon capture and storage. These three main assets of marine biotechnology make it a truly cross-disciplinary field.

[1] European Science Foundation – Marine Board ; http://www.marineboard.eu/

[2] developpement-durable.gouv.fr

[3] *Livre Turquoise* (a report on the current state of and the opportunities and challenges for micro- and macroalgal biotechnology)

DEFINITIONS

The literature contains several definitions of marine biotechnology. We selected two definitions that best represent the specificities of this field in western France.

"The qualification and utilisation of marine bioresources as targets or sources of biotechnology applications". Marine biotechnology feeds into many different fields of application: health, nutrition, agriculture, cosmetics, energy, industrial processing, environment and aquaculture.

According to the OCDE, biotechnology is defined as "the application of sciences and techniques to living organisms to alter living or non-living materials for the production of knowledge, goods and services."

Unlike white, red or green biotechnology, which are characterised by their fields of application (respectively industry, medicine and agriculture), blue biotechnology is defined by its marine component: the resources or the targets of blue (marine) biotechnology are of marine origin.

Why is it useful and important to distinguish marine biotechnology from the other types of biotechnology? First and foremost, life began to evolve in the oceans 3 billion years ago and colonised land only 2 billion years later. This long period of evolution in the ocean led to an incredible amount of marine biodiversity that is to date still poorly studied and explored. Second, the very transient nature of marine environments (compared with terrestrial environments) makes them unique, comprising saltwater habitats that are very diverse, ranging from the intertidal zone to the deep sea. For example, chemical communication and signalling in marine organisms often involve molecules (usually secondary metabolites) that are different from those found in terrestrial organisms and still poorly known.

THE EUROPEAN AND INTERNATIONAL CONTEXT

Marine biotechnology is now recognized as a field of strategic importance in Europe and worldwide. In 2010, the Marine Board of the European Science Foundation published a position paper entitled "Marine Biotechnology: a New Vision and Strategy for Europe" that provided an overview of current knowledge, identified the major challenges for the sector and formulated recommendations for the development of marine biotechnology. In 2011, during the Seventh Framework Programme (FP7), the European Commission funded an 18 month Coordination and Support Action (CSA) called CSA MarineBiotech [1] to lay down the foundation of a European Research Area Network (ERA-NET) in marine biotechnology. The CSA included 11 partners (with the CNRS and Ifremer) from 9 European countries. ERA-MarineBiotech [2] was funded in the last FP7 call for proposals and was officially launched in December 2013. The consortium is made up of 19 partners from 14 countries. The natural partners of ERA-NETs are funding agencies; the primary vocation of an ERA-NET, other than establishing a common strategic vision, is to organise and fund calls for transnational projects. In October 2014, ERA-MarineBiotech issued its first call for research projects, focused on "the development of biorefinery processes for marine biomaterials". The topic of the second call in November 2015, was focused on “Bioactive molecules from the marine environment and Biodiscovery”.

Similarly, the Joint Programming Initiative Oceans (JPI Oceans), set up in 2011, includes marine biotechnology as one of its ten Strategic Areas. Finally, the European Commission's new Horizon 2020 (H2020) framework programme, and in particular the Blue Growth Strategy, clearly identifies marine biotechnology as a special focus area in its 2014-2015 work programme. In 2012, the OCDE organised a Global Forum in Vancouver on marine biotechnology called "Marine Biotechnology — Enabling solutions for ocean productivity and sustainability". This was the first time that the OCDE had officially acknowledged its interest in marine biotechnology, a sector that could potentially "contribute to the grand challenges of food and fuel security, population health, green growth and sustainable industries...". This event and the ensuing report [3] demonstrate that marine biotechnology has socio-economic importance and has become a market reality.

Finally, in the national and European landscape of research and innovation, Brittany and Pays de la Loire have clearly identified marine technology and the development of bioresources as one of their fields of strategic innovation (DIS) and specialisations in their respective regional Smart Specialisation Strategies (SRI-SI).

[1] http://www.marinebiotech.eu/csa-marine-biotechnology

[2] http://www.marinebiotech.eu/

[3] http://www.oecd-ilibrary.org/science-and-technology/marine-biotechnology_9789264194243-en

HIGH-QUALITY SHARED FACILITIES FOR RESEARCH AND BUSINESSES

Biogenouest Core Facilities

Biogenouest is a network of core facilities in western France for life and environmental sciences. Created in 2002, it federates 70 research units in western France and coordinates 32 platforms in Brittany and Pays de la Loire, pooling the technological resources of both regions. Biogenouest covers four main research areas: marine sciences, agricultural sciences, health sciences and bioinformatics.

The Biogenouest core facilities offer, at one or several sites, state-of-the-art equipment and highly-trained personnel to a broad community of users. These facilities provide services to public and private researchers and are structured around 6 technological areas: genomics, proteomics, functional exploration, bio-imaging, structural analysis and metabolomics and bioinformatics. Annex 1 gives a more detailed description of these platforms.

Biological Resource Centres and Animal Resource Centres

Biological Resource Centres (BRCs) are a key element that underlie infrastructures for biotechnology and life sciences. They include service providers and collections of live organisms (microorganisms, marine algae and animals) and derived biological materials (e.g. DNA, tissues), as well as the databases of these collections. Animal resource centres are also key infrastructures for researchers in the life and environmental sciences.

In Brittany and Pays de la Loire, 6 BRCs and 1 animal resource centre are specific to marine biotechnology (see Annex 2).

AlgoSolis R&D facility

Set up by the University of Nantes — the contracting authority — and operated by the GEPEA Laboratory (UMR University of Nantes/CNRS/Ecole des Mines de Nantes/ONIRIS), the AlgoSolis project was selected by the French Investments for the Future scheme for the Pays de la Loire region to establish an R&D facility dedicated to the microalgae production and biorefining. Since May 2015, this public collaborative infrastructure has been facilitating industrial-scale applications involving microalgae, including the production of 3rd generation biofuels, which are still in the research phase, as well as food supplements, animal feed, cosmetics, construction materials and CO_2 reuse.

http://algosolis.com

The AlgoSolis R&D facility © GEPEA -Algosolis

The EMBRC

The Europe-wide infrastructure European Marine Biological Resource Centre (EMBRC [4]), whose strategic importance has been recognised by the European Strategy Forum on Research Infrastructure (ESFRI) is represented in western France by the the Roscoff Biological Station (UPMC-CNRS). The mandate of the EMBRC is to deliver the marine biological resources, services, technology and know-how harboured at European marine stations to the scientific community and businesses at large to foster the exploration of marine biodiversity, from molecules to complex ecosystems. The EMBRC links up with diverse other national and European infrastructures.

Kelp bed in the Iroise Sea © Erwan Amice / CNRS

Competitiveness clusters

Impelled by government-sponsored calls for projects (DATAR and DGE/DGCIS) in December 2004, Brittany and Pays de la Loire formalised new networking tools for research and industry to facilitate innovative public-private projects. The government defines competitiveness clusters as follows: "*Competitiveness clusters federate small and large businesses, research laboratories and training and education institutions located within a well-defined geographic area around a specific theme. Competitiveness clusters were created to support innovation. They foster the development of particularly innovative collaborative research and development (R&D) projects. They also assist the development and the growth of member companies through the marketing of new products, services or processes that arise from research projects. Competitiveness clusters have strong local roots and draw on the existing fabric of structures (industry, campus, local and regional infrastructures, etc.)*"[5]

In 2005, four competitiveness clusters (called *pôles* in French) were created:

- Pôle Mer Bretagne (expanded to include Pays de la Loire, changing its name to Pôle Mer Bretagne Atlantique in 2014) with a set of strategic actions dedicated to marine biological resources, headquartered in Brest.
- Valorial and its interest in marine bioresources as future health and food ingredients, headquartered in Rennes.
- Atlanpole Biotherapies for health-targeted applications of marine biotechnology, headquartered in Nantes.
- Images et Réseaux and its interest in bioinformatics, headquartered in Lannion.

These four competitiveness clusters occupy the inter-regional territory covered by Brittany and Pays de la Loire.

Technology Transfer Accelerator companies

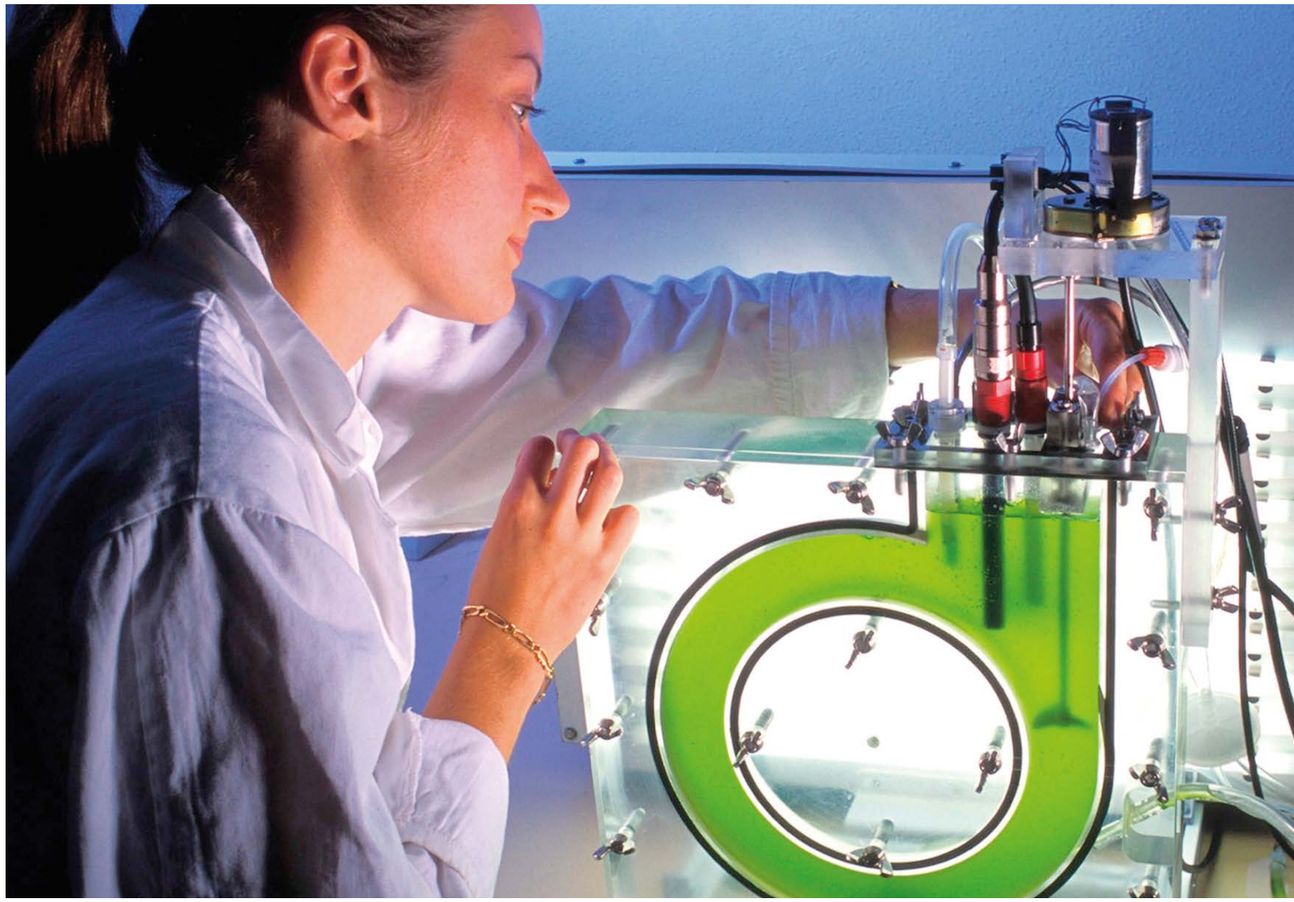
Technology transfer accelerators (TTAs) were created from the Investments for the Future call for projects sponsored by the Ministry for Higher Education and Research.

TTAs are regional agencies that strive to enhance the role that higher education institutions can actively play in regional, national and European economic development. They have funding capacities to invest in R&D projects selected by their staff that correspond to market needs. There are currently 14 TTAs in France and the TTA Ouest Valorisation [6] covers western France.

[4] www.embrc.eu

[5] http://competitivite.gouv.fr/politique-des-poles

[6] http://www.ouest-valorisation.fr/



GEPEA-CNRS Laboratory © University of Nantes

This document was written by the Europôle Mer Working Group on Marine Biotechnology to paint an accurate picture, with some quantitative indicators, of the who-what-where of marine biotechnology in western France today. It identifies the regional strengths and the weaknesses in marine biotechnology and points the way forward to consolidating and improving the current momentum through enhanced cross-disciplinarity and inter-regional coordination. It is divided into three sections — (1) research, (2) education & training and (3) innovation & transfer — and concludes with some recommendations from the Working Group to promote and bolster marine biotechnology in western France.

MARINE BIOTECHNOLOGY RESEARCH

GEPEA © Nicolas Job / HEOS Marine

THE FORCES PRESENT IN BRITTANY AND PAYS DE LA LOIRE

Marine biotechnology is a key field of research in Brittany and Pays de la Loire, two maritime regions that offer undeniable assets. With over 300 people working in its universities and research centres, western France is a European hotspot for marine biotechnology and its applications that target many sectors (human and animal health, nutrition, plant protection and nutrition, cosmetics, environment, aquaculture, bioprocessing and energy). Figures 1 and 2 provide a catalogue of the human resources and the spectrum of marine organisms studied in western France. The research and education institutions draw on the high diversity of marine resources found in these two maritime regions and possess a large range of expertise, spanning marine (micro- and macro-) algae, animals (invertebrates and fish), microorganisms (viruses, bacteria, archaea and fungi, including many extremophiles) and the active compounds extracted from these organisms (enzymes, polysaccharides, lipids, proteins, peptides, etc.). The two regions turn out a high percentage of doctoral students, representing 25% of the total staff involved in marine biotechnology.

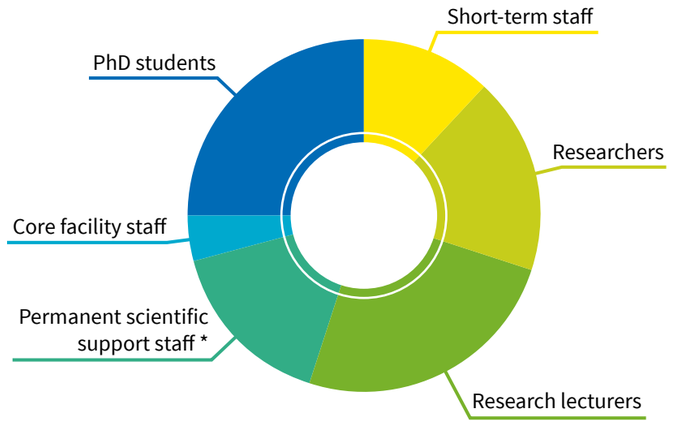
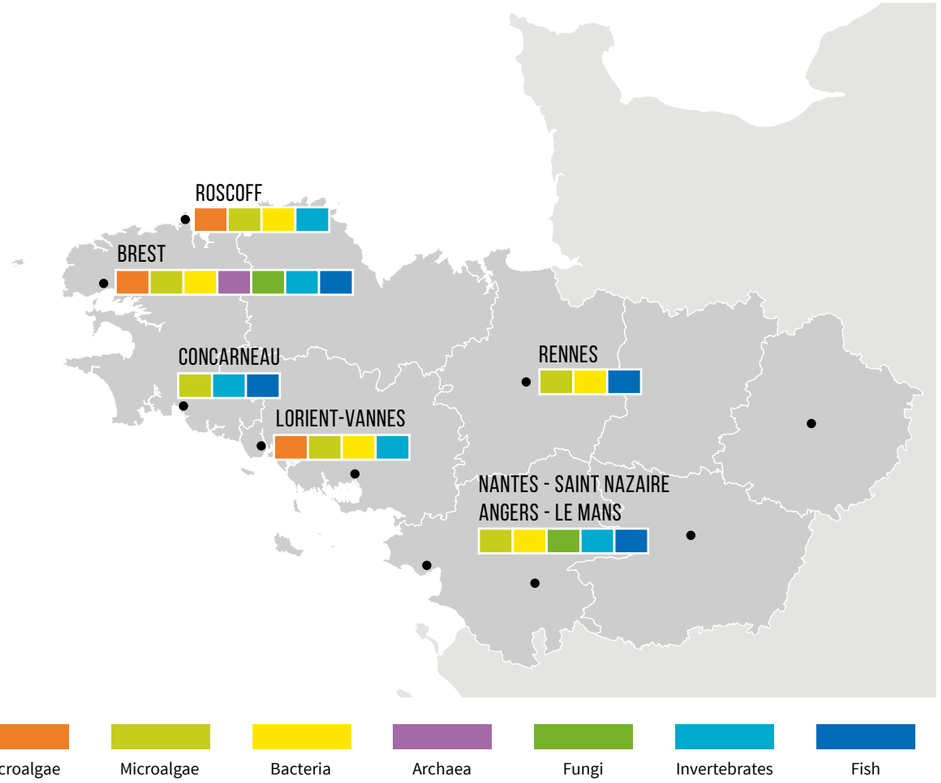


Figure 1. Distribution of people (300 scientists in all) working on marine biotechnology projects in Brittany and Pays de la Loire.

*: Engineers/ Technicians/ Administrative staff



BREST - PLOUZANE: 58 PERS.

Research laboratories:
LEMAR, LM2E, AMURE, Ifremer-RDT, LUBEM, Geoarchitecture

CONCARNEAU: 8 PERS.

French National Natural History Museum (MNHN)

LORIENT - VANNES: 26 PERS.

Research Laboratory : LBCM

NANTES - SAINT NAZAIRE - ANGERS - LE MANS: 145 PERS.

Research laboratories:
GEPEA, MMS, LEMNA, EM3B, PBA

RENNES: 17 PERS.

Research laboratories:
Agrocampus Ouest, LPGP

ROSCOFF: 59 PERS.

Research laboratories:
FR2424, AD2M, LBI2M, P3H

Figure 2. Map of the laboratories involved in marine biotechnology research

THE VALUE CHAIN

Western France benefits from multidisciplinary and complementary expertise in ecology, ecophysiology, phytology, animal production, microbiology, molecular biology, genetic engineering and omics sciences, as well as in biochemistry/chemistry and bioprocess engineering, geared to marine environments. Research groups thus have advanced knowledge of many marine ecosystems and can contribute to all levels of the value chain, from the identification and characterisation of marine models to the production of goods for applications (cited above) in response to pressing economic and societal needs (Figure 3).

Moreover, the presence of high-level skills in sectors peripheral to biotechnology (optoelectronics, photonics, information and communications technology, imaging, computer science, bioinformatics) in Brittany and Pays de la Loire is a major advantage for the development of marine biotechnology.

Furthermore, R&D is one of the priorities and recommendations of the Marine Board [4] and the National Strategy for Research and Innovation (SNRI) [5].

Some examples of marine biotechnology applications and their value chains:

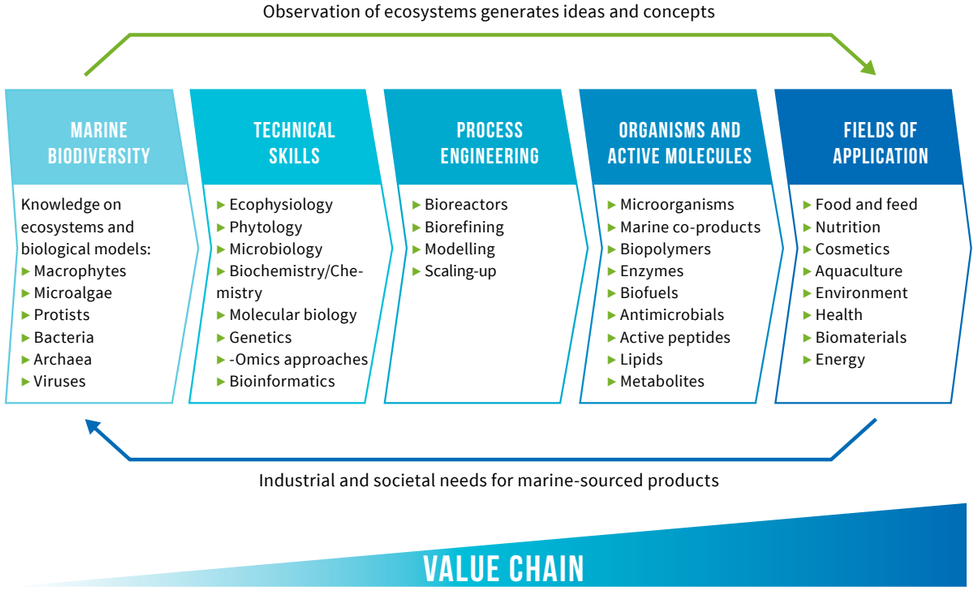


Figure 3. Value chain for marine biotechnology research in Brittany and Pays de la Loire

[4] Position Paper 15 Marine Biotechnology: A New Vision and Strategy for Europe

[5] (*Stratégie Nationale de Recherche et d'Innovation*) (SNRI): environmental emergency and ecotechnologies

The field of marine glycobiology perfectly illustrates the complementary skills and technology found in Brittany and Pays de la Loire.

Western France features a number of assets in this field that come into play across the entire value chain, including in particular:

- expertise in marine biology and marine chemistry research,
- expertise in compound analysis (chemistry and biochemistry of poly- and oligosaccharides),
- facilities and companies to screen and test the activities of active compounds,
- businesses to develop these compounds for food applications (nutraceuticals), cosmetics, plant protection or animal and human health.

Polysaccharides that elicit the natural defence mechanisms in land plants

From 1999 to 2006, a pioneering French private-public joint research unit (UMR) crystallized the close collaboration between Goëmar laboratories, the CNRS and UPMC. Together, they developed the first version of Iodus®, an elicitor of natural plant defence mechanisms. This plant protection product is based on laminarin, a polysaccharide extracted from *Laminaria digitata*, a brown seaweed. All the activities of the value chain took place in western France.

EXTRACTION → SCREENING → CARACTERISATION → VALIDATION → FORMULATION → REGULATION AND REGISTRATION

Polysaccharides for cosmetic applications

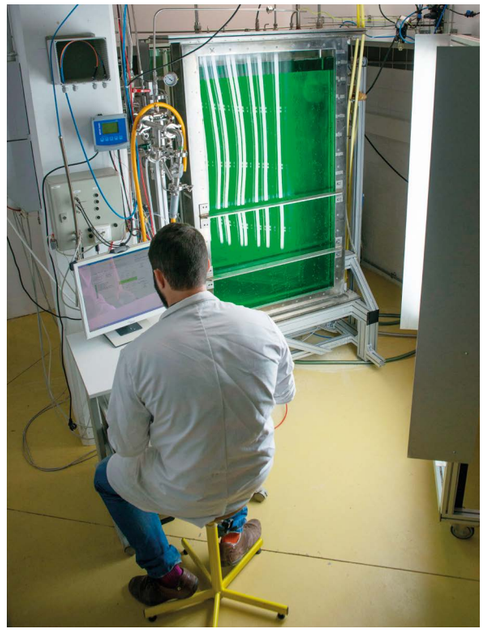
Abyssine®, a Lucas Meyer Cosmetics product, is used in cosmetics. It was developed from exopolysaccharides extracted from an extremophile that Ifremer discovered in marine hydrothermal vents.

PRODUCTION OF BIOACTIVE INGREDIENTS FROM MARINE BACTERIA → PURIFICATION → CHEMICAL MODIFICATION DEPOLYMERISATION → CHARACTERISATION → FORMULATION → REGULATIONS AND REGISTRATION

Gas chromatography analysis of fatty acids in microalgae © Nicolas Job / HEOS Marine

Biorefinery of microalgae and cyanobacteria

In the late 1990s, collaboration between GEPEA-CNRS and the Alpha-Biotech company at Assérac (location of the AlgoSource Group production and refinery site) led to the development of novel bioresources and extracts (pigments and proteins) for the cosmetics and nutraceutical markets (e.g. Spirulysat®). This synergy between a university, the CNRS and private industry continues today and focuses on industrial ecology and circular economy approaches (reuse of CO_2, nitrogen and waste heat produced by factories) targeting industrial-scale utilisation of microalgae for biorefining purposes.

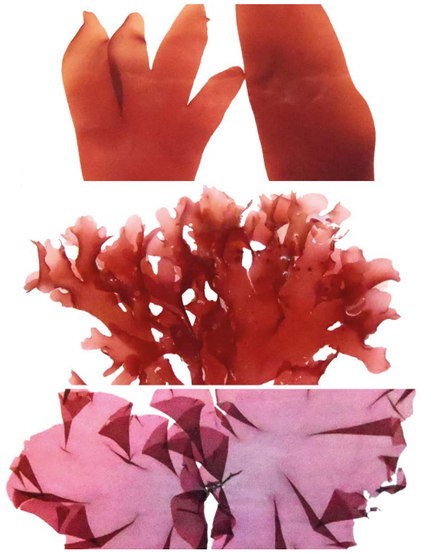


Microalgal cultivation in a glass plate photobioreactor at AlgoSource
© Nicolas Job / HEOS Marine

Red seaweeds and blood disease treatments

Collaboration between the European Institute for Marine Sciences (IUEM-UBO), a leukaemia support organisation (FLE), the Brest University Hospital and CNRS/UPMC led to the discovery of a red seaweed-sourced molecule, called SC2310, that amplifies the host immunity response. A patent was filed in June 2014. SC2310 has been tested in the treatment of blood disorders that respond to immune system stimulation (such as leukaemia, skin melanomas and some cancerous kidney tumors).

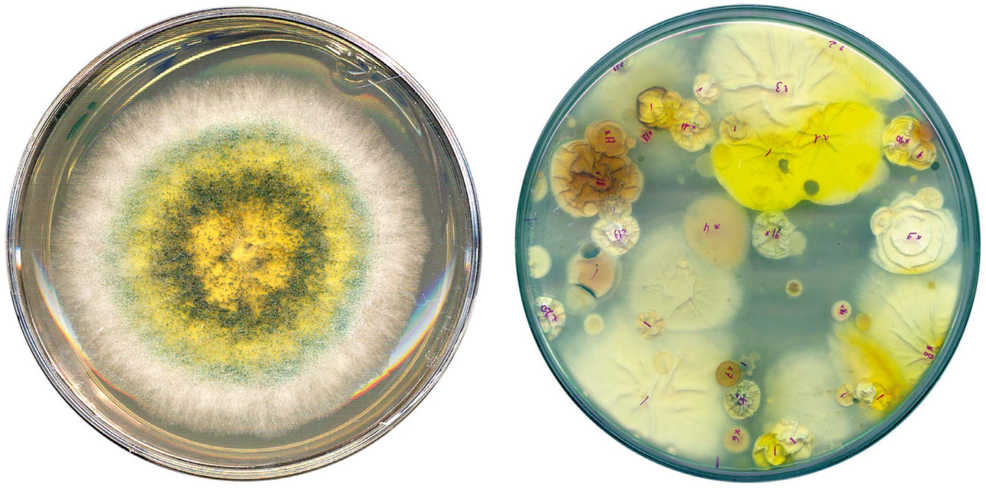
The private research institute IRTMS SAS, equally held by the Quéguiner Group and FLE, was created in Brest on 14 November 2014, .



Red seaweed © Gaspard Delebecq

Marine fungi

Research on bioactive metabolites of terrestrial micromycetes began following the discovery of penicillin. Since then, micromycetes have been an important source of compounds used in medicine, such as cephalosporins, cyclosporins and statins. Although only recently brought into the spotlight, marine fungi are now one of the main reservoirs of new molecules of interest for human and animal health, plant protection, nutrition and protein engineering.



MMS Laboratory © University of Nantes

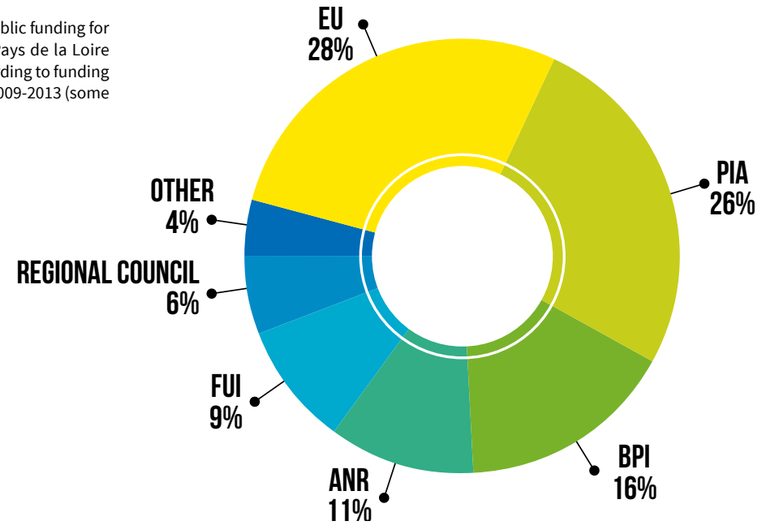
FUNDING SOURCES

In France, there are no specific calls for funding marine biotechnology and marine biology research. However, western France is a key partner in many European projects that involve marine biotechnology (Macumba, BioCare, Marmed, etc. to mention just a few) and in several Investments for the Future (PIA) projects (Idealg, Océanomics and EMBRC, LabexMER, etc.). For the 2009-2020 period, funding sources have diversified and they are distributed in Brittany and Pays de la Loire essentially via European programmes, the PIA scheme and the public investment bank BPI France (formerly OSEO) (Figure 4).

A detailed list of current research projects is given in Annex 3. Private partners generally reap only modest public funds, and thus invest their own funds, contributing up to 45-50% of the project budget for SMEs (European definition) and 25% for holding companies.

The connections between academia and industry are strong. Figure 5 shows that more than half of the funded projects have private-sector partners. From 2009 to 2013, an average of 20 collaborative projects in marine biotechnology were launched each year.

Figure 4. Distribution of public funding for projects in Brittany and Pays de la Loire (for a total of €171m) according to funding source (in percentage) in 2009-2013 (some projects run until 2020).



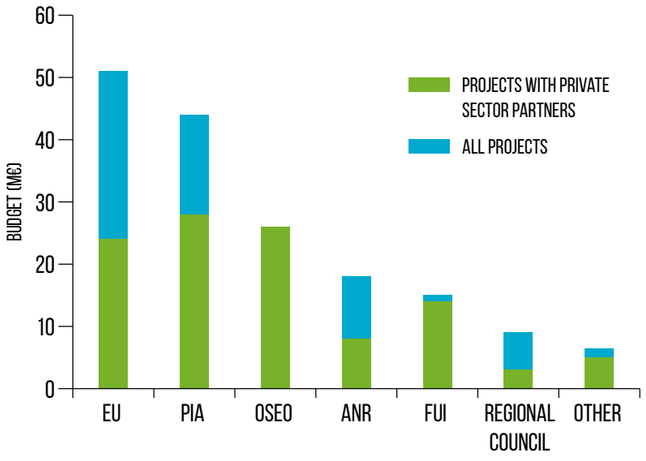


Figure 5. Funding sources for projects involving marine biotechnology in Brittany and Pays de la Loire from 2007 to 2020. In green: projects without private-sector partners. In blue: projects with private-sector partners (see also Annex 3).

SWOT ANALYSIS: RESEARCH

STRENGTHS

- Nationally and internationally renowned basic and applied research
- In-depth knowledge of numerous marine ecosystems and technical expertise in genetic engineering, biochemistry/chemistry, cultures, animal production, extraction (refining)
- Rich and diversified base of actors: critical mass (300 scientists) for international visibility
- Multidisciplinary and complementary skills and expertise in marine resources (culture collections: protists, algae, animals and microorganisms) with a clear utilisation potential for macro- and microalgae, from biodiversity to biorefineries
- Analytical tools, core technology facilities, biological production facilities, high-throughput microorganism isolation techniques, controlled bioreactors, extraction techniques, biochemical, genomic and bioinformatics characterisation

WEAKNESSES

- Lack of a national framework for marine biotechnology, no targeted programmes, no specifically marine-oriented strategy in biotechnology
- Lack of a clear national position at the European level
- Low level of collaboration between researchers in Brittany and Pays de la Loire. There are a few inter-regional projects, but there is ample room for more.
- Lack of high-capacity culture systems for large-scale molecule production processes (culture, production, extraction, purification, etc.)
- Proof of concept: the phase between research, laboratory pilot projects and pre-industrial/industrial upscaling lacks the tools for formalising business arrangements and appropriate funding support.

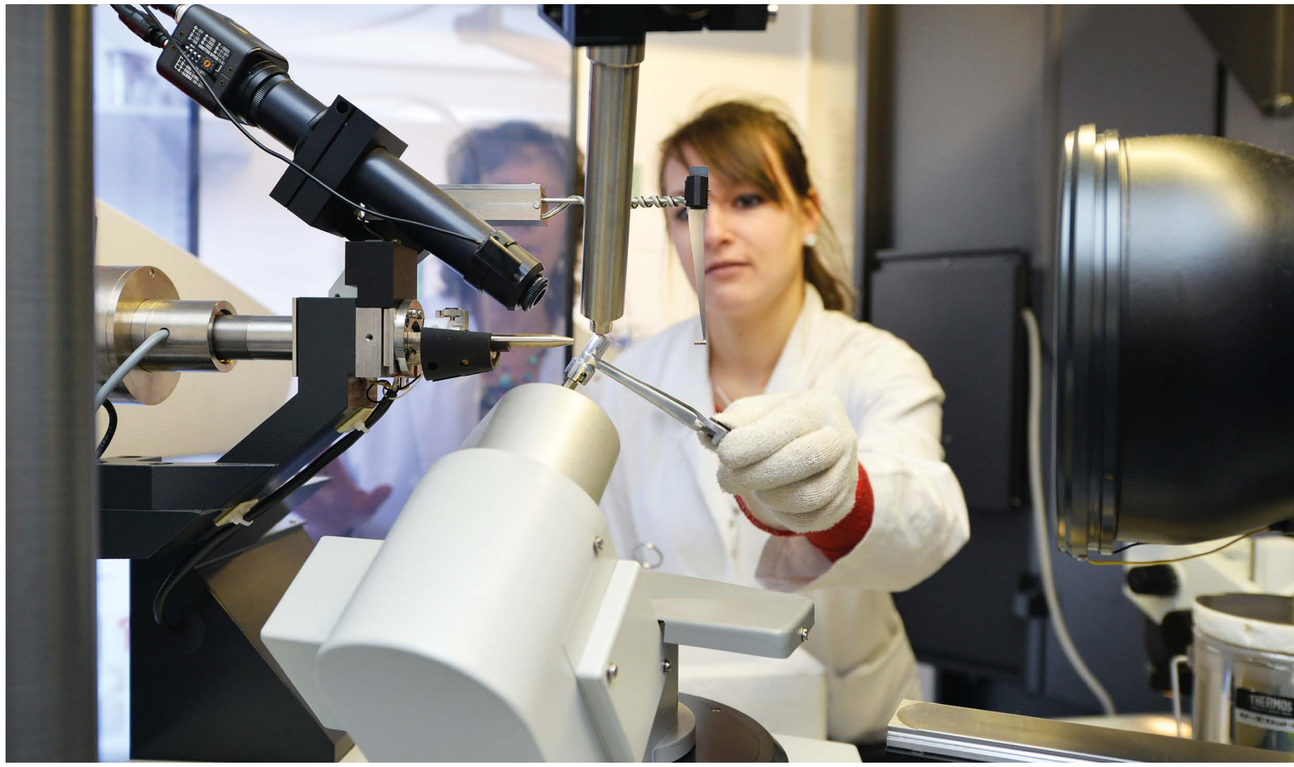
OPPORTUNITIES

- Western France possesses the resources to define a specific framework to cover the spectrum from biodiversity to product/service development (high potential for research, industrial development and coordination) and to consolidate European (e.g. EMBRC Europe), national and inter-regional networks
- Development of the collaborative potential of biology and engineering with the social sciences (law, economy, geography, sociology)
- Synergy between Brittany and Pays de la Loire (UBL COMUE), partnerships between UBL/UPMC . Improvement of inter-regional cooperation and synergy via inter-regional programmes and appropriate funding schemes
- Enhancement of funding tools to accompany initiatives: there are R&D-targeted funds but few carry through to industrial upscaling, which must pass the proof-of-concept, transfer and pre-industrial development phases ("valley of death" between TRL* 3 and 6)

* Technology Readiness Level

THREATS

- Regulations, costs, resulting delays ("novel foods", pre-clinical and clinical trials, etc.)
- Access to resources (biomass security, large-scale microorganism cultures)
- GMOs - risk of dissemination, brand image
- Poor estimation of time required for biotechnological development(s)
- Unfocused activities
- Difficulty in finding a viable economic model for core facilities
- In light of current budget restrictions, risk of favouring short-term, i.e. downstream, strategies at the expense of advances in long-term, upstream knowledge Both strategies must be tackled together.



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Brittany and Pays de la Loire have undeniable strengths in the field marine biotechnology research: a wide range of expertise, international and national renown, more than 300 researchers and novel core facilities. However, given today's world, the sector is fragile. It is important for the long-term development of marine biotechnology to maintain a high level of excellency in basic research to:

- *continue to contribute to discoveries of new molecules and new marine organisms,*
- *consolidate the characterisation of mechanisms of action (structure-function relationships) that underlie the validation of new activities with innovative potential.*

EDUCATION & TRAINING IN MARINE BIOTECHNOLOGY

OVERVIEW AND ANALYSIS OF THE CURRENT MARINE BIOTECHNOLOGY EDUCATION & TRAINING COURSES IN BRITTANY AND PAYS DE LA LOIRE

The 14 marine biotechnology degree programmes [1] draw 250 students per year (most of whom are pursuing a Master's degree) to the universities and higher education institutions (HEIs) of Brittany and Pays de la Loire (COMUE). They are located in Brest (IUEM-UBO), Nantes/Angers/Le Mans (UNAM), Roscoff (UPMC-Biological Station), Lorient-Vannes (UBS) and Rennes/Fouesnant-Beg Mail/Angers (Agrocampus Ouest). In addition, two engineering degree programmes in Process and Bioprocess engineering (Polytech Nantes/Saint-Nazaire) and Microbiology and Quality (ESIAB-UBO) are offered. Although none of the short training programmes (i.e. 3rd year university degree (Licence) and undergraduate technical degrees (BTS, DUT)) have specific electives in marine biotechnology, they are a key link to the education programme. For example, third-year university programmes in Biology or Biochemistry pave the way to the specialised Masters' programmes in marine biotechnology. University Institutes of Technology (IUT) train technicians (mainly in biological engineering and process engineering for bio-industries) who are operational as soon as they obtain their degree. However, more than 30% of DUT degree holders continue on to Masters' courses and nearly 15% go to engineering schools.

Breton biotechnology companies that responded to the Capbiotek survey (Inventaire EducBio CapBiotek 2013) highlight the high scientific quality of the current education & training programmes. However, half of the companies indicated that the technician degree programmes fall short of meeting the needs of the private sector. Recent graduates lack knowledge in one or several of the following fields: cross-cutting knowledge (project management, marketing, business economics), general business operations (budgeting, basic management techniques, etc.), proficiency in English and knowledge specific to a given sector, such as product ranges, product life cycles, clinical research, quality assurance, standards and regulatory aspects (intellectual property, patents, contracts, European schemes, etc.).

In addition, the compartmentalisation of degree programmes (medicine, pharmacy, engineering, life sciences) does not fit well with the multidisciplinary needs of private business. For example, teaching in the health fields is generally geared to care and does not particularly encourage cross-over to industry. In life sciences, the long degree programmes tend to lead to opportunities in basic research rather than applied research. Finally, there are few bridges that allow unconventional, cross-disciplinary course curricula. In biotechnology, common core courses (biology, business management, human resource management) should be distinct from specialisation courses.

[1] *Excerpted in part from the EducBio 2013 Capbiotek report (list of graduate degrees in Annex 5)*

This brief overview of the marine biotechnology education & training landscape in Brittany and Pays de la Loire shows that the degree courses do not clearly cater to local businesses — due in particular to a lack of coordination among HEIs — and do not adequately sell their recent graduates, the skills they've learned nor their fields of predilection. An inter-institution partnership (Roscoff Biological Station, UBS, UBO) was created in 2013 with the new Master specialisation "Marine Biology and Bioresources" (SBR, UPMC). This partnership allows a cross-over of students among the SBR-UPMC Masters' programmes and some core course modules are shared with the other Masters offered at SBR-UPMC, UBS and UBO. This is the first step towards a better coordination of the degree programmes offered at the various universities. In western France, this type of partnership is expected to expand upon creation of an association of universities and HEIs (COMUE) in Brittany and Pays de la Loire. Finally, despite some recent initiatives commended by industry, universities have not sufficiently developed their offer of continuing education modules. However, the skills needed in blue biotechnology evolve at a fast pace, and would benefit from co-constructed training sessions orchestrated by academic and industry professionals alike.

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STRATEGY AND PLANNED ACTIONS

To improve the attractiveness of marine biotechnology degrees for businesses and the draw of recent graduates towards the new jobs created in conjunction with the sustainable development of marine biotechnology value chains (see Annex 5), two main actions are required.

Creation of a regional directory of jobs, skills, and training/degree programmes in marine biotechnology

This directory is managed by UBO in collaboration with the Brest science park (Technopôle Brest-Iroise) and lists all the programmes offered within the Brittany-Loire COMUE and UPMC-Roscoff. It is partially funded by a pilot action (Activity 5) of the European project Atlantic Blue Tech that aims to "devise and support the marine bioresources sector in 2014-2020".

The directory will be dedicated to the sustainable exploitation of marine biodiversity and will cover the four value chains (see Figure 6), the affiliated jobs and skills and the training programmes that lead to those jobs. The directory will also be available in electronic formats.

Enhancing the offer of continuing professional education programmes

Based on recommendations formulated in the SWOT analysis, links with the business world must be strengthened by developing an original continuing education programme, associating the vocational schools, the engineering schools and the universities in western France.

The goals are to:

- Supplement the degree programmes offered in higher education and research institutions in western France
- Meet the specific needs of businesses, and anticipate them by training recent graduates for the jobs of the future and in all the necessary skills, from basic to practical knowledge (researchers, engineers, technicians, sector professionals). Continuing education programmes will showcase the latest tools and the latest research results at the crossroads of biological sciences, metrology and data processing, social sciences, etc. to meet the expectations and the needs of the business world.
- Offer training programmes that address emerging concepts and models. These programmes target operators, supervisors, managers as well as entrepreneurs to enhance the skillbase of businesses in Brittany and Pays de la Loire with training in cutting-edge technologies (processes, omics, etc.), innovation, market and marketing expertise, business plans and models, etc.

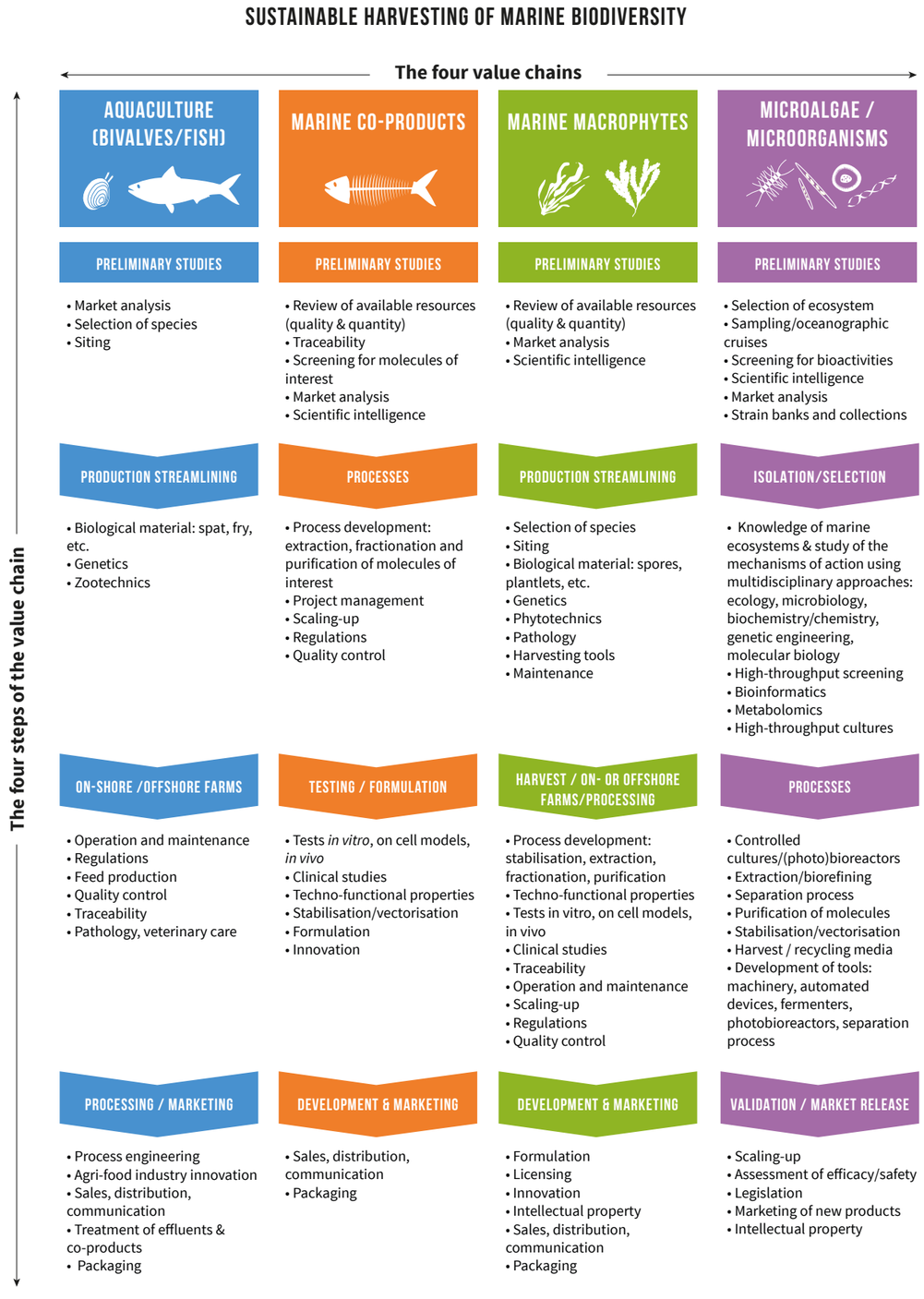

Figure 6. Value chains for marine biotechnology education & training in Brittany and Pays de la Loire

A CATALOGUE OF CONTINUING EDUCATION PROGRAMMES THAT CATER TO THE VALUE CHAIN

A catalogue of short courses (1 to 2 days) will be issued each year in collaboration with the continuing education departments of HEIs and with organisations that already offer continuing professional education courses (i.e. ADRIA, CRITT, etc.). It will be sent out by email to marine biotechnology businesses via the competitiveness clusters, science parks, technical transfer centres, SATT, Carnot Institute, etc.

Technical training

...provided through courses, conferences, workshops with case studies.

Examples of possible themes:

The "Fish/Shellfish Farming" value chain

- Production of microalgal feeds for aquaculture (Ifremer, Univ Nantes)
- Bivalve model: Managing the early developmental stages of farmed species: reproduction, nutrition, metabolism, etc. (Ifremer)
- Fish model: Managing the early developmental stages of farmed species: reproduction, nutrition, metabolism, etc. (Ifremer)
- Aquaculture operations and disease prevention in bivalve hatcheries (Ifremer, UBO)
- Omics techniques for traceability, genotyping, QTLs, etc. (SBR-UPMC, CNRS, UBO, Ifremer).

The "Marine Co-products" value chain

- Upgrade marine waste and co-products using membrane separation systems (UBO, Univ Nantes, CNRS, Ifremer, ONIRIS)
- The flavour of marine products: How should it be assessed? How can it be improved? (Univ Nantes, ONIRIS, UBO)
- Marine lipids: diversity, analytical tools and biotechnology applications (CNRS, UBO, Univ Nantes, SBR-UPMC)
- Enzymatic hydrolysis for the production of new functional peptides: pH-stat method; quality control (NIR, SEC-FPLC). Uses in Cosmetic and food sectors (UBO, CNRS, IFREMER, ONIRIS)

The "Seaweeds and Marine Plants" value chain

- Seaweeds: resources, extraction, fractionation/purification, characterisation of therapeutic substances (UBO, SBR-UPMC, Univ. Nantes, CNRS)
- Seaweeds: Taxonomy (UBO-SBR-UPMC), Resources (CEVA & Ifremer), Food uses (CEVA)
- Seaweeds and their uses for food, drugs and cosmetics: overview and potential for development (UBS, UBO, SBR-UPMC)
- Seaweed cultivation: methods, maritime spatial planning and regulations (SBR-UPMC, UBO, Ifremer)

The "Microalgae & Microorganism" value chain

- Photobiotechnology and culture of marine microorganisms in bioreactors: strain selection, extraction, biorefining, development (Univ Nantes, CNRS, Ifremer, UBO)
- Microalgae, biorefining (Univ Nantes, CNRS)
- Bacterial biofilms and anti-biofilm activities (UBS, UBO, Ifremer)
- Technological potential of new culture methods designed for marine microorganisms and/or extremophiles (UBO, Ifremer, Univ Nantes, CNRS) and development of their biomolecules

Other possible training courses

- Adding value to biological resource centres by upgrading cultures to meet international standards
- Membrane separation to reuse marine substances
- Introduction to Process/Bioprocess engineering

Cross-cutting training programmes

...in conjunction with innovation

- Creativity and risk analysis for innovative development in marine biotechnology
- Efficient information data trawling and scientific intelligence
- Intellectual property and patents
- Regulations and laws
- New markets (agro-support, biomaterials, green chemistry, energy, etc.)
- Innovation ecosystem to foster research partnerships
- Positioning western French businesses to participate in European H2020 programmes

SWOT ANALYSIS: EDUCATION & TRAINING

STRENGTHS

- High level of excellency in education & training with attractive programmes on a national level
- Critical mass and a regional distribution of research and training expertise
- The Pôle Mer Bretagne Atlantique competitiveness cluster endorses select training programmes, thereby highlighting their pertinence with regard to the new professions created by innovation projects and making them more attractive to students (higher education and vocational degree courses)
- Investment for the Future projects
- Core facilities for demonstration and training
- Identification of similar fields of strategic innovation (DIS)* in Brittany and Pays de la Loire: maritime activities for blue growth (Brittany) & maritime industries (Pays de la Loire)

WEAKNESSES

- Businesses do not preferentially call on graduates of the degree programmes offered in Brittany and Pays de la Loire
- Recent graduates may lack general and cross-cutting business education
- Culture of innovation and entrepreneurship needs nurturing
- Few or no interdisciplinary programmes that cut across sectors, markets or industries

OPPORTUNITIES

- Creation of a Brittany-Loire COMUE to promote the emergence of structured and attractive training programmes (Bioprocessing and blue technology was explicitly identified in the Coastal and Marine Sciences department at UBL, as at SBR-UPMC)
- Multiple transversal research and innovation assets that feed into Masters' programmes
- The need to update skills, expertise and qualification of all personnel within companies
- Development of e-learning

THREATS

- Poor coordination among degree programmes and scant interdisciplinarity
- Competition between universities
- Students' relative disinterest in the sciences
- Drop in competitiveness of French businesses due to an insufficient level of qualification in emerging technologies

* DIS : Fields of Strategic Innovation

MARINE BIOTECHNOLOGY TECHNOLOGY TRANSFER & BUSINESSES

GEPEA © Nicolas Job / HEOS Marine

Marine biotechnology contributes to the development and optimisation of new products for health, agriculture, agri-food, cosmetics, fine chemistry and environmental protection. It thus targets niche markets for its high value-added products turned out in limited volumes (particularly fine chemical reagents), but also the mass market for products such as bio-sourced polymers.

WESTERN FRANCE: A MARITIME REGION FOR THE TRANSFER AND INDUSTRIAL DEVELOPMENT OF MARINE BIOTECHNOLOGY

In terms of development, "Blue Biotechs" are part of the regional expression of European policies that aim to invest in **productive hubs of economic activity in maritime regions**. Marine biotechnology is clearly mentioned as a new economic opportunity stemming from marine science and technology research, particularly for pharmaceutical and food uses.

To support technology transfer, biotechnology businesses benefit from a rich and diversified R&D network in western France. The major research partners (namely the CNRS, Ifremer, universities, MNHN; see Figure 2) rely on national and/or European scientific projects. Innovation activities are organised into networks (science park associations, technology transfer centres, competitiveness clusters, etc.) to accompany businesses during their whole developmental cycle and help them interact with research institutes, support agencies (SATTs), etc.

Marine biotechnology constitutes the building blocks of the Investments for the Future programmes fuelled by the national government and the regional and inter-regional economic development strategies for biotechnology (Capbiotek, Blue-Cluster, Pôle Mer Bretagne Atlantique).

PANORAMA IN WESTERN FRANCE

Map of businesses

Some marine biotechnology businesses are still **exploratory in nature** and have not yet matured. These businesses extend the exploration of marine resources to identify, using more applied research, new biological resources. The oldest companies must continue to innovate to remain competitive, particularly in light of recent regulatory changes (e.g. REACH), which often involve large investments. Businesses in western France are often SMEs or large corporate groups. Middle-market companies are relatively rare in western France.

However, several international studies indicate that the prospects for marine biotechnology businesses are very good, with a **high potential for growth**; they occupy the "Research-Development-Innovation" niche touted as the **European competitive advantage**.

In terms of knowledge transfer, other than the traditional issues of intellectual property (IP), marine biotechs also include a **specific legal component** for exploiting marine biodiversity, given the bioprospecting regulations in various geographic zones (access to Public Maritime Domains, Rio Convention, EEZs, MPAs, OMRs, etc. [6]

In 2014, 125 business were censused in Brittany and Pays de la Loire (Figure 7). One-quarter of them focus their activities on screening strains, characterising biological materials, or the production and transformation of marine biomass. Other businesses specialise in the development of new products and/or services emanating from marine biomass for various industries (food, nutrition, cosmetics, health, etc.).

The vast majority of these business are microenterprises (fewer than 10 employees). Of these, spin-off companies from research institutes, such as Ifremer or CNRS, universities, have considerable potential for development. Academic expertise is valuable for the development of these innovative new companies.

Similarly, other businesses from the economic sphere also draw on public laboratory expertise to ensure their development.

[6] EEZ-Exclusive Economic Zone, MPA- Marine Protected Area, OMR-outermost regions

MARINE BIOTECHNOLOGY IN BRITTANY AND PAYS DE LA LOIRE: 125 BUSINESSES

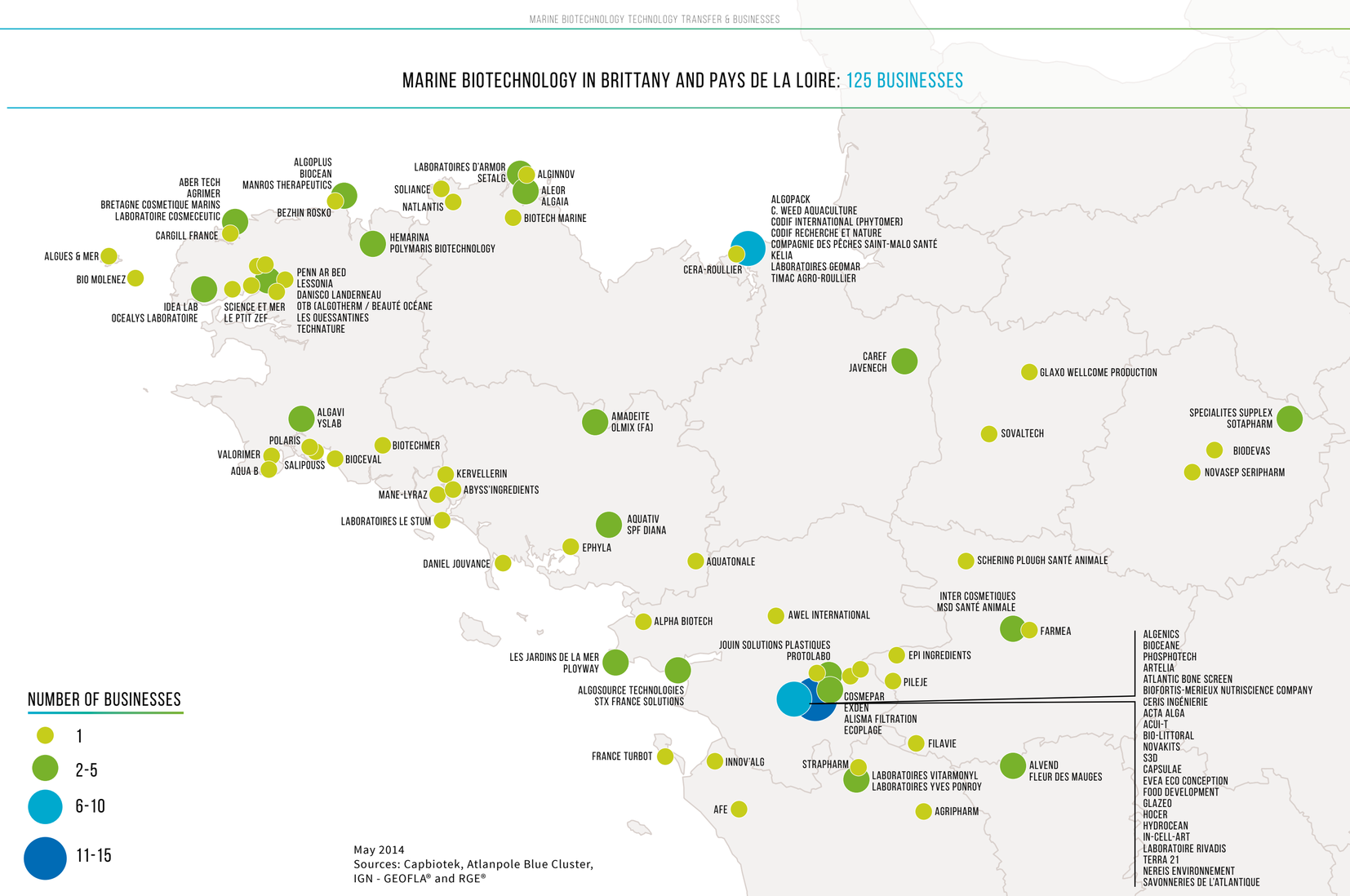

Figure 7. Map of marine biotechnology businesses in Brittany and Pays de la Loire

The dynamics of technology transfer and business creation

The players in technology transfer and innovation

The innovative character and the high originality of marine biodiversity promise to be sources of intellectual and industrial property and high added value. **SATT Ouest Valorisation**, **science parks**, **European Business and Innovation Centres (BICs)** and **incubators**, **innovation & technology transfer agencies** (**CBB Capbiotek** et **ID2Santé**) and **technical centres** (CEVA, ID-Mer, Vegenov) are all references for the emergence, transfer and development of innovative projects. They also assist academic spin-offs, the creation of start-ups and businesses and the development of existing businesses.

Stakeholders, laboratories and businesses are organised in various networks, including the competitiveness clusters Pôle Mer Bretagne Atlantique (PMBA), Valorial, Atlanpole Biotherapies. They all accompany innovative public-private collaborative projects, with the goal of promoting excellency and creating jobs, thus nurturing and consolidating the development and transfer ecosystem in western France. These networks are part of regional actions that endorse biotechnology: Capbiotek in Brittany and Blue Cluster in Pays de la Loire.

Regarding competitiveness clusters, the national strategy called 3.0 (transition from the "project factory" to the "product factory") is a key factor in the support of industrial development and transfer activities. Pôle Mer Bretagne Atlantique has a special role to play. Its strategic road map for 2013-2018 includes six Strategic Action Domains (DAS), one of which is dedicated to marine biological resources (DAS4), including marine biotechnology (Federating Programme PF7).

Encompassing Pays de la Loire since 2014, Pôle Mer Bretagne Atlantique is also working to expand and include Basse-Normandie. Pushing back the borders of western France will ramp up the transmission between research and the economic and corporate worlds and serve as a tremendous vehicle for development.

Overview of industrial property

The development of a marine biotechnology industry relies on patents, a key driver behind innovation. The analysis of filed patents provides an indication of the dynamics of innovation in a given field.

From this original viewpoint of economic dynamics, the analysis shows that the marine biotechnology industry in the Brittany and Pays de la Loire regions is growing strong, with 381 patents filed from 2000 to 2011. This figure is very promising given the profile of the businesses involved, mainly start-ups, microenterprises and SMEs. The temporal pattern of patent filing paints an interesting picture of the production of innovation in a field. Figure 8 shows a steady increase in the number of patents filed over 10 years. Patents filed today are innovations placed on tomorrow's market.

In addition, Figure 9 indicates that the academic sector is the leading filer, with the next three being — unsurprisingly — businesses. Nationwide, across all sectors, private industry is the leading patent filer (for 20 patents filed, 17 are filed by private companies and 3 are filed by a public institution [7]).

This analysis also shows that only 7 of the 124 businesses listed in the biotechnology sector in Brittany and Pays de la Loire) are in the top 20. This observation indicates that businesses need to strengthen their industrial property assets, particularly through partnerships with academic research.

In addition, the analysis of marine biotechnology patents in France (Annex 6) demonstrates that research in western France fosters high vitality in this field.

[7] L'Expansion "**Les champions français du dépôt de brevets par Samuel Baudoui**", published on 05 April 2013

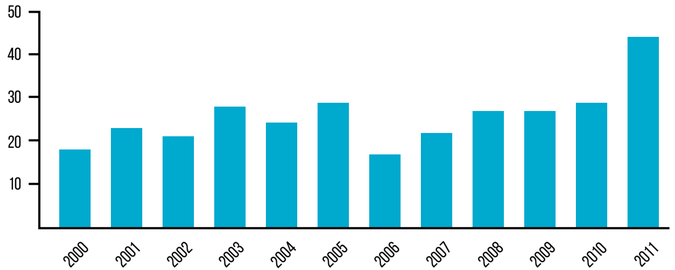

Figure 8. Number of patents filed yearly in Brittany and Pays de la Loire from 2000 to 2011.

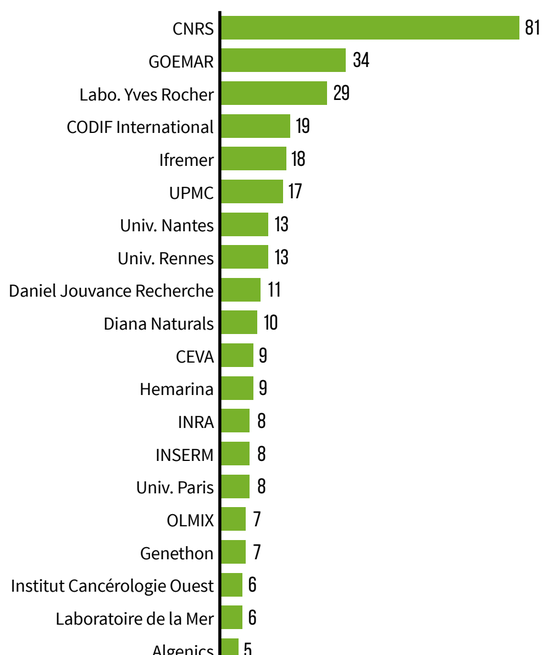

Figure 9. Leading patent applicants in Brittany and Pays de la Loire

The transfer value chain

The production and utilisation of biomass requires the selection and characterisation of organisms, the production of biomass (culture or collection), the separation of biomass from water, water recycling, biorefining, and the qualification and development of molecules of interest. Products output from this value chain are intended for various markets: energy, environment, cosmetics, agri-food and health.

One of the major economic targets is the design and optimisation of processes.

The main challenges that remain are
- the exploration and exploitation of biodiversity and its functions
- the utilisation of all biomass (biorefining)
- the control of production costs
- the upgrading of wastewater
- water recycling: minimisation of environmental impacts,
- the acceptability of new uses and new products,
- the great increase in regulatory hurdles
- the conflicts of use for access to marine areas.

VALUE CHAIN: MASS PRODUCTION AND DEVELOPMENT OF BIOMASS

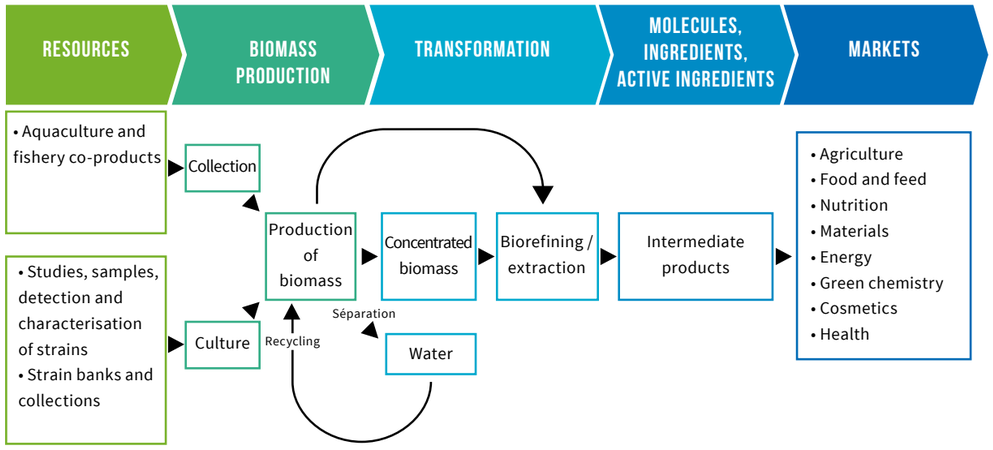

Figure 10. Marine biotechnology value chain for economic development

MARINE BIOTECHNOLOGY TECHNOLOGY TRANSFER & BUSINESSES

Markets

There are many areas of application: cosmetics, food, feed, nutrition, health, agriculture, materials, green chemistry and energy.

The markets for cosmetics, food and feed and nutrition are the most mature. They have double-digit annual growth rates owing to the current popularity of natural ingredients. In nutrition, the market is turning more and more to healthfood in the goal to "live longer and healthier".

The market for the health sector is still in its early stages. This market is taking two approaches: (1) using the marine organism as a "cellular factory" to produce molecules of interest (proteins, vaccines, etc.) or (2) using marine biomass as a source of marine molecules (pigments, secondary metabolites, polymers such as exopolysaccharides, etc.) for the fight against cancer, tissue repair, reduction of obesity, the fight against neurodegenerative disease, infectious diseases, etc.

Finally, energy and green chemistry are emerging markets, but hold high promise in the long term. No products are currently on the market, but there are important R&D programmes (3rd generation biofuels, bioasphalt, biodegradable plastic, wastewater treatment, etc.). The agro-support market is in a more advanced stage, with products already on the market.

All of these markets aim to increase the added value of their products, find economic and eco-efficient models, and strive to attain large-volume, low-cost production. In certain cases, profits can only be turned by implementing a **biorefining** approach that utilises all the biomass produced or extracted. Marine biotechnology associated with bioprocessing can also contribute to the establishment of a veritable industrial ecology that produces value-added biomass while decreasing industrial-sourced CO_2, nitrogen, phosphorus and waste heat.

SWOT ANALYSIS - TRANSFER

STRENGTHS

- 124 companies, innovative job-creating SMEs, with high growth potential
- Dynamic research laboratories and core facilities that work with businesses
- Network of partners at all stages of the value chain
- High awareness of industrial protection rights in academic research since 2007
- High-growth markets: food/feed, cosmetics, health, environment, materials, energy...
- Presence of technology transfer centres, innovation support agencies and science parks
- Presence of inter-regional competitiveness clusters: Pôle Mer Bretagne Atlantique, Atlanpole Biotherapies, Valorial, Images et Réseaux
- Availability of local resources (vertebrates, invertebrates, plants/algae) that can be developed for added value.
- Presence of Biological Resource Centres

WEAKNESSES

- Modest bioproduction capacity: small volume, low industrialisation
- Many microenterprises (<10), few mid-market companies
- Few investment funds solicited for marine bioresources
- Many regulatory barriers (environmental, administrative, etc.) for production
- Low level of participation of businesses in European and international projects, lack of local research-business interactions
- Low number of companies applying for patents

OPPORTUNITIES

- Social challenges of the H2020 programme
- Strong national government endorsement for the development of biotechnology
- Strong regional strategies to support the development of biotechnology
- Marine biomass, an alternative to food biomass,
- High consumer demand for bio-sourced natural products
- Increased regulatory requirements on the traceability and quality of products
- Strong need for storage and added value of biological data and skills in western France to meet these requirements (IT and bioinformatics expertise)
- Increased regulatory requirements on product quality (absence of contaminants): opportunity for bioservice companies

THREATS

- Development of bioproduction or biorefining tools in other geographic areas
- Private capital difficult to attract in France
- Student disinterest in the sciences: loss of competitivity in higher education institutions, risk of recruitment difficulties for businesses Uncertain protection of biotechnology inventions in the USA

According to the Regional Strategy for Economic Development, Innovation and Internationalisation (SRDE3I) in Brittany and the la commission Plant, Marine, Agriculture Commission (VAM) of the regional committee for research and technological development (CCRRDT) in Pays de la Loire.

MARINE BIOTECHNOLOGY TECHNOLOGY TRANSFER & BUSINESSES

Freeze-dried powder and microalgae © Nicolas Job / HEOS Marine

Ultrafiltration pilot plant GEPEA-CNRS © Nicolas Job / HEOS Marine

CONCLUSIONS AND RECOMMENDATIONS

Microalgae bioreactor GEPEA-CNRS © Nicolas Job / HEOS Marine

WESTERN FRANCE, A HUB OF EXPERTISE IN MARINE BIOTECHNOLOGY

With more than 3000 km of coastline and numerous talents, Brittany and Pays de la Loire are two maritime regions that make western France a major hub of marine biotechnology, boasting high-quality world-class research laboratories and university degree programmes in marine biology and engineering, a high technology transfer rate and a network of diverse industries (SMEs, mid-market companies, large corporations). Western France benefits from a fabric of more than 120 businesses that have access to a structured inter-regional ecosystem (SATT, GIS Europôle Mer, ID2Santé, CBB Capbiotek, Atlanpole Blue Cluster, Pôle Mer Bretagne Atlantique, Valorial, Atlanpole Biothérapie competitiveness clusters…) that fosters their development.

Marine biotechnology is one of the strategic innovation domains of the Strategic Plan to Promote Innovation (S3) in Brittany and Pays de la Loire.

Despite this hotbed of talents, marine biotechnology still suffers from low visibility and support in western France (near absence of inter-regional schemes) as well as on a national level (weak lobby in Europe and few earmarked programmes) and would benefit from enhanced inter-regional coherence and stronger synergy among partners.

COMMUNICATION

Define a genuine coordinated, common, co-operative, proactive communication strategy.

Currently, many marine biotechnology events are organised in both regions. The multiplicity of these events tend to dilute the message and dissociate those who attend them. Without going so far as merging events into one single convention, inter-regional coordination of forums, meetings, conferences, etc. is desirable. For example, the Blue Cluster Forum, which was organised for 4 consecutive years in Pays de la Loire, with 3 sessions in partnership with Pôle Mer Bretagne Atlantique, could switch off between Brittany and Pays de la Loire. In addition, a large bi-regional flagship fair with an international scope could alternate between regions and, insofar as possible, incorporate existing events. This type of well-advertised, periodic event would be a showcase for marine biotechnology in western France and would help create bridges between all the stakeholders in the field. This approach could be extended to other recurrent events that take place in Brittany and encompass Pays de la Loire. Thus, Western France could become more attractive for hosting big-name conferences on marine biotechnology, national and international congresses (ex. National conference of the French Process Engineering Society, Alg'n'Chem, International Society for Applied Phycology (ISAP) Congress, etc.).

Design a brochure

...(in French and in English) to present the various areas activity in marine biotechnology (Research, Education & Training and Transfer) and keep it up to date.

RECOMMENDATIONS

1. Streamline and align marine biotechnology events

2. Design a brochure that promotes the marine biotechnology landscape

RESEARCH

The current trend is to favour downstream/short-term projects and disconnect basic knowledge acquisition from biotechnology innovation potential. It is essential to construct and maintain a continuum between basic and applied research to avoid drying up the reservoir of discovery on the medium term and thus fragmenting the value chain. Effective, high-quality applied research requires basic research to translate knowledge and technology for businesses and the local economy. Therefore, the resources for basic research must be maintained and even enhanced. Methodological research at the interface of traditional fields of study also needs to be enhanced.

RECOMMENDATIONS

1. Maintain funding for research projects in marine biology and ecology

2. Sponsor inter-regional Brittany/Pays de la Loire programmes

3. Support the development of core facilities (omics and screening) that perform research and development

4. Support the development of marine biological resource centres to ensure access to marine organisms and improve cultivation skills

5. Support the development of demonstrators that lead to scale changes and upstream pilot studies for industrial projects, a key stage in securing biomass production and refining

6. Provide long-term funding for proof-of-concept activities (to avoid fragmentation of the value chain)

EDUCATION & TRAINING

Training is the key factor to ensuring the position of Brittany and Pays de la Loire in the large European and world centres for marine biotechnology. A self-diagnosis must be carried out to improve businesses' perception of marine biotechnology courses and degrees and to attract young people to the new employment opportunities in this area. Recommendations, offered in this document, will be coupled with two actions of high priority. Finally, new degrees are in the pipeline, such as International Masters with courses given in English, favouring coordination and cooperation with Masters' programmes offered in Brazil, Norway, Ireland, Denmark and Quebec. The goal is to set up a new network of HEIs among the world leaders in marine biotechnology. Special emphasis will be given to (1) new teaching methods that integrate IT such as the development of e-learning and on-line learning management systems and (2) exchanges of visiting professors among universities and the creation of International Chairs for a better coordination between training and research in innovative fields.

RECOMMENDATIONS

1. Identify the skills required at each link in the value chain — "from idea to market" — to offer training that covers the entire value chain, from resources to experimentation, including industrialisation and commercialisation

2. Improve training courses in marine biotechnology through the creation of an inter-regional directory of the available degree programmes, jobs and skills required with regard to marine biotechnology

3. Develop inter-disciplinarity of training courses to efficiently link marine sciences with health, agri-food, IT, social science and environmental science fields

4. Develop courses for a mixed classroom with traditional students and continuing education students to stimulate discussions and idea sharing

5. Use training to enhance the skills and expertise of technology transfer personnel and those at the research/industry interface to revitalise and update their skills.

6. Encourage involvement of entrepreneurs in designing course curricula through participation in continuing education committees and teaching activities

7. Organise short training modules for continuing education co-constructed by academia and industry

TRANSFER

To identify innovative marine biotechnology projects, it is now necessary to go beyond the 2000-2005 era when marine biotechnology projects were *de facto* considered as innovative owing to the originality and emergence of the field. Today, marine biotechnology projects that aim to develop knowledge, understand mechanisms and devise different forms of added value are now more numerous. Thus, the criteria of innovation must be explicitly defined to promote the discovery of new active ingredients, new functionalities, new processes for biomass transformation or new added-value development solutions for existing markets or for new and emerging markets. To accompany innovation in these areas, the European Commission's Horizon 2020 scheme uses the technology readiness level (TRL) scale to assess research-development-innovation (RDI) projects. To understand the level of research-development these projects require with respect to current knowledge and developments (in research or industrial development), the TRL scale puts the cursor on the level of readiness of the work proposed in a given project. This degree scale helps gage the technological maturity of the RDI work in a project. The TRL scale also clarifies the proof-of-concept step where a technology crosses the threshold from the laboratory towards the pre-industrial scale.

These projects are then candidates for different funding sources. When it issues Horizon 2020 calls for projects, the European Commission indicates the expected TRL level. For public funds, this criterion also provides for better distinction between downstream and upstream projects (ANR-BPI France and other national agencies, such as ADEME, etc.).

It is now urgent that public and private decision-makers assess the potential of blue biotechnology in western France and in France as a whole by inventing new ways to accompany marine biotechnology through the various TRL stages (especially between TRL 4 and 8: technology development ▶ technology demonstration ▶ system development).

To meet the needs of the market, western France must have:

- large-scale bioproduction tools and demonstrators (AlgoSolis)
- biorefinery tools

To increase the prominence and attractiveness of western France with regard to blue biotechnology, it is necessary to plan for the construction of blue biotechnology clusters that combine research, training and transfer activities in one place.

RECOMMENDATIONS

1. Provide both regions with a strong federating project following the model of the pre-industrial demonstrator Toulouse White Biotechnology (TWB) or the Picardie Region Plant Innovation (PIVERT) centre for plant chemistry in Compiègne.

2. Support market studies on various application fields and integrate the concept of biorefinery

3. Define a national strategy for the development of marine biotechnology activities

4. Promote and facilitate the creation of public-private laboratories

5. Capitalise on the attractiveness of research in western France (Connect Talent in Pays de la Loire; negotiation of State-Regional Plan Contracts (CPER); health laboratories in Nantes; overseas examples: CRBM-CQVB in Quebec City, case study in Japan)

6. Accompany the creation of new companies with a view to the sustainable development of biomass

7. Accompany and inform partners of changes in regulations (implementation of the Nagoya protocol)

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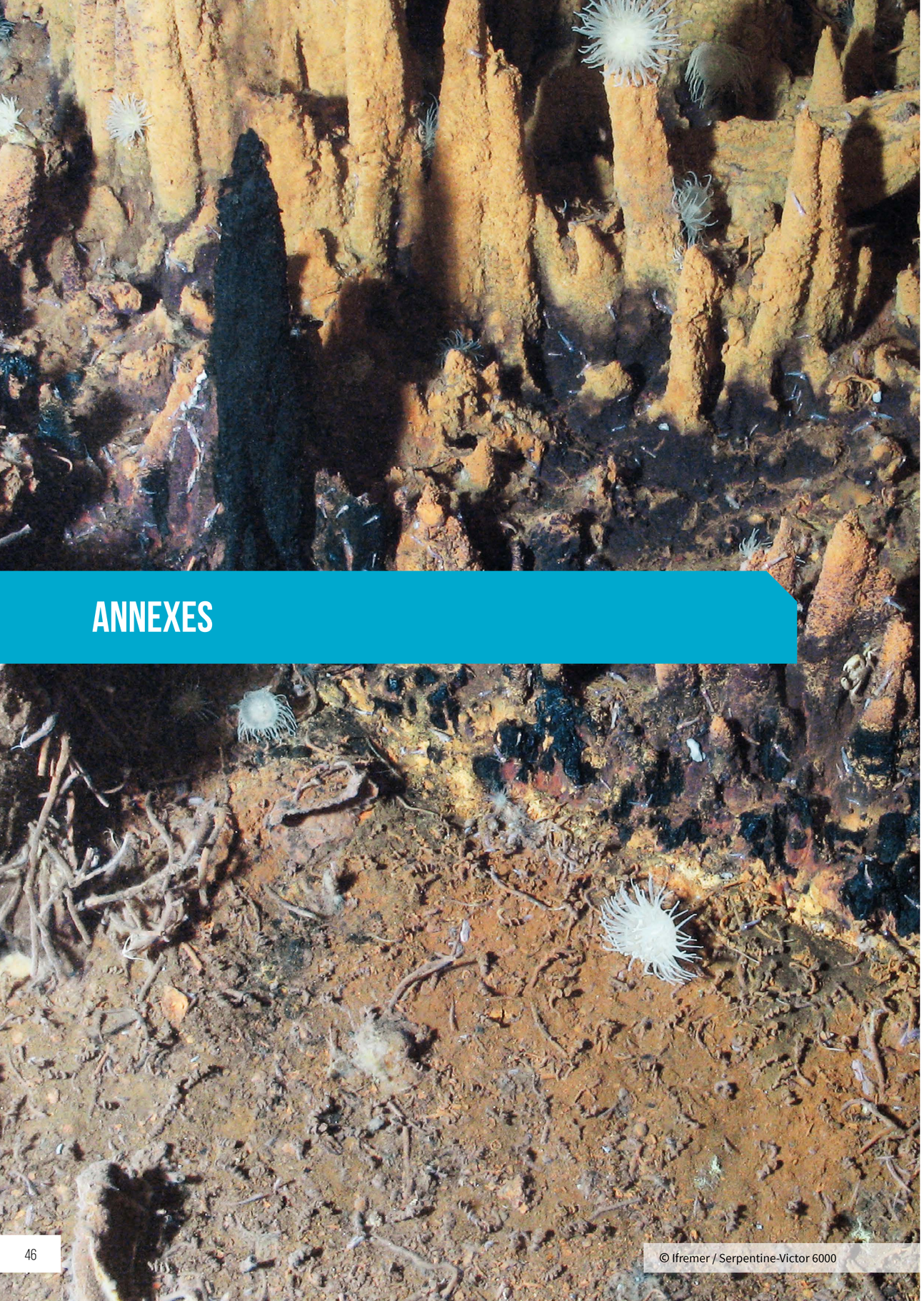

ANNEXES

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Annex 1

BIOGENOUEST CORE FACILITIES NETWORK

http://www.biogenouest.org

Biogenouest facilities are organised around six types of technology

- **Genomics services** with 4 platforms: Genomics Nantes, Environmental and functional genomics (Rennes), Health genomics (Rennes) and Marine genomics (Roscoff)
- **Proteomics services** with 2 platforms: Proteomics and mass spectrometry imaging (Protim, Rennes), Molecular interactions proteins microarrays activities (IMPACT, Nantes)
- **Functional exploration** with 11 platforms and 3 sub-areas:
  - 1.Viral and non-viral vectorisation: Production of pre-clinical and clinical viral vectors (Nantes), Production of synthetic vectors (SynNanoVect, Brest and Rennes)
  - 2.Transgenesis and animal models: Xenopus transgenesis (Rennes), Rat transgenesis (TRIP, Nantes), Large animal laboratory (LGA, Nantes)
  - 3.Screening and functional analysis: Functional exploration core facility for small animals (Cardiex, Nantes), Imaging for Cell Content Analysis (ImPACcell, Rennes), marine biomolecule extraction, purification and analysis (Biodimar, Brest), Kinase inhibitor specialised screening facility (KISSf, Roscoff), Synthesis of organic molecules core facility (CHEM-Symbiose, Nantes), Induced pluripotent stem cells (iPSC, Nantes)
- **Bio-imaging services** with 9 platforms : Microscopy Rennes imaging centre (MRic, Rennes), Functional imaging (PRISM, Rennes), Histopathology (H2P2, Rennes), Cellular and tissular imaging (MicroPICell, Nantes), Cyclotron (Arronax, Nantes), Imaging and neuroinformatics platform (Neurinfo, Rennes), Plant molecular cytogenetics (PMCV, Le Rheu), Animal histopathology (Apex, Nantes), Marine samples imaging (Merimage, Roscoff)
- **Structural analysis and metabolomics** includes Biopolymers, structural biology (BIBS, Nantes), Metabolic analyses and metabolomics core facility (Corsaire, distributed across Angers, Brest, Nantes, Rennes and Roscoff) and Plant phenotyping (Phenotic, Angers)
- **Bioinformatics** with 3 platforms: GenOuest (Rennes), BiRD (Nantes) and ABiMS (Roscoff).

Annex 2

BIOLOGICAL RESOURCE CENTRES

MARINE BIOLOGICAL RESOURCE CENTRE (CRBM)

- Curator: Ian Probert
- Address: Station Biologique de Roscoff – Place Georges Teissier – 29680 Roscoff
- Institution: CNRS/UPMC
- Website:

http://www.sb-roscoff.fr/fr/station-biologique-de-roscoff/services/centre-de-ressources-biologiques-marines

- IBiSA Quality Label for the microorganism culture collection (Roscoff Culture Collection)
- Type of biological resource(s) held: The CRBM houses two types of resources:
  - The Roscoff Culture Collection provides access to cultures of unicellular organisms (microalgae, bacteria, viruses)
  - The Biological Models department provides macroorganisms (animals, macroalgae) from cultivated or wild stocks.
- Preservation/isolation techniques: research aquarium (non-filtered temperature-controlled seawater, open or closed circuit with treatment of waste), controlled-environment culture chambers, cryopreservation (liquid nitrogen/deep-freezers at -150°C)
- Operating practices:
  - Access, rules and restrictions: open for research and internal and external (French & international) teaching needs for the species/strains listed in the catalogue. Agreements set up on an individual basis for private research.
  - Services provided: Organism (live or preserved) supply, aquariums, R&D service
  - Restrictions and requirements for the supplier and the applicant: Material Transfer Agreement (MTA)
- The CRBM is part of the ESFRI marine station network EMBRC-Europe (European Marine Biological Resource Centre), the Investment for the Future project EMBRC-France (3 UPMC/CNRS marine stations: Roscoff Biological Station, Oceanographic Observatory at Banyuls-sur-Mer, Oceanographic Observatory at Villefranche-sur-Mer).

UBO CULTURE COLLECTION (UBOCC)

- Address: UBOCC-ESIAB - Technopôle Brest Iroise - 29280 Plouzané
- Curator: Amélie Weill
  - Technical manager for marine bacteria and archaea strains from extreme environment samples: Nadège Quintin
  - Technical manager for pure strains of moulds, yeasts, mesophilic bacteria from natural, agricultural and industrial environments: Amélie Weill
- Institution: University of Western Brittany (UBO)
- Website:

www.univ-brest.fr/ubocc

- UBOOC is operated by the Extreme Environment Microbiology Laboratory (LM2E/ UMR6197) and the University Laboratory for Microbial Biodiversity and Ecology (LUBEM/EA3882)
- Type of biological resource(s) held:
  - Pure strains of moulds, yeasts, mesophilic bacteria from natural, agricultural and industrial environments
  - Marine bacteria and archaea strains from extreme environment samples
- Preservation, isolation techniques:
  - Conservation at −80°C in replicate cryotubes stored in two different places
  - Freeze-dried fungi
  - Cultures are indefinitely maintained at ambient temperature or at 4°C.
- Operating practices:
  - Access, rules and restrictions: Unrestricted strains are provided upon written request submitted on-line via the website, pricing varies with applicant's home institution
  - Access: The collection accepts deposits from private industry and research laboratories and supplies unrestricted strains to credible requests received via the website
  - Services provided: Collection and supply of pure strains or isolates from marine extreme environment samples
  - Restrictions and requirements for the supplier and the applicant: Information required on request form and payment for deposits made from without UBO, in particular private companies, and for strain requests
  - Terms of payment:
    - Collection funded as a Core Service by UBO's research bonus grant (BQR).
    - Pricing for external requests: Private company: €60 - University: €40.

PATHOGENIC MARINE BACTERIA STRAIN BANK

- Address: Ifremer - Avenue de mus du Loup – 17390 La Tremblade The strain bank is also available at Ifremer-Brest and LEMAR (CNRS/ UBO)
- Curator: Marie-Agnès Travers
- Institution: Ifremer
- Type of biological resource(s) held: Marine bacteria of the genus Vibrio
- Preservation, isolation techniques: Storage at -80°C in Zobellglycerol at 3 sites
- Operating practices:
  - Access, rules and restrictions: on-line request for strains Access open to the scientific community.
  - Services provided: regular re-isolation and distribution of strains Restrictions and requirements for the supplier and the applicant: For strain distribution, only postage fees are charged. Phenotyping is subject to a fee. Restrictions as to the use of the distributed strain have not been defined. A minima, strains cannot be sold or donated to a third party.
  - Terms of payment: postage fees

NANTES CULTURE COLLECTION (NCC)

- Address: UFR des Sciences et Techniques de Nantes - 2, rue de la Houssinière - 44322 Nantes Cedex. The NCC is operated by the 'Marine trophic networks and contaminants in coastal and estuary environments' group at the Sea, Molecules, Health (MMS) (EA 2160) Laboratory
- Curator: Vona Méléder
  - Administrative manager: Yves-François Pouchus
  - Technical manager: Vona Méléder
- Institution: University of Nantes
- Website:

http://ncc.univ-nantes.fr/

- Type of biological resource(s) held: The NCC houses a microalgae collection containing primarily benthic diatoms from the French Atlantic coast. Half of the strains belong to the genus Haslea (microalgae that produce a blue pigment, marennin).
- Preservation, isolation conditions: Strains are isolated from natural populations sampled *in situ* (coastal mudflats, estuaries, oyster beds, etc.) Isolated strains are preserved in temperature-controlled culture chambers (16°C) with a 14:10 photoperiod in 150 mL liquid culture (enriched seawater: F/2 Guillard medium). The strain collection is re-isolated every 5 weeks.
- Operating principles:
  - Access, rules and restrictions: Requests for strains must be made to Vona Méléder. Except the genus Haslea, biological material is distributed under an MTA, established by the Transfer Office at the University of Nantes. This MTA, between the supplier and the applicant, is discussed before signature to protect each party and facilitate R&D activities. For the genus Haslea, which is a species with high economic potential and intensely studied at the NCC, all requests are examined by the NCC Steering Committee to discuss the request in a collegial manner. If accepted, the request for Haslea also requires an MTA.
  - Access: Academics, private and public industry, associations, etc.
  - Services provided: Strains, culture media Cultures in small, medium and large volumes (600 L). Production of algal pastes and extracts. In collaboration with other MMS research groups (and external partnerships): screening for biological activity, metabolites of interest.
  - Terms of payment: Strains and/or by-products are sent for a fee, as indicated in the MTA except in the case of scientific collaboration (e.g. common research project). Strains are sent without charge for teaching purposes (in secondary and higher education institutions). Pricing:
    - The price of the strain depends on its originality and how difficult it is to preserve.
    - The prices for by-products depends on the techniques used to obtain them and time spent.
    - The price is mentioned in the MTA before signature.

MARINE FUNGI STRAIN BANK

- Curator: Yves-François Pouchus
  - Administrative manager: Nicolas Ruiz
  - Technical manager: Thibaut Robiou du Pont
- Address: Laboratoire Mer, Molécules, Santé (MMS) - Bâtiment ISOMer - UFR Sciences - 2 rue de la Houssinière - BP 92208 - 44322 Nantes Cedex 3
- Institution: University of Nantes
- Type of biological resource(s) held: Filamentous marine fungi
- Preservation, isolation techniques: mineral oil and freezing Direct isolation from sediment and marine bivalve samples.
- The collection is primarily intended for MMS Laboratory research. Some strains are studied in collaboration with private partners. The collection is distributed outside the laboratory on an individual basis, for research programmes, for CIFRE (public-private) doctoral research, etc.

CRYOAQUA, A CRYOBANK FOR FARMED AQUATIC SPECIES (FISH, MOLLUSCS, ETC.)

- Address: Creavia - Les Landes de la Rencontre - 35 Saint Aubin du Cormier
- Curators: Gildas Michel (Creavia), Catherine Labbé (INRA), Pierrick Haffray (Sysaaf), Marc Suquet (Ifremer)
  - Technical manager: Alain Lemarchand
- Institution: Creavia (private artificial insemination cooperative) / INRA / Ifremer / Sysaaf (trade union for aquaculture operators) / National Cryobank (CbN) (GIS IBiSA)
- Website of the National Cryobank:
  www.cryobanque.org
- The National Cryobank has earned the IBiSA quality label.
- Type of biological resource(s) held: Sperm, embryo and somatic cells of farmed species (trout, sea bass, seabream, turbot, oyster, etc.) The sites holding these resources must be certified free of regulated diseases.
- Preservation, isolation conditions: Liquid nitrogen, vials
- Operating practices:
  - Access, rules and restrictions: Restricted, controlled access
  - Except the National Cryobank collection, the culture collections have restricted distribution; however, deposits are accepted from any organisation.
  - Services provided: freezing of cells, storage in liquid nitrogen, shipment upon request to the depositor.
  - Restrictions and requirements for the supplier and the applicant: Service agreement signed by Creavia and the depositor. Regulations on the disease-free status of the source farm. Requests for public, distributed resources are made via the National Cryobank.
  - Culture requests: For freezing and/or storage, the applicant directly contacts the curator Gildas Michel. For all resources held at the National Cryobank, the applicant must follow the procedure detailed on the website (http://www.cryobanque.org/)
  - Terms of payment: Freezing, storage, distribution of cultures by Creavia (quote and price schedule are available from Gildas Michel). Fixed fee for all depositors (public or private).

The National Cryobank is part of the Investment for the Future programme CRB Anim.

This cryobank, whose governance is complex, provides freezing and storage services for depositors; private or public research laboratories, a private company and the National Cryobank (CryoAqua is a mirror site of CbN) can all deposit cultures. The only restriction is the disease-free status of the farm from which the deposited culture was isolated. Distribution of the collections found in the CbN (the only public resource of the culture collection centre) is not yet in effect. It is planned as part of the CRB Anim project.

ANIMAL SUPPLY FACILITY AT THE VIRAL FISH PATHOGENS RESEARCH UNIT

- Address: Unité de pathologie virale des poissons (UPVP) - Technopole Brest Iroise - BP70 - 29280 Plouzané
- Curator: Thierry Morin
  - Administrative manager: Benoît Charvet
  - Technical manager: Morgane Danion
- Institution: ANSES, Ploufragan-Plouzané Laboratory
- ANSES website:
  www.anses.fr
- Laboratory website:
  www.anses.fr/en/content/ploufragan-plouzané-laboratory
- This animal supply facility is held at the Viral Fish Pathogens Research Unit, which is the National Reference Laboratory (NRL) for regulated fish diseases studied as part of the unit's research on fish virology and ecotoxicology.
- Certifications: Certification no. C29-212-3 from the Finistere prefecture
- Type of biological resource(s) held: Freshwater and marine fish
- Conservation, isolation conditions: Disease-free rainbow trout farm; 3 biocontainment laboratories; 2 chemical containment laboratories; 1 laboratory for trout breeding. Continuous feeding in freshwater or seawater with possible temperature control. Appropriate wastewater treatment: chlorination for biological waste (installation of an ozoner in progress) and activated carbon for chemical waste
- Operating practices:
  - Access, rules and restrictions: Access restricted to authorised personnel. Personnel who work on disease-free farms are distinct from those who work with farms under biological experimentation. Labcoats are changed upon entry into any testing laboratory. Foot baths and hand sanitisation.
  - Access: Access restricted to laboratory personnel. Outside personnel can obtain access under a specific agreement. Collaborations possible on the laboratory's two main research areas: fish virology and ecotoxicology. Other proposals are examined for collaboration on broader research areas, regarding fish farming (e.g. genetic selection, assessment of immuno-stimulating properties in feed, etc.)
  - Services provided: Experimental contamination with fish pathogens (viruses, bacteria) or chemicals (pesticides, etc.). As part of its reference activities, the Laboratory can accommodate fish that may be infected with a pathogen for surveillance and diagnosis.
  - Restrictions and requirements for the supplier and the applicant: All experiments for research purposes must be authorised by the Ethics Committee ComEth.
  - Terms of payment: Research agreement or service contract. Variable pricing.

Annex 3

MAP OF PROJECTS RUNNING IN 2013-2015

Type of project [2009-2014]	Type of project (e.g. FP7, ANR, CBB, etc.)	Dates	Project leader (lab, investigator)	Leader location Brittany/Pays de la Loire	Total project budget *Budget for the leader lab	Nb of partners	Project title	Industrial partners yes/no
ERA-NET	FP7 IB	2013-2017	CSIC, ES	SBR-LBI2M	€147m *	8	FIBERFUEL	yes
EU	FP7-NMP	2013-2017	CSIC, ES	SBR-LBI2M	€4m	9	CELLULOSOMEPLUS	
EU	FP7 KBBE	2009-2013	Münster Univ, DE	SBR-LBI2M	€730k *	15	PolyMODE	yes
EU	FP7-KBBE	2012-2016	NiOZ, NL	SBR-AD2M, IUEM-LM2E	€9m	23	MACUMBA	yes
EU	FP7-KBBE	2009-2013	Bangor University, UK	IUEM-LM2E	€2.8m	11	MAMBA	yes
EU	FP7-KBBE	2010-2014	Ifremer Plouzané	Ifremer	€700k *	12	REPROSEED	yes
EU	FP7-KBBE	2011-2013	Ben-Gurion Univ, Israel	MMS	€5.6m		GIAVAP	no
EU	FP7-KBBE	2010-2014	Danmarks Tekniske Universitet (DTU)	Ifremer	€91k	12	PRO-EEL	yes
EU	FP7 PEOPLE ITN	2012-2016	Aberdeen University O. Ebenhoeh	GEPEA	€4.03m	10	ACCLIPHOT	yes
EU	FP7-PEOPLE	2011-2015	MMS,	UBS-LBCM	€185k	8	BIOVADIA	
EU	FP7 PEOPLE IRSES	2010-2014	Univ Mainz, DE	MNHN	€680k	3	MARBIOTEC EU-CN	
EU	FP7-PEOPLE IRSES	2011-2014	Univ Le Mans		€186k	4	BIOVADIA	no
EU	FP7-PEOPLE Marie Curie	2014-2016	SBR-USR 3150		€279k *	3	IOP OCEAN CHARCOT	no
EU	FP7-Infrastructures	2011-2014	SZN Italy	SBR-FR2424	€3.88m	13	EMBRC-pp	no
EU	FP7-ENV	2012-2015	Jakob Univ, Bremen, DE	SBR-AD2M	€230k *	32	MicroB3	yes
EU	FP7 SME	2010/2013	CETMAR, ES		€2.475m	16	OYSTERECOVER	yes
EU	FP7 ERA-NET	2013-2017	RCN Norway	SBR-FR2424	€1.8m	19	MARINE BIOTECH	no
EU	FP7 ERA-NET	2013-2016	IMR Bergen, Norway	IUEM-LEMAR	€2.17m	5	Seas-ERA INVASIVES	no
EU	FP7 ESA	2013-2015	ESA	GEPEA	€300m	2	MELISSA	no
EU	Interreg Espace Atlantique	2012-2014	3B'S, Univ Minho, Portugal	IUEM-LEMAR	€2.06m	10	MARMED	no
EU	Interreg Espace Atlantique	2012-2014	CCDR-N, PT	Ifremer EM3B	€2.25m	6	LABELFISH	no
EU	Interreg Espace Atlantique	2009-2012	UBO	IUEM-LEMAR	€2.3m	12	BIOTECMAR	yes
EU	INTERREG 2 seas	2012-2014	ILVO	Ifremer/ IUEM-LEMAR	€3m	5	MICROPLASTICS	no
EU	INTERREG 2 seas	2012-2014	Brighton University, UK	Ifremer EM3B	€2.0m	4	Marine Biocare	yes
EU	ESF COST	2013-2015	Juan Asturiano, Valencia, Spain	INRA-LPGP	Network	35	Aquagamete	no
EU	DCF	2011-2014	MNHN	Ifremer, UN	€804m	7	Chondrychtien	no

Type of project [2009-2014]	Type of project (e.g. FP7, ANR, CBB, etc.)	Dates	Project leader (lab, investigator)	Leader location Brittany/Pays de la Loire	Total project budget *Budget for the leader lab	Nb of partners	Project title	Industrial partners yes/no
EU	FEP/Regional Council	2013-2016	Ifremer EM3B	PARM Martinique		2	ECOSYP	no
Other International	Non-thematic ANR SVSE7 International	2014-2016	INRA LPGP UR1037, Y Guiguen		€350m	2	PHYLOSEX	no
National	Non-thematic ANR SVE7	2012-2014	SBR-LBI2M		€509m	4	Vibriogen	no
National	Non-thematic ANR SVE7	2014-2017	INRA LPGP UR1037		€360m	5	Maternal Legacy	no
National	Non-thematic ANR SVE7	2011-2014	IUEM-LM2E		€720m	5	Living deep	no
National	Non-thematic ANR SIMI 9	2013-2015	Ifremer EM3B		€462m	3	IONIBIOGEL	no
National	Non-thematic ANR SIMI 9	2011-2014	ENSIACET	GEPEA	€730m	4	AlgoRaffinerie	yes
National	ANR JCJC SVSE 5	2011-2014	IUEM-LM2E		€292m	1	Arch-Pol	no
National	ANR RIB	2007-2011	SBR-UMR 7139		€472k	3	Ulvoligo	yes
National	ANR RIB	2008-2011	Hemarina SA	SBR-UMR7144	€857k	4	HEMORGAN	yes
National	ANR CP2D	2008-2013	SBR-UMR 7139		€511k	6	CRAZY-POL	yes
National	ANR ALIA	2010-1014	INRA Jouy en Josas	Ifremer EM3B	€703k	10	ECOBIOPRO	yes
National	ANR ALIA	2010-2014	Institut Pasteur Lille	Ifremer EM3B	€1.848m	9	Fish-Parasites	yes
National	ANR CD2I	2013-2015	ARVAM CRT	UBS-LBCM	€850m	6	Biopaintrop	yes
National	ANR Génomique	2011-2014	INRA LPGP UR1037		€480m	5	Phylofish	no
National	ANR Bio-ME	2012-2015	Ifremer BPA		€688k	3	Facteur 4	
National	ANR- BioME	2012-2015	GEPEA		€1.03m	4	DiesAlg	yes
National	ANR CESA	2013-2016	IUEM-LEMAR	Ifremer BPA	€440k	5	ACCUTOX	
National	ANR Bioénergies	2012-2015	GEPEA		€5.0m	5	AlgoH2	no
National	ANR Agrobiosphère	2012-2016	Ifremer Brest	MMS	€709k	10	GIGASSAT	yes
National	ANR SYSTERRA	2011-2013	Ifremer Port en Bessin	Ifremer, LEMAR, AMURE	€977k	4	COMANCHE	no
National	ANR EMERGENCE	2013-2015	GEPEA		€234k	3	PRIAM	no
National	PIA Infrastructures	2013-2019	INRA, Jouy en Josas	Ifremer-LEMAR	€11m	≈ 40 (8 partner teams)	CRB Anim	yes
National	PIA Infrastructures	2012-2019	SBR-FR2424		€16m	3	EMBRC-France	no
National	PIA Biotech & Bioressources	2013-2019	SBR-AD2M	SBR-FR2424	€7m	12	OCEANOMICS	yes
National	PIA Biotech & Bioressources	2011-2020	SBR-LBI2M	Ifremer, UBS-LBCM, Agrocampus, UN, SBR-AD2M, SBR-FR2424	€10m	18	IDEALG	yes
National	Coll. Industrial???	2011-2012	SBR-UMR 7139		€70k	2	oligo-algues	yes
National	BPI-FUI	2012-2015	CITPPM	Ifremer EM3B	€929k	6	IDThon	no
National	BPI-FUI	2013-	Séché Environnement.	IUML-GEPEA	€4.9m	5	SYMBIO2	yes
National	BPI-FUI	2011-2014	Compagnie du Vent	Ifremer BPA	€6.8m	11	Salinalgue	yes
National	BPI FUI - Pôle Mer	2013-2016	OLMIX	UBS-LBCM, IUEM-PF BioDimar	€2.7m	5	VALORALG	yes
National	OSEO ISI ULVANS	2012-2015	AMADEITE	UBS-LBCM	€26m	7	ULVAN	yes

Type of project [2009-2014]	Type of project (e.g. FP7, ANR, CBB, etc.)	Dates	Project leader (lab, investigator)	Leader location Brittany/Pays de la Loire	Total project budget *Budget for the leader lab	Nb of partners	Project title	Industrial partners yes/no
National	programme INRIA,	2013-2015	INRIA	IFRMER BPA	€2k	6	Algae in silico	
National		2014-2017	MNHN		€20k	4	PECMED	yes
National	MENESR (DCF)	2012-2014	MNHN		€389k	2	MISLABELLING	no
National		2013-2014	MNHN		€5k	7	DELIRE	yes
National	Coll. Industrial???	2008	SBR-UMR7139,		€65k	2	Enzymes/algues	yes
National	DGA/DGAC	2011-2016	IFPEN	IUEM-LEMAR + GEPEA	€4.2m	7	CAER	yes
National	National Programme Energie CNRS	2009-2012	Univ Nantes	UBO-CEMCA UMR6521	€150k	3	LIPALG	no
National		2011-2013		IUEM-LEMAR		2	HALOSUBNAT	no
National	PSDR Grand Ouest	2008-2010	Univ Nantes	UBO (F GUERARD)	€430k	20	Gestion Durable	no
National	Water Framework Directive - Transitional and Coastal Waters	2008-2013	ONEMA - Ifremer	IUEM-LEMAR	€180k*	7	Development of tools for the ecological assessment of water status - National Expert - European Intercalibration	no
National	Rebent	2008-2013	Ifremer	IUEM-LEMAR	€572k *	6	Study of intertidal seaweed communities	no
National	ANRT-CIFRE	2012-2015	SBR-LBI2M		€160k	2	STIMALG	yes
National	ANRT-CIFRE	2007-2013	MMS -IUML		€150k		NESATA	yes
National	ANRT-CIFRE	2007-2010	SBR-UMR 7139		€147k *	2	Structural analysis of carrageenans	yes
Regional	Maturation funds Brittany Regional Council	2010-2012	SBR-UMR 7139		€80k	1	Oligomar	no
Regional	Maturation funds Brittany Regional Council	2012	IUEM-LM2E		€60k	1	Characterisation of the biotech potential of a single-stranded binding protein for genetic engineering	no
Regional	AAP-IMA-CBB Brittany	2011	SBR-UMR 7139		€22k	2	Phaeolam	yes
Regional	AAP IMA CBB Brittany	11/12-10/13	LUBEM,		€31k	2	Cosmic Blue	yes
Regional	AAP IMA CBB Brittany	2014	Société Science et Mer	LEMAR	€25k	2	RIV'ALG	yes
Regional	GIS Europôle Mer	2008-2010	SBR-UMR 7139		€110k	2	CRAZY-POL	no
Regional	GIS Europôle Mer	2009-2011	LEMAR		€146k *	2	PhlorotanING	no
Regional	RTR Biologie-Santé (UEB)	03/13-03/14	LUBEM, UBO		€8k	3	LPS	no
Regional	Brittany Regional Council	2008-13	SBR AD2M		€175k *	3	RB HEMORGERE	yes
Regional	RDT Feasibility Programme (OSEO and Brittany Regional Council)	2010	EMBALJET company	IUEM-LEMAR	€12.5k	2	Development of bivalve shells for their antimicrobial properties	yes

Type of project [2009-2014]	Type of project (e.g. FP7, ANR, CBB, etc.)	Dates	Project leader (lab, investigator)	Leader location Brittany/Pays de la Loire	Total project budget *Budget for the leader lab	Nb of partners	Project title	Industrial partners yes/no
Regional	Water Framework Directive Loire-Bretagne, Transitional and Coastal Waters	2008-2013	Agence de l'eau Loire-Bretagne	IUEM-LEMAR (E. Ar Gall)	€120k	6	Ecological assessment of water quality in transitional and coastal waters	
Regional	Region Bretagne, Finistere Departmental Council, Quimper agglomeration, Pôle Mer	2013-2015	Société MerAlliance	IUEM-LEMAR	€1.2k	5	Pesk&Co	yes
Regional	Inter-regional Brittany-Loire	2012-2014	PAO	Ifremer/ IUEM-LEMAR (R. Robert)	€72k	5	TRACES	yes
Regional	Inter-regional Brittany-Loire	2012-2014	CRC Bretagne Nord	Ifremer/ IUEM-LEMAR	€300k	5	PERLE	yes
Regional	France Filière Pêche	2012-2014	MNHN		€537k	2	Pocheteaux	no
Regional	Brittany Regional Council	2011-2016	MNHN		€287k	6	Fish traceability	yes
Regional	Brittany Regional Council	2013-2015	MNHN	Ifremer	€564k	8	PREDATOR	yes
Regional	Brittany Regional Council, Finistere Departmental Council, Morbihan Departmental Council, Brest agglomeration	2010-2012	France HALIOTIS	MNHN, LEMAR, Ifremer	€1.155m	7	ORMEAUX	yes
Regional	Brittany and Pays de la Loire Regional Councils	2014-2015	Ifremer EM3B		€562k	4	MAKIMINI	yes
Regional	Brittany Regional Council	2013-2014	LBCM UBS		€30k	2	EVHELSANE	yes
Regional	Brittany Regional Council (AAP SAD)	2014-2016	INRA LPGP UR1037		€76k	1	Molecular profile of a high-quality fish egg and screening for markers	no
Regional	Technopole ADECAL	2013-2015	Ifremer BPA		€1.87m	2	Amical	
Regional	Basse-Normandie Regional Council	2012-2013	CNAM Intechmer	MMS	€14k		C3MarMo	
Regional	SMIDAP (Pays de la Loire)	2013-2014	MMS IUML		€151.8k		PANDHA	
Regional	SMIDAP (Pays de la Loire)	2012-2013	IUML-MMS		€38k		UTILE -	
Regional	Pôle Mer Bretagne	2011-2013	IUML-MMS		€60k		TopLipid	yes
Regional	Brittany Regional Council	2013-2015	Ifremer/Pelagos and Ifr/LER/BO		€300k	2	Daoulex	no
Regional	Pays de la Loire Regional Council	2011-2014	Ifremer-PHYC	MMS IUML	€205k	2	ChiMiMar	no
Regional	Pays de la Loire Regional Council	2013-2016	IUML		€2.2m		COSELMAR	no
Regional	Brittany Regional Council (PhD scholarship)	2010-2013	LUBEM, UBO		€90k	1	Biprobio	no

Type of project [2009-2014]	Type of project (e.g. FP7, ANR, CBB, etc.)	Dates	Project leader (lab, investigator)	Leader location Brittany/Pays de la Loire	Total project budget *Budget for the leader lab	Nb of partners	Project title	Industrial partners yes/no
Regional	Brittany Regional Council (PhD scholarship)	2013-2016	LUBEM, UBO		€90k	1	ExMIM	no
Regional	Dynamique collective???	2015-2018	IUML-GEPEA/ Ifremer/ Univ du Maine	GEPEA	€1.5m		AMI	no

GDR Research Federations					
Type of project	**Name of the GDR**	**Duration**	**Brittany-Pays de la Loire participants**	**Nb of partners**	**Theme**
National	PHYCOTOX	2014-2017	Ifremer, SBR, IUEM LEMAR, IUML	29	toxic microalgae and phycotoxins
National	ARCHEAE	2014-2017	Ifremer/IUEM-LEMAR	37	Biodiversity, origin, basic cellular processes and biotechnology
National	BIOCHIMAR	2009-2014	UBS, LEMAR, SBR	30	Marine Biodiversity and Chemodiversity
National	MEDIATEC	2014-2017	SBR, LEMAR, MMS, LBCM	45	Chemical signalling in the environment
International	DEBMA (France-Chile-Brazil)	2013-2016	SBR	11	Diversity, Evolution and Biotechnology of Marine Algae

Annex 4

TITLES AND ACRONYMS

Acronyms:

AAP-IMA: Call for projects: Ingredients & molecules, materials, analysis methods

ADRIA: French Agro Industry Technical Institute, Quimper, France

ANR: French National Research Agency

ANR RIB: Innovative Research and Biotechnology

Non-thematic ANR SIMI 9: Engineering, Material, Process and Energy Sciences (9th non-thematic SIMI call)

ANR ALIA: Nutrition and Food Industry

ANR Bio-ME: Biomaterials and Energy

ANR CESA: Contaminants and Environments: Metrology, Health, Adaptability, Behaviour and Uses

ANR CD2I : Sustainable Chemistry – Industry – Innovation

Non-thematic ANR SVE7: Life, Health and Ecosystem sciences: Biodiversity, Ecosystem Evolution, Productive Ecosystems, Agronomy

ANR CP2D: Chemistry and Processes for Sustainable Development

ANR Agrobiosphere: Viability and adaptation of productive ecosystems, lands and resources in regard to global change

BDI: Brittany's regional development and innovation agency

CBB: Brittany Biotechnology Centre

CEVA: Center for Study and Promotion of Algae, Pleubian, France

CNRS: French National Center for Scientific Research

COMUE: Universities and Institutions Community

COMUE UBL: COMUE Bretagne-Loire University

CPER: State-region plan contract (every 5 years)

CRITT: Regional Centre for Innovation and Technology Transfer.

DCF Data Collection Framework : The European Commission's Data Collection Framework (DCF) establishes a European Community framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the Common Fisheries Policy (CFP)

ESA: European Space Agency

FUI: French Inter-ministerial Fund for Research and Development

GEPEA: Process engineering – Environment – Agri-food

ID-Mer: Technical Institute for the Development of Seafood Products, Lorient, France

ID2-Santé: Innovation and Development of Health in Britain, Rennes, France

IRD: Institut de Recherche pour le Développement

PHC: Hubert Curien partnership

PMBA: Pôle Mer Bretagne Atlantique

PSDR GO: Research Programme "For and on regional development in Western France"

SATT : French Technology Transfer Acceleration Companies

SMIDAP: Regional Economic Development Agency for Aquaculture and Fisheries in Pays de la Loire

UBO: University of Bretagne Occidentale

UBS : University of South Brittany

UPMC: Pierre et Marie Curie University

Vegenov: RTO (research and technology organization), specialized in plant biotechnology and pathology.

Project titles

ACCLIPHOT: Environmental Acclimation of Photosynthesis

ACCUTOX: Assessment of the impact of toxic algal blooms and modification of the environment on the feeding behaviour, physiological response and bioaccumulation of toxins in oysters.

Algae in silico: Forecast and optimise microalgae productivity according to their growth medium

AlgoH2: Optimisation of the genetics, metabolism and process of hydrogen bioproduction in the green microalga *Chlamydomonas reinhardtii*

AlgoRaffinerie: Integrated microalgal refining system

AMI: Atlantic Microalgae, Microalgae Cluster in Pays de la Loire.

AMICAL: Creation of an industrial microalgae production sector in New Caledonia

Aquagametes: Assessing and improving the quality of aquatic animal gametes to enhance aquatic resources

Arch-Pol: Screening for new DNA polymerases and biotechnology applications

Biopaintrop: Tropical-origin biomimetic anti-fouling coatings

BIOTECMAR: Biotechnological exploitation of marine products and by-products

BIOVADIA: Biodiversity and valorization of blue diatoms

C3MarMo: Metabolic conversion in marine microalgae: development of a cellular model

CAER: Alternative fuels for aeronautics

CaPaBIOC "Functional characterisation and role of prokaryotes associated in microphytobenthic biofilms in intertidal mudflats in the nitrogen and carbon cycles"

ChiMiMar: Chemical diversity of eukaryotic marine microorganisms, programme that lead to the development of the ThalassOMICS platform.

Chondrychtiens: Study of cartilaginous fish in French landings

COMANCHE: Ecosystem interactions and anthropogenic impacts on king scallop populations in the English Channel

COSELMAR: Understanding coastal and marine ecosystems to improve the development of marine resources, risk prevention and management

Daoulex: Blooms of *Alexandrium minutum* in the Bay of Brest at Daoulas

DELIRE: diversity of Lesseppsian species: impact on harvested resources

DiesAlg: Biodiesel production using microalgae

EVHELSANE: Mixtures of essential oils with biological properties targeted for animal health

Facteur 4: Non-GMO improvement of microalgal growth and production

Fish-Parasites: Fish parasites: identification of the danger, impact and research to develop an effective prevention strategy

GIAVAP: "Genetic improvement of Algae for Value Added Products" "Transposable elements and mutagenesis for genetic modification" Work package

IDThon: Identification and quantification of species in canned tuna

LABELFISH: Atlantic network on genetic control of fish and seafood labelling and traceability

Living deep: Genomic and molecular bases of high-pressure resistance in *Pyrococcus yayanosii* CH1, an obligate barophile

MARMED: Development of innovating biomedical products from marine resources valorization

Maternal Legacy: Molecular profile of high-quality fish eggs

MELISSA-ESA: "New generation of photobioreactors", Inst. Blaise Pascal CNRS, with the participation of GEPEA

MISLABELLING: Mislabelling of cartilaginous fishes in French fisheries

NESATA : Natural extract screening for antitumoral activity

PANDHA Anti-microbial properties of *Haslea ostrearia*

PECMED: History of Mediterranean fisheries

PERLE 2: Emerging Energy Research Cluster in Pays de la Loire

PESK&CO: development of high added-value fish co-products for nutrition and health

Phylofish: Phylogenomic analysis of genetic duplications in teleost fish

PHYLOSEX: Evolution of the major sex determining factor in fish

PRIAM: Design of an internally lit photobioreactor

PRO-EEL: Reproduction of the European Eel: Towards a Self-sustained Aquaculture

REPROSEED: Research to improve the production of seed of established and emerging bivalve species in European hatcheries

Salinalgue: Large-scale microalgae culture in salt marshes

SYMBIO2: Innovative, integrated, hybrid system for microalgae production for food, symbiosis with industrial and/or urban buildings (began in 2013). Coordination Séché Environnement

ULVAN: Development of green algae

UTILE: Using remote sensors to estimate wild oyster stocks in the Bay of Bourgneuf (in Loire-Atlantique): an assessment

VALORALG : The added value of plant/seaweed biomass in Brittany

Annex 5

LIST OF GRADUATE PROGRAMMES IN THE BRITTANY AND PAYS DE LA LOIRE REGIONS

FIELD	DEGREE PROGRAMME	AREA OF SPECIALISATION	CONCENTRATION	INSTITUTION	
	Engineering	Microbiology and Quality		ESIAB - UBO	
Marine and Coastal Sciences	Master of Science	Marine Biology	First year	IUEM-UBO	
	Master of Science	Marine Biology	Second year - Marine organismal biology	IUEM-UBO	
	Master of Science	Marine Biology	Second year - Ecosystem approach to fisheries	Agrocampus-Ouest/ IUEM-UBO	
	Professional Master's	Marine Biology	Biotechnological development of marine resources (VALBIOREM)	IUEM-UBO	
Sciences - Technology	Master of Science	Ecology, Environmental Sciences and Earth Sciences	Oceanography and marine environments	SBR-UMPC	Brittany
	Master of Science	Integrative Biology and Physiology (BIP)	Comparative Biology and Physiology, adaptation to the environment: 5 courses are offered at Roscoff	SBR-UMPC	
	Master of Science	Molecular developmental biology and evolution	Cellular developmental biology and stem cells	SBR-UMPC	
	Master of Science	Biology and Health	Marine Biology and Bioresources (BBMa)	SBR-UMPC	
	Master of Science	Ecology, Environmental Sciences and Earth Sciences	Ecology, biodiversity and evolution	SBR-UMPC	
Sciences - Technology - Health	Master of Science	Marine Environment and Biotechnology	Biotechnology: Biomolecules, microorganisms, bioprocessing	UBS	
	Master of Science	Biology and Health	Basic and Applied Microbiology	UBO	
	Engineering		Process and Bioprocess Engineering (Ecole Polytech)	Univ Nantes	Pays de la Loire
	International Master's degree		Microalgal Bioprocess Engineering (in 2016, Ecole Polytech)		
Sciences - Technology - Health	Master of Science	Ecosystems and bioproduction (Univ Nantes)	Ecosystems and bioproduction (Faculty of Sciences and Techniques)		
Erasmus	Erasmus Master	AquaCulture, Environment & Society	AquaCulture, Environment & Society (since 2015)	Univ Nantes & SAMS (UK) & Univ Crete	
Sciences - Technology - Health	Master of Science	Ecology-Environment, Ecological Engineering and bioindicators	Ecology-Environment, Ecological Engineering and bioindicators	Univ Angers	

Vocational Licence: Aquaval, with a concentration in Aquaculture biotechnology (earned a quality label in Sept 2012) - IUT Quimper- UBO

IUT: DUT: Biological engineering (IUT Quimper, IUT Brest, IUT La Roche sur Yon, IUT Angers, IUT Le Mans); DUT Process engineering (option Bioprocessing) (IUT Pontivy, IUT Saint Nazaire)

Technician degrees BTS/BTSA: Aquaculture (Lycées in Bréhoulou, Quimper-Fouesnant, Vocational Lycée in Guérande)

Annex 6

SURVEY OF "MARINE RESOURCES" PATENTS FILED IN FRANCE

Only 1.4% of all patents filed worldwide between 2000 and 2011 dealt with marine biotechnology; however, in France, this figure reached 3% with at least one inventor residing in France.

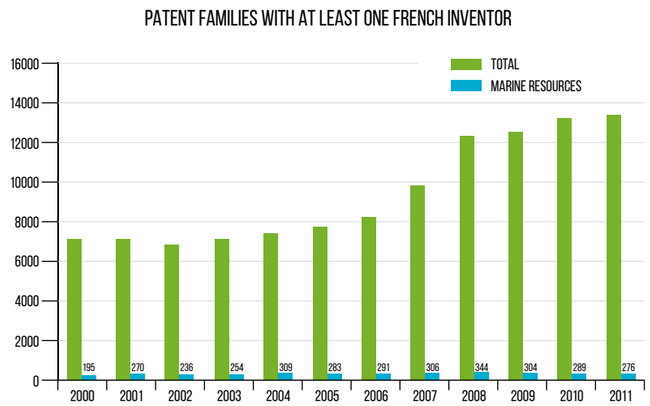

Figure A: Analysis of French patents on marine resources

However, since 2007, there has been a decrease in the number of patent applications in France (306 in 2007 and 276 in 2011).

Over this same 2000-2011 period, marine biotechnology patents accounted for 11% of French industrial protection applications in this field, clearly demonstrating the vigour of research in western France. Moreover, although the number of patent applications has decreased in France (Figure A), there has been a continuous increase in western France between 2007 and 2011.

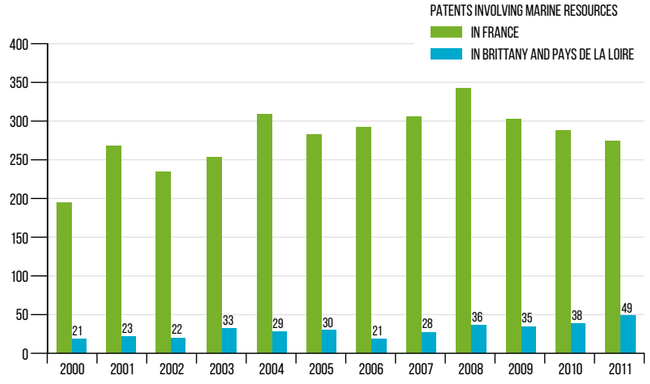

Figure B. Distribution of "Marine Resources" patents in western France with respect to national patent applications

This high proportion of patents comes primarily from public research institutes as shown in Figure C.

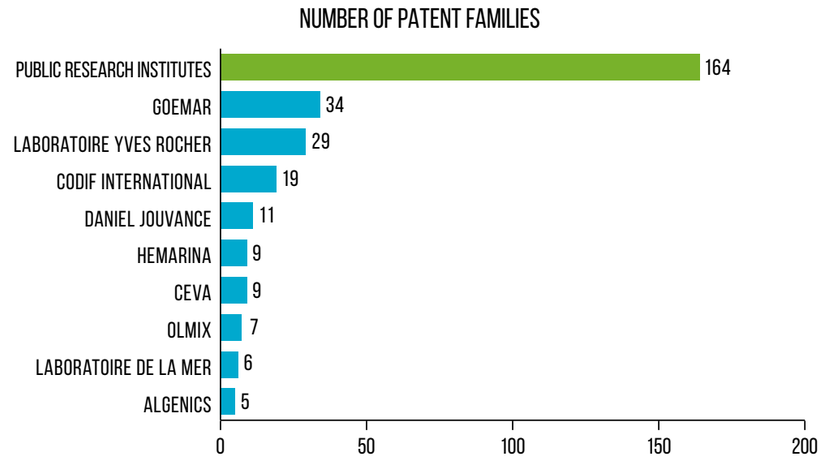

Figure C. Distribution of patents among public and private organisations in western France

UNIVERSITÉ DE NANTES

Université de Bretagne Occidentale

CNRS UPMC INSU
Station Biologique
Roscoff

MUSÉUM
NATIONAL D'HISTOIRE NATURELLE
SERVICE DU PATRIMOINE NATUREL