IDEALGs support to the seaweed sector in France
Regional Implications: BREIZH'ALG Program

Several IDEALG partner scientists are members of the regional program BREIZH’ALG Steering Committee, which represents a consultation body for the whole seaweed sector in Brittany. This program is also an excellent opportunity to combine the developments of many corporate projects with the scientific advances developed within IDEALG.

One of the founding concepts of BREIZH’ALG offers reciprocal opportunities for seaweed and oyster farmers to join together with the aim to diversify oyster farming activities and allow seaweed hatcheries to access concessions for cultivation. However, these developments cannot be improvised within the oyster territories which are likely to expose constraints regarding the prior selection of certain seaweed species adapted to tidal emersion and water turbidity, which is more important than in open sea environments.

It appears to us that, with the exception of a few seaweed farming companies which have started to propagate certain locally isolated cultivars, an important task of selecting strains (genotypes) adapted to the environmental conditions and the expectations of the seaweed processors remains to be done. Upstream aspects such as genetic diversity management and more restrictive aspects such as preserving industrial interests on crop varieties or know-how, need to be addressed. All these aspects have initiated technical meetings between seaweed farmers, shellfish farmers and scientists to define the research needs and to promote the best possible way to transfer the knowledge.

For this reason, we are not yet decided on a definitive choice of species for these projects, but we are ready to discuss, for example, upon the choice to develop the cultivation of a local species of nori, such as *Porphyra umbilicalis* or *Porphyra purpurea* by confronting opinions between experts from IFREMER, IUEM, CNRS-SBR and CEVA and in line with the developments of companies such as C-Weed aquaculture, Biocean, Bezhy Rosko and Aleor, working together in IDEALG. Moreover, in this scheme, the opportunity to integrate the harvesters of wild alga into the process must not be forgotten. Harvesters have precious knowledge on seaweed cycles and local environments which are also an asset for future success.

IDEALG suggests to further consultation meetings on future projects aiming to extend seaweed crops. This will allow IDEALG to coordinate studies, on one hand on the reproductive biology and genetics of certain species and on the other hand to anticipate potential impacts of crop propagation through experimental trials in an open environment.

From an economical point of view, the new seaweed sector, as initially described by BREIZH’ALG in 2011, did not seem to capitalize on the existing assets of different private companies already exploiting the local wild biomass. IDEALG took great care not to confront sustainable seaweed harvesting of wild populations against the development of seaweed aquaculture (cultures on the open sea, on seeded lines in nurseries, catchments, crops on land, in ponds or bioreactors, etc.). Today, we are looking at complementing rather than substituting crops for additional biomass in order to increase seaweed production. The developments needed in the view of boosting the existing seaweed sector are not different from those indicated in the BREIZH’ALG program, namely conservation and first processing, in particular the drying or stabilization. Moreover, taking into account the REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) Directive in application in 2012, the use of formalin for the preservation of seaweeds before processing is now forbidden.

In addition to the sustainable development era and serious reflections on improving production life cycles, processing companies are also thinking of limiting their imports and exploiting the local resource. Traditional seaweed processing plants can interact with the agro-food industry and IDEALG can support synergies linking nutrition and health properties of seaweed with other types of terrestrial food or biomass, as being supported by the Competitivity cluster specialised in Food VALORIAL. In terms of market analysis of seaweed based products, IDEALG thought that it would be preferable to extend the studies to markets other than Asian. Indeed, it is known that it is extremely difficult to enter the Asian market given the importance of the sensory qualities required by Asian consumers.

As far as the analysis of the markets for food algae is concerned, we have also found it desirable to extend the studies to markets other than the Asian food seaweed market. Indeed, Europeans are not familiar with fine sensory qualities required by Asians consumers.
The status of Wakame farming in France and perspectives

In order to establish seaweed farming practices on oyster farms, CEVA, ALEOR company and a few oyster farmers initiated the CHACO project (2009). The project had the ambition to establish demonstrators on approximately 60 ha of concessions, essentially propagating two species of brown algae, of which the reproduction and cultivation is well controlled.

On the one hand, the Japanese brown seaweed *Undaria pinnatifida* (Wakamé) introduced in France by IFREMER in 1984 for cultivation trials in Ouessant and then propagated in some Breton sites through projects of marine farms which have known different fortunes. The annual production reaches today an average 50 tonnes per year, cultivated by a few Breton companies for niche markets that do not compete with the major Asian producers of this seaweed (Japan, South Korea, China). On all the breton sites where the Wakamé was introduced between the years 1980 and 2000, the seeds spread into the wild and became the subject of a dynamic regional expansion. Propagation by other vectors such as boating and new artificial immerged substrates (quays...) accelerated this expansion. Any new introduction of this seaweed into cultivation is forbidden in Europe according to the recommendations of ICES (International Council for the Exploration of the Sea) and control of the introduction and expansion of the introduced species are integrated into the indicators of good Ecological state aspects of the marine environment (see for example DCSMM- Marine Strategy Framework Directive). In Brittany, the pioneering character of this seaweed involves the greatest caution in terms of expansion.

On the other hand, the local specie *Saccharina latissima* (Kombu Royal), whose propagation methods are very similar to those of Wakame, was part of the demonstration CHACO project. The Royal Kombu was already commercialised with biomass harvested from wild populations. However, the impact of massive propagation of the species crops has not yet been studied on adjacent ecosystems and in terms of genetic exchange with the wild population genotypes.

*S. latissima* was selected within IDEALG as a flagship species with the main objective of analysing the risks of genetic pollution that might result from open-sea the cultivation practices. An initial state of wild populations will have to be undertaken.
IDEALG: a support to resource management committees

Martial Laurans from IFREMER Brest (WP 8) is the scientific referent within the Regional Fisheries Committee (CRPMEM) for the concerted management of harvesting wild population of Kelps (*Laminaria digitata* and *L. hyperborea*). Thirty-five harvesting boats operate throughout the year. *L. hyperborea* is exploited according to a new management tool. Under the aegis of the commission chairman, Yvon Troadec, harvesters have adopted a new exploitation grid of 1 mile per 1.5 miles (2 km²) to harmonize fishing efforts according to the recent IFREMER studies. These studies have monitored seaweed harvesting over the last five years and has mobilized all the available data in order to evaluate the extent of exploitable biomass. These data, enriched by the more fundamental studies carried out within the IDEALG WP8, can be superimposed on the activity data of the harvesting vessels, all of which are willfully equipped with geo-localisation tracking systems.

Dominique Davoult from the Roscoff Marine Station, is a scientific referent within the Fisheries Committee (CRPMEM) for the management of seaweed harvesting on the shore. In consultation with the Seaweed industrial cluster (CSAVM), the cluster grouping shore-seaweed harvesters currently manages the working group on shore seaweed within the Seaweed Committee of the CRPMEM of Brest (monitoring of the cohabitation between Professional and casual harvesters, access to the resource, dates of campaigns, follow-up of fallow sites, etc.) In this context, the CSAVM, in association with the Iroise Marine Park, established new grids allowing harvesters to precisely locate their harvesting sites. It is in this context that the scientific work of IDEALG WP8 is carried out and provides useful data to understand the regeneration of shore-seaweed. Moreover, IDEALG is working hand in hand with CRPMEM within the BIOMASSE-ALGUES project, aiming to evaluate the level of standing biomass of shore-seaweed on the Brittany coasts.
Dissemination and new outcoming projects

The annual Forum: a favourable environment for open discussions

The IDEALG FORUM is a one-day conference organised every year by the coordinating team. The Forum is located every second year at the Roscoff Marine Station, for intermediate years the Forum is hosted by one of the project partners (INRIA-Rennes in 2012 and IFREMER-Brest in 2014, UBS-Lorient in 2016). The FORUM was set up to create a favourable environment for meetings, exchanges and consultations between all stakeholders in the seaweed sector in France. On a regular basis, this FORUM aims to communicate on major advances of the IDEALG project, to share the fundamental knowledge and to stimulate exchanges around subjects that are identified as development factors for the algae sector. A growing number of participants was registered at the FORUM, reaching 100 people in 2015. The main participants are private companies from the Brittany region, however, since 2014 actors from the Mediterranean coast and the DOM-TOM (Guadeloupe) are now constantly present.
A socio-economic committee to support the evolving sector

The Socio-Economic Committee of IDEALG meets once a year since 2013. The committee is represented by partners studying the socio-economic impacts of the developing sector, such as the SBR, CEVA, UBO, IFREMER and Agrocampus Ouest, with all 4 companies (CWeed Aquaculture, Bezhin Rosko, Aleor and France Haliotis). Other participants can be invited to the discussions according to the topics, Pole Mer Bretagne Atlantique (PMBA), CCIs, trade unions, external scientific referents and other companies in the sector. The role of the committee is to highlight the difficulties of the sector and suggest targeted actions able to be developed within IDEALG, or through other parallel projects. The main aim is to keep regular and close contact to the evolving sector and respond to the real needs.

Several points have been identified as potentially problematic in the view of developing the seaweed sector. IDEALG has addressed these points by suggesting target actions, of which some are under progress (Table-1).

<table>
<thead>
<tr>
<th>Identified hindering points</th>
<th>IDEALG suggestions and undergoing actions</th>
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</thead>
<tbody>
<tr>
<td>The seaweed sector is lacking organisation. Private companies, harvesters and scientist do not work together.</td>
<td>The IDEALG forum already brings together the diverse community of the seaweed sector, private companies, scientists, seaweed farmers, harvesters and politics. Time is a prerequisite for direct communication to establish and to foster new ideas together. Thanks to the Forum, transversal projects are under progress, hence increasing the interactions within the sector.</td>
</tr>
<tr>
<td>Seaweed aquaculture is difficult to establish in France: societal barriers, heavy administrative and financial procedures...</td>
<td>IDEALG communicates with the general public on seaweed aquaculture in order to transfer the knowledge and counter preconceived ideas: open debates in 2015 (café des sciences Quimperlé, journée de l’algue à Plougerneau...), communication supports in 2016 (Ecomusée des Goémoniers et Musée de Lanildut). IDEALG takes part in consultation meetings with the local maritime governmental authorities (DDTM) for the attribution of new seaweed farming concessions.</td>
</tr>
<tr>
<td>The management plan of the wild resource needs to be improved: no information about the standing biomass, no preservation scheme for local strains (in case of pollution or climate change).</td>
<td>IDEALG is involved in the new ALGAE-BIOMASS project held by the CRPMEM which aims to evaluate the standing biomass along the Britany coasts. IDEALG is currently implementing the very first culture collection of seaweed strains in France. At this stage, the selection involves mainly strains originating from Britany coasts and are all brown seaweed.</td>
</tr>
<tr>
<td>Seaweed co-products such as arsenic et iodine are problematic in terms of environment as well as public health.</td>
<td>IDEALG is examining the iodine problematic with the objective of reducing the natural content through variety selection processes.</td>
</tr>
<tr>
<td>The seaweed sector is lacking visibility at a national and European level.</td>
<td>IDEALG has initiated a working group to elaborate an official document on the socio-economic importance of the seaweed sector in France: Ministry of Labour DIRRECTE, CCI Brest, CCI Morlaix, CEVA, SBR, Agrocampus. Publication in 2017</td>
</tr>
</tbody>
</table>
The leverage effect

The IDEALG trajectory aims to leverage new collaborative projects or other forms of partnership with companies outside the initial partnership. Nearly 30 companies now take part in IDEALG’s collaborative platform and many new research and innovation projects stem from IDEALG in both aquaculture and algal biotechnology. The ALGOLIFE bio-refinery project, involves four Breton companies, the Roscoff Marine Station, and an ANSES laboratory began in January 2015. The direct contribution for IDEALG represents a co-funding of €2 million over five years for the transfer of enzymatic technologies and bioconversion. The first results already lead to a technology transfer to Agrival company and to the licensing through the SATT Ouest-Valorisation.

The consultation around new projects is also carried out within a regional committee of the "Breizh'alg" program set up and led by the services of the Brittany Region Council. The stakes for the development of access to the algal resource are multiple, notably for the management of harvesting of kelps or of shoreline algae with the establishment in early 2016 of new monitoring projects such as the BIOMASSE-ALGUES program led by the Regional Committee for Fisheries. After, the PhD defence at ENSCR in 2015 of a project co-funded by Goemar-Arysta and Brittany region, a CIFRE thesis with the company Goémar- Arysta was defended on September 30, 2016 and is protected by the filing of a patent expected in 2017. The graduate student Céline Conan has obtained an Arysta job position since January 1st 2017 and is now based in Saint Malo where she will continue its collaboration with IDEALG to finalize the STIMALG project. Another CIFRE thesis with the company OLMIX in connection with IDEALG WP5 will be defended in autumn 2017. Another one is being prepared with Cargill Texturants. The RIV-AGE 2.0 project involving C-Weed company, was selected for funding in the 20th FUI call of 2015 and started in early 2016. At the SBR, the SATT-Ouest Valo funded a 18-month contract to reinforce the Ectocarpus PKSII patent of 2011. The hired engineer led to results confirming the feasibility of protein engineering to generate molecule platforms for the production of resins or d Adhesives by green chemistry. He led the SATT Ouest-Valo to promote a pre-industrial development project on the platform of the demonstrator Toulouse White Biotechnologies which was visited in September 2016. Discussions with a TWB industrialist are underway. An engineer also completed the Oligomar-Skin project with Lessonia in November 2016. The marketing of a new cosmetic active ingredient is scheduled for 2017 after positive feedback from the first customer tests and its production will be carried out by the company Agrival who benefits from the transfer of enzymatic technologies from the SBR through the Algolife project. Several new collaborative projects have just been submitted in early 2017.

IDEALG has also reached a European dimension, in particular through responses to calls within "Horizon 2020". The ITN-laboratory and company network ALFF project for a PhD- programs led by Oban's SAMS has started in 2015 and 2 European PhD students have been hired at the Roscoff Marine Station within the UMR 8227 (Partner 2) on projects related to the WP3 and 4 of IDEALG. Following failures with Danish and Norwegian led consortia for Blue Growth calls (RIA projects BG-03 and BG-04) in 2014, several projects were submitted in 2016 in the field of seaweed and biorefineries with the opportunities of the calls for projects H2020: Blue Growth 2016-01 « Large-scale algal biorefineries "and the FEAMP 2016-2020 funds in partnership with seaweed and shellfish farmers.

The DOMESTALG project with the company BRE'TALG at Roscoff was selected at the FEAMP Innovation in June 2016, but unfortunately the company has to give up on matters of financial equilibrium. This also results in a dismissal of a doctor trained by IDEALG who could only work 5 months on this project. The POLISTR project with the CRC Bretagne Nord will be submitted to the FEAMP Innovation in May 2016 and will be coordinated by the Beg-Meil Agro-Campus Ouest team to develop algae cultivation in oyster concessions.
Conclusions and Perspectives for 2020
Preliminary conclusions

After almost six years of basic and applied research, IDEALG has achieved more than 50% of its output targets, in the form of formal deliverables, as well as more than 85 publications with as many communications and reports. IDEALG has particularly enabled the development of genetic, chemical and mathematical tools in order to better understand the physiology, metabolism and evolution of algae in their environment. The development of biological tools involves the use of a brown algae model (*Ectocarpus siliculosus*). Selection by genetic breeding methods and the analysis of the different biosynthesis pathways of compounds of interest such as polysaccharides, phlorotannins or mannitol are tools which can be transposed to other algae species presenting commercial interests such as *Saccharina latissima*. Moreover, this work led to the construction of the first metabolic map of brown algae (ECTOGEM) and that of a red alga (ChondrusGEM). Other valorization pathways are studied for applications in green chemistry, in particular the production of biological surfactants, but also in health and hygiene for the control of bacterial biofilms. Certain bacteria associated with algae are a source of molecules, including a range of characteristic and recombinant enzymes that now exceed a total of 50, capable of transforming algal compounds by conferring specific high added value activities. Algae recombinant enzymes, to a lesser extent, are also the subject of biotechnological developments in partnership with SATT Ouest-Valorisation.

Impact studies, which at first focused on the monitoring of exploited wild populations, have produced valuable results which will now be used to improve the resource management plans. Regarding seaweed aquaculture, a SWOT analysis of the development of seaweed farming was carried out in consultation with major actors of the sector. This analysis had the objective of serving as support for decision-makers willing to address the issue. Similarly, the implementation of an ecosystemic analysis model for seaweed farming has also highlighted the tool as a more technical support for decisions involving compensatory measures. Finally, a national survey on the consumption of seaweed published a set of documents which was largely distributed in order to communicate on the seaweed sector through seaweed as a food.

In 2017, access to macro-algae resources remains a major challenge at local and international levels. An integrated and ambitious research project willing to unlock this issue, can not alone bring all the solutions and recommendations, nor can it resolve the gap between supply and demand for very high-quality algae at very low or even moderate prices. It can only illuminate the choices of citizens to accept or not new activities in the maritime or coastal field. Recent conflicts over the acquisition of new large-scale concessions on the Brittany-South coast or the Saint-Malo region reveal this fragility. Some citizens require more than compensatory measures as an outcome of consultation meetings, before the establishment of new concessions. Such needs are independent of the size of the project but revert to better communication and presentation of potential alternatives.

In France, most of the seaweed resource comes from wild populations harvesting and is represented by Laminaria species (kelps). Kelp harvesting experienced a small revolution after the severe winter of 2013-2014. Continuous swells over several weeks of big spring tides disturbed the ground-floor and beach-casted nearly half of the standing stock of *Laminaria digitata*. That has accelerated the development harvesting of the “deep-sea” kelp (*Laminaria hyperborea*) fishery to complement the landings. The alginates extracted from this species are well known for interesting pharmaceutical applications. The mutation of factories has accelerated in order to adapt their processes to this new type of resource. This particular winter also showed the fragility of the shore seaweed stocks and especially highlighted the extent of the unknown on current available biomasses in terms of sustainable harvesting management. IDEALG has largely contributed to define the scientific basis of this management.
Perspectives and Blue growth

After six years of fundamental and applied research, clearer trends have emerged. Beyond the fact of securing seaweed supplies in quantity and in quality, which will necessarily involve seaweed farming and genetic selection to supplement or substitute certain crops, biomass extraction processes must also evolve towards a complete valorisation of all seaweed fractions. The bio-refinery concept, which predominantly favours co-products from terrestrial plants to applications with varying degrees of added value, will surely be based on current developments in enzyme biotechnologies for macroalgae.

IDEALG has implemented a large number of tools, often organized in modules for the processing of genomic, genetic, biological and chemical information (especially computer pipelines), which are used for basic and finalized research. By 2020, more than 40 new brown algae genomes will be explored. It will thereby expose new mechanisms, biosynthetic pathways and new enzymes. Red and green algae genomes and an exponential number of bacterial genomes and metagenomic data will also be annotated, modelled or exploited for new applications.

The IDEALG community has been organized to meet these challenges on Horizon 2020 and the project has seen many spin-off collaborative projects with other academic and industrial research teams. These new projects will also define the prospects beyond IDEALG. Indeed, by the end of 2019, much of expected results will enrich conclusions of IDEALG. But many transfers to innovation projects for the development of the sector will still be in stages of prototypes, pre-pilots before commercialization of new processed products, new varieties or selection processes for seaweed farming. Techno-economic studies will also help to clarify the choices for transferring research to the creation of new activities and new jobs. But true innovation will also be societal. IDEALG must also succeed in disseminating its knowledge to society through scientific and technical diffusion centres, education and environmental protection associations, users of the maritime environment and of course political and economic decision-makers. "Blue growth" will only happen if it is shared and benefits all actors.
GENIALG project
France, the European leader of seaweed biorefinery

The GENIALG project is one of the two winners of the 2016 Horizon 2020 "Blue Growth" European Call for Projects. The project is held by the Roscoff Marine Station, and coordinated by Dr Philippe Potin. A total of 11 million euros is attributed to the project with the aim to demonstrate the technical feasibility and economic viability of large scale seaweed biorefinery. To achieve this objective, GENIALG brings together a trans-sectoral and complementary consortium of 19 research institutes and private companies.

GENIALG focuses on the production of marine biomass in open sea or on-shore and aims to implement the biotechnologies which would guarantee a 100% valorisation of the algal biomass and on an industrial scale. The aim of the GENIALG project is to capitalize on important advances in R&D on seaweed and to accelerate innovations which will stimulate the economy of blue biotechnology.

Two European high-yield seaweed species will be assessed: the brown alga *Saccharina latissima* and the green alga *Ulva sp*. Strains presenting interesting traits will be selected for improvement studies. The partners of the consortium will use the knowledge already available on algae biotechnologies, environmentally-friendly tools and methods to produce high yielding strains in quantities and qualities which are economically profitable. The development of industrial demonstrators using new biotechnological processes will provide a wide range of chemical compounds for existing applications and markets, for example in the fields of cosmetics for animal health and biomaterials.

The project will also seek to anticipate the impact of these developments on economic benefits and job creation that will increase the socio-economic value of blue biotechnology. Finally, issues regarding resource conservation and biosafety will also be addressed, as well as societal aspects such as acceptability and conflicts with other maritime activities (competition for space and access to seawater, for example).
1- List of Figures and Table 1

Table 1: Problematic points identified by the socio-economic committee potentially hindering the development of the seaweed sector in France, and target actions within IDEALG to overcome these points.
2 - Publications & Patents


18. Coste F, Gaëlle Garet, Jacques Nicolas: A bottom-up efficient algorithm learning substitutable languages from positive examples. ICGI 2014: 49-63


26. Ficko-Blean E, G Michel - 2015 Sweet and sour sugars from the sea: the biosynthesis and remodeling of sulfated cell wall polysaccharides from marine macroalgae. Perspectives in Phycology, 2: (1), p. 51-64


62. Montecinos AE, Guillem in ML, Couceiro L, et al. (sous presse) Hybridization between two cryptic filamentous brown seaweeds along the shore: Analysing pre-and post-zygotic barriers in populations of individuals with varying ploidy levels. *Molecular Ecology*.


4. Oligo-ʄ-carraghénanes, composition cosmétique, dermatologique et pharmaceutique les contenant, et leur utilisation BNT218167FR00 -

5. Oligoporphyranes, procédé et médicament BNT218168FR00 -

6. Alpha-1,3-(3,6-Anhydra) -D-Galactosidases et leur utilisation pour hydrolyser des polysaccharides BNT218168FR00-GC9QK -

7. Nouvelle ulvane lyase et son utilisation pour cliver des polysaccharides BNT221378FR00 -
3- PhDs within IDEALG

1. KOWALCZYK Nathalie (2010-2013)

IDEALG – WPs 1 “Omics” & 3 « Interactions »

Abiotic stress in the Red Alga Chondrus crispus: development of a model for physiology and molecular biology

PhD in Biological Sciences- Doctoral School Diversité du Vivant, supervise de Catherine Boyen et de Jonas Collen.
Defended in 2013 at University Pierre et Mare Curie. Funded by Region Bretagne (ARED)

Abstract

Chondrus crispus is a red macroalga, chosen as a model for multicellular rhodophytes. It is believed that the response of C. crispus to abiotic stressors related to its tidal environment; light, desiccation, heat, rainfall; explains to a large extent its distribution on the shore. The aim of this thesis was to test this hypothesis using a multiscale approach. Two foci are the metabolism of reactive oxygen species (ROS), thought to be important in stress tolerance, and photosynthesis, the principal ROS producer and major indicator of physiological status. The first goal was a global genomic study with the expert annotation of the C. crispus genome, for a better understanding of the functioning of stress-related metabolism and photosynthesis. Then using next generation sequencing technologies to carry out transcriptomic experiments in order to characterize the gene expression of the three major life stages of C. crispus and identify new candidates implicated in the stress response, leading to future targeted studies. The second goal of this thesis was to analyze the response of the photosynthetic apparatus to light, using chlorophyll fluorescence and spectrometry. These technics are often used in green organisms and cyanobacteria, however, red algae possess a unique photosynthetic apparatus, intermediate between the green plants - with a similar PS I antenna - and the cyanobacteria, having phycobilisomes as PS II antenna; they also lack known mechanisms of energy dissipation using carotenoids. We had to establish a suited protocol to interpret the generated data, and thus characterize an original and controversed photoprotection phenomenon, the spill-over, an efficient energy transfer resulting from the physical contact between PSII and PSI, controlled by the redox state of the plastoquinone pool.

2. LECLERC Jean-Charles (2010-2013)

IDEALG – WPs 3 « Interactions » & 8 « Impacts »

Biodiversity, trophic structure and functioning of communities Laminaria hyperborea under natural conditions and exploited in Britain

PhD in Sciences of Environment, supervised by Pascal Riera and Dominique Davoult.
Defended in 2013 at University Pierre et Mare Curie. Funded by Doctoral school

Abstract

Kelp forests are emblematic habitats of temperate rocky reefs. In Brittany, these ecosystems are dominated by Laminaria hyperborea, this species is harvested for its alginic acid content. The aim of this thesis work is to characterize the biodiversity, structure and trophic functioning that feature these communities in natural and harvested conditions. The incidence of at least 572 species (110 algae and 462 fauna) was reported from sampling performed within two stations off the coast of Brittany. Diverse assemblages were highlighted according to the stratification of kelp forests in various microhabitats, with contrasting complexities. The link between habitat stratification and associated biodiversity suggests that considering this stratification is necessary for a sustainable management of this ecosystem. Within local food web, while the resource was partitioned at micro-scale, trophic pathways were based on phytoplankton, kelp and associated seaweeds. The seasonal cycle (i.e. the alternation of growth and senescence phases) of food sources proved to influence consumption by associated communities (both indirect consumption through detrital pathways and direct consumption through grazing). The results of this thesis highlighted the importance to ascertain the overall functional diversity within kelp forests. This diversity needs to be taken into consideration at a multi-scale level in order to comprehend ecosystem stability.
Spatio-temporal study of the biodiversity of kelp forest from Brittany coasts by an integrated approach of population genetics and community ecology.

PhD in Ecology and Evolution
Supervised by Line Le Gall and Myriam Valero.

President of the jury: Nicolas Mouquet.
Jury: Eric Feunteun.
Rapporteurs: Sophie Arnaud-Haond, Inka Bartsch.

Abstract

The topic of this PhD thesis was the study of biodiversity patterns and the assessment of the underlying processes within the kelp forests. The focus of this work was to characterise the variability of biodiversity over space and time at both the intra and inter specific level. Population genetic diversity of the two sister species Laminaria digitata and Laminaria hyperborea, and the specific diversity of the understory macroalgae were studied in Brittany (France) at several hierarchical levels (along a coastline of 500 km) between seasons and across the last twenty years. Results revealed that populations of L. digitata, inhabiting the lower margin of the intertidal, were less diverse and more structured than the populations of L. hyperborea, a subtidal species. Similarly, algal communities associated to L. digitata were less diverse and more structured than those associated to L. hyperborea. These observations are likely related to the higher dispersal distance of spores and gametes in the subtidal than the intertidal. Our results demonstrated the presence of mosaic biotic conditions at the scales of the Brittany coast with contrasted spatio-temporal characteristics. This variability is most certainly the main explanation of the differences observed in biodiversity patterns. Cold waters occur along the two adjacent regions of Morlaix Bay and Iroise Sea which are characterised by moderate temperature variations between seasons and across years. These two regions were the less impacted by global warming compared with the other regions of Brittany studied. Here, high levels of diversity and connectivity were reported for both intra and inter specific biodiversity in the two targeted species of kelp. Conversely, St Malo Bay had the lowest level of diversity and connectivity at the genetic and specific levels for both species L. digitata and L. hyperborea. In this region, seasonal variations of temperature amplitude were the highest observed in Brittany and this trend intensified over the two decades. In South Brittany, where sea surface temperatures were the highest, biodiversity patterns varied according to the species considered (L. digitata being at its southernmost range) and the level of diversity considered. In conclusion, our results have shown the occurrence of a mosaic of environmental conditions at a scale from 10 to 250 km. This scale is often not taken into account in ecological niche models. Moreover, correlations between spatial patterns of diversity at both the genetic and specific levels (SGDC) were generally positive. Despite the strength of association, their significance varied depending on the space and the species considered.

Structural and functional studies of enzymes of the metabolism of the laminarin of two emerging model organisms, the brown alga Ectocarpus siliculosus and the marine bacterium Zobellia galactanivorans

PhD in Biology, supervised by Gurvan Michel.
Abstract

Laminarin is a storage polysaccharide found in brown algae. Ectocarpus siliculosus has been recently established as a genetic and genomic model for brown algae. The analysis of its genome sequence revealed some candidate genes involved in the central metabolism of laminarin. In order to go onto functional studies, I have applied a medium throughput cloning strategy on these genes. Brown algae being an important coastal biomass, laminarin is also a significant carbon source for marine heterotrophic bacteria. The marine bacterium Zobellia galactanivorans is currently being established as a model bacterium for the bioconversion of algal polysaccharides. Its genome sequence encodes 5 putative laminarinases displaying various modular architectures. The heterologous expression and the purification of the catalytic modules ZgLamAGH16, ZgLamCGH16 and those of the carbohydrate-binding module CBM6 appended to ZgLamCCBM6, have enabled their biochemical characterization. Inactive mutants of the catalytic modules were obtained by site directed mutagenesis. They were used to generate enzyme-substrate complexes. The 3D-structure of ZgLamAGH16 was solved by X-ray crystallography, and oligoglucans of natural substrates were present in the catalytic site. ZgLamCGH16 was obtained in complex with a thio-hexasaccharide of β-1,3-glucan. The ZgLamCCBM6 structure associated with microcalorimetry experiments suggests that this CBM6 can bind laminarin simultaneously in its two binding clefts. The whole results are discussed and integrated in a biologic and evolutive context.

5. FOURNIER Jean-Baptiste (2010-2013)

IDEALG – WPs 5 « Enzymes »

Evolution of the mechanisms of accumulation and transport of iodine in marine organisms : structure/function study of proteins of iodine metabolism in the marine bacterium Zobellia galactanivorans

PhD in Biology, supervised by Catherine Leblanc.
Deefnded the 16-01-2014 à Paris 6, École doctorale Complexité du vivant (Paris).
Funding : ARED Région – Commissariat à l’Energie Atomique

Abstract

In marine environment, biogenic emissions of iodinated compounds play an essential role in biogeochemical cycle of iodine. Nevertheless, enzymatic process involved in absorption and storage of iodine or in the synthesis of iodinated compounds are unknown marine organisms, especially in bacteria. Several genes, potentially involved in iodine metabolism, have been identified in the genome of a marine bacterium, Zobellia galactanivorans. One of these genes codes for a vanadium iodoperoxydase (VIPO), an enzyme specific of iodide oxidation. The main part of the thesis project was to understand molecular mechanisms controlling the specificity vanadium halopéroxydase (VHPO) for some halide, by studying the VIPO from Z. galactanivorans by directed mutagenesis and structural biology. To lead this project, twelve mutated enzymes were produced and characterized at biochemical level. For some of them, mutations lead to a loss of activity or to modification of catalytic properties or to a slight VBPO activity. The wild type enzyme and three mutants were also analyzed by X ray absorption and diffraction spectroscopy in order to link the structural modifications to their catalytic properties. The results of this study suggest that the main factor modulating the specificity in these enzymes is modification of redox potential of the peroxovanadate. Biochemical analyses lead with two other proteins identified in the genome of Z. galactanivorans. The first protein was characterized as a new VIPO. For the second protein, similar to mammal iodothyrosine deiodinase, the biochemical activity remains to be characterized. Z. galactanivorans seems to have several enzymes which oxidize iodide or split C-I bond. In parallel at this work, the localization and speciation of iodine were analyzed by chemical imaging in Z. galactanivorans and in the kelp L. digitata, known to concentrate highly iodide. All this information allow to a better understanding of molecular mechanisms involved in the specificity for halide in VHPO and the bacterial origin of these proteins. More generally, these studies assess to understand the role of iodine metabolism in some marine bacteria and their role in biogeochemical cycle of this element.
6. CREIS Emeline (2011-2014)

**IDEALG – WPs 3 « Interactions » & 5 « Enzymes »**

**Study of the biosynthesis pathway of phlorotannins in brown algae, toward biochemical characterization of recombinant enzymes and study of ecophysiological responses**

PhD in Marine Biology, supervised by Erwan Ar Gall and Philippe Potin.
Defended the 06-03-2015, Paris 6, École doctorale Complexité du vivant (Paris), in collaboration with the Laboratory of integrative biology of marine models.
Jury: Alain Bouchereau, Joël Boustie, Christophe Destombe, Geneviève Chiapusio and Florian Weinberger.

**Abstract**

Phlorotannins are polymers of phloroglucinol that are specific phenolic compounds of brown algae (Phaeophyceae). These metabolites present antioxidant activities and are potentially involved in the formation of cell-walls but their biosynthetic pathway is currently uncharacterized. The genome annotation of the brown algae Ectocarpus provided some information about conserved genes which are implicated in the synthesis of phenolics in terrestrial plants. One polyketide synthase of type III (PKSIII) has been successfully characterized: it produces phloroglucinol. The search for other targets has been pursued in brown algae focusing mainly on chalcone isomerase-like (CHI-like) genes, as well as on phenol-sulfotransferases, which are implicated in the sulfation of flavonoids. The characterization of CHIL has revealed their implication in fatty acid binding (FAP). However, the level of interest for this new family has led to their biochemical characterization and to functional studies by complementation of gene in the Arabidopsis thaliana FAP mutant. The progressive elucidation of the phlorotannin biosynthesis pathway has been used in order to discover mechanisms which regulate this metabolism in brown algae. By combining integrated approaches of gene expression profiling with the quantification and profiling of soluble phlorotannins, we have shown that these metabolites ensure the constitutive protection in Fucus vesiculosus against UV-B radiation and could also be induced as a very early response to grazing. The development of specific molecular tools for this metabolic pathway opens some new perspectives in ecophysiological and ecological studies.

7. PRIGENT Sylvain (2011-2014)

**IDEALG – WP 4 « Metabolic networks»**

**Combinatorial completion for metabolic network reconstruction, and application to the model organism for brown algae Ectocarpus siliculosus**

PhD in computing, supervised by Anne Siegel and Thierry Tonon.
Defended the 14-11-2014 in Rennes 1, École doctorale Mathématiques, télécommunications, informatique, signal, systèmes, électronique (Rennes), in collaboration with the Institut de recherche en informatique et systèmes aléatoires (Rennes)(laboratory) Université européenne de Bretagne (PRES) and DYLISS (laboratory).

**Abstract**

In this thesis we focused on the development of a comprehensive approach to reconstruct metabolic networks applied to unconventional biological species for which we have little information. Traditionally, this reconstruction is based on three points: the creation of a metabolic draft from a genome, the completion of this draft and the verification of the results. We have been particularly interested in the hard combinatorial optimization problem represented by the gap-filling step. We used Answer Set Programming (or ASP) to solve this combinatorial problem. Changes to an existing method allowed us to improve both the computational time and the quality of modeling. This entire process of metabolic network reconstruction was applied to the model of brown algae, Ectocarpus siliculosus, allowing us to reconstruct the first metabolic network of a brown macro-algae. The reconstruction of this network allowed us to improve our understanding of the metabolism of this species and to improve annotation of its genome.
Abstract

This thesis proposes a new approach to discover signatures of families (and superfamilies) of enzymes. At first, given a sample of aligned sequences belonging to the same family, this approach infers context-free grammars characteristic of this family. To do this, new principles of generalization and new classes have been introduced based on substitutability. An algorithm has also been developed for this purpose, which produces a reduced grammar able to retain the structure of examples. In a second step, this manuscript presents a method for classification of a superfamily sequences into families with a formal concept analysis based on alignment sequences allowing detection of new families and the discovery of patterns to improve functional previous signatures.

Abstract

Every eukaryotic organism has its own microbiota, either found as epibionts or endobionts, which exert tremendous physiological and developmental influences on the host. In recent years, better understanding into the microbial diversity associated with macroalgae has been obtained and the microbial-algal associations are recognized as meta-organisms or holobionts: a functional unit of eukaryotic cells and microorganisms. The holobiont concept proposes the need for a collective view of all interactions and activities within and between a host and all its associated organisms. Knowledge of many individual aspects of these interactions has rapidly expanded in the last few years, including the chemical interactions between bacteria and seaweed hosts, bacterial diversity, and microbial diseases of algae. In this thesis, we studied the symbiotic relationship between the brown algal model *Ectocarpus* sp. and its associated microbiota.

The first chapter highlights the critical role of bacteria on reproduction, growth and development of *Ectocarpus* sp. I demonstrated that several bacterial isolates impacted *Ectocarpus* sp. development. Although the mechanisms involved in these interactions were not deciphered, the results suggest that some kind of communication seems required to display the effects recorded during the experiments. Bacterial effect on the algal physiology was also remarkable since one single bacterial isolate triggered major changes in the algal exometabolomic profile.

The second part of the thesis shows that cytokinins, and not auxin, produce the same effect that bacterial isolates on the development of erect filaments. I speculate that bacteria capable to trigger upright filament development in *Ectocarpus* exert their effect by producing cytokinin-like compounds and/or also producing auxin antagonists. Future
studies on the mechanisms underlying crosstalk between phytohormones and those involved in *Ectocarpus*-bacteria interactions should provide some clues on how conserved are these two phenomena in land plants and brown algae. The third chapter describes bacterial communities associated to cultured and wild *Ectocarpus*. It was established that culture conditions of *Ectocarpus* impose pressures that shape bacterial communities more than other variables, such as algal geographic location. Despite the general differences between bacterial communities, it was possible to distinguish a 'core' community probably selected by specific host traits. The predicted functional similarity between bacterial communities points out to ecological redundancy among microbial taxa.

Altogether, this thesis presents a general view of the interaction between *Ectocarpus* *sp.* and its associated microbiota. The results from this study highlight the relevance of bacteria to their macroalgal partners, extending the current knowledge on eukaryote-bacteria interactions.

10. CONAN Céline (2013-2016)

**IDEALG – WP 9 « Industrial collaborative projects»**

**Metabolomics investigations of seaweed extracts used as plant growth biostimulants and transcriptomics studies of their physiological effects on Arabidopsis thaliana.**

PhD Thesis in Biology, supervised by Philippe Potin et Anne Guiboileau.
Defended on the 30-09-2016 at UPMC, École doctorale de Complexité du vivant (Paris), in collaboration with Goemar-Arysta company and the laboratory of Integrative Biology of marine models. Grant agreement CIFRE-ANRT
PhD committee: Sophie Tomasi, Benoit Lacombe, Antoine Gravot, Pascal Richomme, Bernard Kloareg

Abstract

To further develop a sustainable agriculture, new bio-solutions include the use of biostimulants such as seaweed aqueous extracts to improve plant growth or/and alleviate the effect of biotic and abiotic stress. These commercial products aim to improve plant nutrition, in order to impact yield and quality parameters. In this domain, some modes of action have been proposed by the Goëmar-Arysta R&D center. However, the bioactive ingredients have not been identified so far, using classical methods of bioassay-guided fractionation. Therefore, their mechanisms of action remain also elusive.

The aim of this thesis project was first to identify, using a strategy of metabolomic profiling of seaweed extracts, the bioactive compounds responsible for plant growth stimulation. The 1H-NMR-based profiling and LC-MS metabolomic analyses of commercial seaweed extracts were not suitable to identify candidate molecules that promote plant growth. A classical bioassay-guided fractionation achieved on a Goëmar extract provided a growth promoting purified fraction and further bioactive sub-fractions.

In parallel, the physiological effects of these seaweed extracts were studied in the model plant Arabidopsis thaliana through transcriptomic approaches in order to decipher patterns of gene regulation in response to a crude commercial extract and purified fractions. Finally these two approaches combining, metabolomics-guided and bioassay-guided fractionation of extracts from the brown seaweed Ascophyllum nodosum, and global transcriptomics in Arabidopsis provided several new insights into the nature and structure of different molecules that trigger physiological responses in plants.


**IDEALG – WP 5s “Enzymes” & 9 « Industrial collaborative projects»**

**Chemical modification of laminarin in order to increase its efficacy as a resistance inducer against grapevine’s downy mildew. Importance and characterisation of foliar biodisponibiliy**

PhD in Chemistry, supervised by Vincent Ferrières and Xavier Daire.
Defended in 2015 at École nationale supérieure de chimie (Rennes), École doctorale Sciences de la matière (Rennes), in collaboration with Institut des Sciences Chimiques de Rennes (laboratory) and the Université européenne de Bretagne (partner).

**Abstract**

In order to decrease the amount of chemical fungicides to control grapevine downy mildew, an attractive alternative is the use of resistance inducers to activate plant defences. This strategy implies the detection of highly conserved molecular patterns called MAMPs (Microbe Associated Molecular Pattern) by PRR (Pattern-Recognition Receptors) located on the plant cell plasma membranes. Laminarin, a β-(1→3)-glucan extracted from the brown algae Laminaria digitata is a MAMP, known to elicit defence reactions in grapevine. However, protection provided against downy mildew by foliar treatment of laminarin remains inconsistent for its use in vineyard. We hypothesized that this insufficient efficacy was mainly due to a poor penetration of the polysaccharide through the hydrophobic leaf cuticle leading to a lack of in planta bioavailability. Thus only a small amount of resistance inducer could reach its cellular targets. This study highlights the importance i- of using a suitable penetration enhancer and ii- of treating the lower leaf surface to increase laminarin penetration rates and consequently its efficacy in grapevine. For the first time, we show that the penetration of saccharides mainly occur via stomata, only located on the lower surface of grapevine leaves. Moreover, the synthesis of chemically modified laminarins with various degrees of hydrophobicity allows us to show that this penetration pathway seems to be preponderant regardless of the polysaccharide modification. Our results also indicate that certain chemical modifications of laminarin lead to an increase in its efficacy but that this increase is probably due to fungicide properties against the pathogen instead of a better bioavailability.

12. BONIN Patricia (2012-2015)

**IDEALG – WPs 4 « Metabolic networks» and 5 “Enzymes”**

Study of mannitol metabolism in the model brown algae Ectocarpus siliculosus: characterization of the key enzyme mannitol-1-phosphate dehydrogenase.

PhD in Biology, supervised by Catherine Boyen and Thierry Tonon. Defended the 09-12-2014 in Paris 6, École doctorale Sciences de la nature et de l’Homme. Évolution et écologie (Paris), in collaboration with the Roscoff Marine Station(Roscoff) (laboratory) and the laboratory of Integrative Biology of marine models. Jury: Marie-Pascale Prud’Homme, Rémi Lemoine, Bernard Kloaregand Didier Flament.

**Abstract**

Brown algae are multicellular photosynthetic organisms belonging to the stramenopile lineage and which are mainly found in the intertidal zone. One of their metabolic characteristics is to store carbon fixed by photosynthesis through the production of mannitol, a 6-carbon non-cyclic polyol. Synthesis and recycling of mannitol in these organisms occur through the mannitol cycle, which includes two steps for synthesis and two for recycling. Among brown algae, Ectocarpus siliculosus represents the model organisms to study different aspects of their biology. During the PhD thesis, three genes coding for the enzymes involved in the first step of the mannitol cycle, the mannitol-1-phosphate dehydrogenase (M1PDH), were studied (EsM1PDH1, EsM1PDH2, and EsM1PDH3). M1PDHs catalyze a reversible reaction between fructose-6-phosphate and mannitol-1-phosphate. One modified version of the EsM1PDH1 gene, coding for a N-terminal truncated protein in order to deleted a domain of unknown function, was overexpressed in the bacteria Escherichia coli. The truncated recombinant protein was purified and biochemically characterized, notably to determine kinetic parameters in both directions of the reversible reaction catalyzed by M1PDH. These results were completed by analysis of changes in expression of genes encoding enzymes involved in the mannitol cycle during the diurnal cycle. These observations contribute to increasing the understanding of a key metabolic pathway in brown algal physiology.
Primary production and functioning of intertidal communities dominated by *Fucus* canopy

Supervised by Dr Aline Migné and Prof. Dominique Davoult


Abstract

Along intertidal rocky shores, communities dominated by canopy-forming brown algae (Phaeophyceae) are particularly widespread. Their functioning is however largely understudied, especially concerning the influence of seasonality and shore height on primary production and respiration, on food webs or on successional process. The aim of this study was to investigate the functioning of two intertidal Fucus communities which are established at different tidal levels. During this study, a special consideration was given to the effects of environmental conditions. On the coasts of Brittany (France), communities dominated by Fucus vesiculosus Linnaeus and Fucus serratus Linnaeus are characteristic of mid-intertidal and low mid-intertidal levels, respectively. In situ measurements of metabolism (primary production and respiration) carried out at different periods of a year highlighted a strong seasonal influence on carbon fluxes and emphasized the importance of canopies in the metabolism of whole communities. Metabolism was higher during emersion than during immersion periods, for which light intensity regularly limits the primary production. Based on these measurements and on high-frequency measurements of environmental parameters, an annual primary production was calculated by modelling for both communities. These annual estimations confirmed that these communities are among the most productive systems of coastal region and specify their regulation at the tidal cycles scale. Food webs, which were analysed through carbon and nitrogen stable isotopes, are based on the use of almost all available sources of organic matter by consumers, and revealed a strong conservation of food webs across seasons. The colonisation survey of bare substrates shows that Fucus species improve the settlement success of numerous species and increase rapidly primary production of whole assemblages. Overall, despite some differences in metabolism and successional sequences according to the shore height at which they are located, these communities exhibited similar functioning due to the canopy which damns the environmental conditions.

Chemical signaling and defense in brown algal kelps during interactions with herbivores

Defended on 12-2016 at Roscoff, with Faculté des Sciences Biologiques de l’Université Pontificale Catholique du Chili (PUC). Ecole Doctorale 227 of the UPMC. Funded by Region Bretagne (ARED)

Abstract

Kelps are founding species of temperate marine ecosystems; they evolve in the intertidal coastal areas where they are often challenged by herbivores. As most of sessile organisms, kelps develop defensive strategies against herbivory. In the kelp *Laminaria digitata*, elicitation by oligoguluronates induces regulations of transcription and metabolic pathways, leading to production and release of metabolites, such as aldehydes, in the environment. Moreover, this kelp species feature systemic responses upon defense elicitation and waterborne compounds surrounding a kelp bed have shown to modify its defense physiology. Such distant chemical signaling during defense
responses are reminiscent of systemy and priming mechanisms in plants. In marine kelp beds, it should have a major ecological role in structuring marine algal and herbivore communities.

In the context of kelp/herbivore interactions, we investigated the defense responses and signaling processes in two emblematic kelp species from north Atlantic and South Pacific coasts, involved in specialized interactions with their herbivores, *L. digitata* in interaction with *Patella pellucida* (Brittany, France) and *Lessonia spicata* with *Scurria scurra* (Chile). Combined approaches of metabolomics and bio-assays were carried out to decipher the nature of the putative chemical cues, and their biological and ecological roles in algal defense against herbivores.

Results showed that, in response to grazing, kelps featured metabolic modifications such as induction of fatty acids, oxylipins and amino acids biosynthetic pathways, as well as transcriptomic modifications. Moreover, we observed that kelps co-incubated with grazed algae exhibited endo-metabolome changes compared to grazed one, and seemed to be less consumed during a subsequent grazing, suggesting the perception and integration of herbivory-induced algal compounds in neighboring algae. As field and lab studies previously highlighted a strong release of aldehydes into the air and the seawater following biotic and abiotic stresses, we further explored the biological roles of aldehyde-based signaling in kelp/herbivore interactions. We found that aldehydes could modify algal metabolism, including the activation of fatty acid metabolism, and that the application of 4-HHE on *L. digitata* could significantly reduce later algal consumption by herbivores. Thus, these results contribute to a better understanding of defense responses following grazing in kelps, and revealed the occurrence of distance signaling during interaction with herbivores, which could involve algal emitted compounds, such as aldehydes.

15. MONTECINOS Alejandro (2012-2016)

WP2 « Genetics »

Species delineation and hybridization in the brown seaweed *Ectocarpus* complex

Defended on 10-2016 at Roscoff, UPMC en co-tutelle with Faculté des Sciences Biologiques de l'Université Pontificale Catholique du Chili (PUC). Ecole Doctorale 227 of the UPMC. Funded by BECA Chile.

Abstract:

The genus *Ectocarpus* Lyngbye (Ectocarpales, Phaeophyceae) comprises marine filamentous algae characterized by an alternation between two independent multicellular organisms of different ploidy. The general objective of the thesis was to study species delineation and speciation within this genus. We started clarifying the number of cryptic species using two unlinked loci (COI-5P and ITS1) and an integrative approach associating barcode gap detection analyses with phylogenetic reconstructions.

We showed the presence of at least 15 species partitioned within a monophyletic group composed of *E. crouaniorum* (Ecro) and two closely related species and a paraphyletic assemblage composed of the remaining 12 other species including *E. siliculosus* (Esil). Second, Rad sequencing and phylogenomics analyses allowed to resolve the relationships within the paraphyletic assemblage.

The different species becomes well separated into two divergent clades (Ecro and Esil). A diversity of taxa with various levels of divergence was revealed within the clade Esil and hybridization between the closest and sympatric species was suggested.

Finally, the importance of reproductive isolation among the two commonest but most divergent species Esil and Ecro was studied using species-specific nuclear and cytoplasmic markers jointly with 9 microsatellites. We showed that meiosis acts as a strong reproductive barrier among these two species and demonstrates that the species of the genus *Ectocarpus* are excellent systems to study evolutionary consequences of hybridization and introgression for the maintenance or breakdown of species because of their haploid diploid life cycle.

PhDs within IDEALG in progress


- Semantic-based reasoning for biological pathways analysis
  Supervised by: Olivier Dameron, Nathalie Theret and Jacques Nicolas

17. LEGRAND Erwann (2014-2017) in progress
• Impact of ocean acidification on the diversity and functional role of communities associated with macroalgae.

This thesis is financed by the Ministry of Higher Education and Research (MENRT) and the Brittany Region (ARED). Supervised by Dr Sophie Martin and Prof. Dominique Davoult

18. QUI MINET Zhuaila (2014-2017) in progress
• Response of maërl beds to global and local changes

This thesis is financed by the Mexican Government (Bourse CONACyT, Consejo Nacional de Ciencia y Tecnología). Supervised by: Dr Sophie Martin (CNRS) & Dominique Davoult (UPMC)

19. MATARD Maria (2014-2017) in progress
• Discovery and biochemical characterization of enzymes active on marine polysaccharides with a potential of valorisation in animal nutrition and health.

This thesis is financed by a CIFRE allocation from ANRT to the OLMIX Company and UMR 8227/CNRS/SBR. Supervised by Dr Mirjam Czjzek (CNRS) and Dr Pi Nyvall-Collén (Olmix)

20. LACHAMBRE Sébastien (2014-2017) in progress
• Genetic selection and breeding of the European abalone *Haliotis tuberculata* and feeding behavior and benefits on five seaweed species.

This thesis is financed by the a CIFRE allocation from ANRT to France Haliots and LEMAR/UBO/IUEM. Supervised by Dr Sabine Roussel and Prof. Jacques Clavier (LEMAR/UBO) and Dr Sylvain Huchette (France Haliots)

• Location and roles of cell-wall polysaccharides during development in the brown alga *Ectocarpus*

This thesis is financed by the Region Bretagne (ARED_8979 ECTOPAR) and the doctoral school Complexité du Vivant.

22. BERNARD Miriam (2015-2018) in progress
• Defence and resistance against endophytic pathogens in the brown macroalga *Saccharina latissima*

This thesis is financed by the EU-ITN ALFF Algae Friends & Foes. Supervised by Dr Catherine Leblanc and Dr Akira Peters (Bezhin Rosko)

23. KLEINJAN Hetty (2015-2018) in progress
• *Ectocarpus subulatus* microbiota: roles of associated bacteria in the acclimatization and adaptation to low and high salinity.

This thesis is financed by the EU-ITN ALFF Algae Friends & Foes. Supervised by Simon Dittami and Dr Catherine Boyen

- Exploring the concept of preferences in Answer Set Programming to study interactions between species of an ecosystem at the genome-scale.


- Structural and functional analysis of sulfatases and other enzymes specific to marine polysaccharides

This thesis is financed by the Regions Bretagne (ARED) and Pays de la Loire in the frame of the Glyco-Ouest network. Supervised by Dr Mirjam Czjzek and Pr Charles Tellier


- Trophic connectivity between ecosystems: role of subtidal and intertidal detritic accumulations exported from kelp beds.

This thesis is financed by the Region Bretagne (ARED) and the Doctoral School ED227. Supervised by Pr. Dominique Davoult et Dr P. Dauby

27. **BUNEI Nishima** (2013-2016)

- Regional growth and marine biotechnology

This thesis supervised by Dr. Benis Bailly was interrupted for illness of the PhD student.

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5- CONFERENCES AND COMMUNICATION

**WP1**


C. Boyen « Seaweeds in your plate » Conférence TAG, Exposition universelle Milan, sept 2015


Gobet A., Mest L., Perennou M., Caralp C., Coulombet C., Dittami S., Huchette S., Roussel S., Michel G. and Leblanc C. Description des communautés bactériennes impliquées dans la digestion des algues par l’ormeau. Invited seminar, Journée Génomique et Bioinformatique, Nantes, December 14th 2015.


E. Corre. La plate-forme bioinformatique ABiMS : un outil et des services dédiés au service du traitement de la donnée en biotechnologies marines. Conférence Biosciences en Finistère. 12 octobre 2016 CCI de Brest


Avia K., Coelho S., Lerck F., Mauger S., Montecinos G., Faugeron S., Valero M., Cock J.M., Boudry P. Studying temperature and salinity stresses in the model brown alga Ectocarpus sp. by QTL mapping. 5th International Conference on Quantitative Genetics (ICQG5), 12-17 Juin 2016, Madison, USA. Poster

WP3


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Chevallier et al. Handling the heterogeneity of genomic and metabolic networks data within flexible workflows with the PADMet toolbox. JOBIM Lyon, 30 juin 2016.

M. Aite *User-control metabolic network reconstruction within flexible workflows with the PADMet Toolbox*, INRA Food Working Group annual assembly, Paris (Jul. 2016)


A. Siegel *Combinatorial problems related to the reconstruction of genome-scale metabolic networks*, University of Lille, Workshop of the BIOSS working group on metabolism (Nov. 2016)

Wp5


GlycoOuest November 2013 : Présentation du projet IDEALG à la réunion/séminaire annuelle du réseau interrégional GlycoOuest, 7-8 Novembre 2013 au Croisic. (M. Czjzek)


GTBio Grenoble 2014: G. Michel on Bacterial laminarin degrading system


IDEALG Forum, Roscoff 2015 : V Ferrières Des protéines d’algues aux sucrres


St Brieuc, Gen2Bio 2016: G. Michel Marine enzymes as biotechnological tools
IDEALG Forum, Lorient 2016 : M. Czjzek Les enzymes pour la biotechnologie bleue : une boîte à outils de la mer

WP6

CAUDAN, 2016, Obtenir une nouvelle concession d’algues, de la théorie à la pratique, General assembly Idealg 8-9 Novembre 2016, UBS-Lorient
JAMES, 2016, Quelles techniques pour le développement de l’algoculture en Bretagne. Journée sur les perspectives de développement de l’algoculture en Bretagne », St Malo, 03 octobre 2016
JAMES, 2016, Quelle place pour la culture de macroalgues en France ? Salon Nationale de la conchyliculture, Vannes 07 septembre 2016.
LE GOFF 2016, Synopsis on brown seaweed cultivation technics 2011 to 2016, General assembly Idealg 8-9 Novembre 2016, UBS-Lorient
PETERS, DUCHEMIN, 2016, Cultivation of floating Ectocarpus strains. AG IDEALG, 9 nov. 2016, Lorient.
JAMES, 2015, D6.1 Effect of an Ascophyllum n. extract (AMPEP) on the growth of juvenile of Saccharina latissima (CEVA –ALEOR), general assembly IDEALG 5-6 November 2015
PERROT, 2015, Identify potential areas for different aquaculture systems and for various algal species in nearshore and offshore waters. Case study for the Britanny coasts, general assembly IDEALG 5-6 November 2015, CNRS Roscoff
PETERS, DUCHEMIN, 2015, Cultivation of non-attached Ectocarpus strains. AG IDEALG, 6 nov 2015, Roscoff.
CHAMPENOIS, 2014, Variation in biochemical composition of Saccharina latissima in response to different treatments, WP 6 – Action 6.3 (Deliverable 6.10), General assembly Idealg 13-14 octobre 2014, Ifremer Brest
JAMES, 2014, Culture de macroalgues en France : Avancées techniques (Projet IDEALG : WP6 culture), Forum Idealg 15 octobre 2014 CCI Brest
LE GOFF, 2014, Work on Porphyra/Pyropia species WP 6 – Action 6.1 (Deliverables 6.1, 6.4), General assembly Idealg 13-14 octobre 2014, Ifremer Brest
FERNANDEZ, CHAMPENOIS 2013, OPTIMISING SEEDING DENSITY FOR LONGLINE MARICULTURE OF Saccharina latissima, AG IDEALG, 21 oct 2013, Roscoff.
PETERS, 2013, Ectocarpus: from a genetic model towards a cell factory. Universidad Austral, 5 dec 2013, Puerto Montt, Chile.
CHAMPENOIS 2012, Mariculture of large and attached species - Ongoing work at CEVA, WP6 sub-task 6.1, Forum annuel Idealg, Rennes 27-28 sept 2012

WP7

Poster: ISS 2016 (June Copenhagen) « Fermentation of Saccharina latissima as a viable storage process? », H. Marfaing R. Pierre
Poster & Flash communication: Polymerix 2015 (28th May, RENNES) « Interactions and hybrid complex formation of anionic algal polysaccharides with a cationic glycine betaine-derived surfactant », Dr. Y Wang
Oral Communication : ISG2 (la Rochelle, may 2013)
Poster Communication: ISS (Bali, June 2013) “Saccharification of starch extract from Ulva” C. Le Guillard
Poster communication : Cosmin’g (St Malo, June 2013)

WP8


Laurans, M. 2013, Conférence grand public au centre Ifremer de Brest devant 250 personnes. Présentation des résultats au cours de réunion avec les acteurs professionnels (récoltants et représentants de la profession)


Conférences scientifiques


Bataillon-Hongre E., 2016, Understanding seashore seaweed social and economic system in Brittany and improving its governability, poster presented at the TBTI Symposium on European SSF and global linkages, June 29-July 1st 2016, Tenerife, Spain.


Girard S., Frangoudes K., « Seaweed farming development in France: Analysis of undergoing decision making process” à la Conférence MARE juin 2013, Amsterdam.

Katia Frangoudes « Governability of marine ecosystems and their uses: The Iroise Sea Natural Marine Park case” IMPAC, October 2013, Marseille.

WP9

14 Novembre 2016 - UBS, Vannes, France : Littoralg
3 Octobre 2016. St Malo, France Journée algoculture : Les perspectives de développement de l’algoculture en Bretagne,

27-28 Septembre 2016 - Portugal: Seagriculture

26-27 Novembre 2015 - Ile de la Réunion : Atelier Macro-algues (Pole Qualitropic)
22-23 Septembre 2015 - Cherbourg, France : Seagriculture
29-29 Mai 2015 - Rennes, France : POLYMERIX BiopolymeresSources et Applications
25 - 27 Juin 2014 - Galway, Ireland: British Phycology Society meeting

16-19 avril 2014. Wando International Marine Algal Symposium (Seaweeds for Future Industry), Wando, South Korea)
4 - 10 Août 2013 - Florida, USA : 10th International Phycological Congress IPC10
13 - 17 Juillet 2013 - Lisbonne, Portugal : 9th EBSA European Biophysics Congress.
2 - 3 Avril 2013- Brest, France : Conférence de la Recherche UEB
March 21, 2013. Qingdao Sino-German symposium on algae kicked off on the Yushan campus of Ocean University of China (OUC)

21-22 Septembre 2012 - Brest, France : 1eres rencontres scientifiques "Santé, Mer et Algues"
10 September 2012 - Pontivy, France: Symposium OLMIX "Algues: la révolution bleue pour une chimie durable"
30-31 May 2012 - Vancouver, Canada: OECD Global Forum on Biotechnology
January 4-6th 2012: British Phycological Society annual winter meeting, Newcastle, UK

Conferences and communication « Grand Public »

26 January 2017 - Brest, France: Médiathèque Les Capucins
06 December 2016 - Brest, France: Océanopolis

13-18 July 2016: Quai des Sciences des Fêtes Maritimes de Brest 2016, animation de stands d’accueil du public. Les grandes algues face au changement climatique
21-22 November 2015 - Brest, France: SeaFood Fusion Table ronde atelier culinaire algues alimentaires

Press release

Many articles in the Regional daily newspapers Ouest-France and Le Télégramme (see www.idealg.ueb.eu)
2012 INFOBIO-Industries Québec, Canada http://crbm-mbrc.com/biomar/IBI-ProjetIDEALG_vF.pdf
2013 Dans les algues, nos molécules des années 2020 Revue Armen
2014 Migaud M Filière Algues: S’ouvrir pour se développer. Interview de Philippe Potin, Directeur de recherche à la Station biologique de Roscoff, et rédaction d’un article pour la rubrique Tank 11
2015 Algues Trésor sous-marin Revue Armen. sept-oct 2015
2015 Des algues pour nos assiettes Le Chasse Marée n°279.
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