European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 14 November 2014

COST 096/14

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action FA1406: Advancing knowledge on seaweed growth and development

Delegations will find attached the Memorandum of Understanding for COST Action FA1406 as approved by the COST Committee of Senior Officials (CSO) at its 191th meeting on 12-13 November 2014.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action FA1406
ADVANCING KNOWLEDGE ON SEAWEED GROWTH AND DEVELOPMENT

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 "COST Action Management" and document 4112/13 "Rules for Participation in and Implementation of COST Activities", or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to unify a scattered European research landscape to increase the basic knowledge on seaweed development and growth, and to ensure efficient transfer to aquaculture RTD bodies.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 40 million in 2014 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Section *2. Changes to a COST Action* in the document COST 4114/13.

A. ABSTRACT AND KEYWORDS

Seaweeds (macroalgae) are an alternative, additional source of food, feed, fuel and livelihood for humans. Currently 16M tonnes of seaweeds are collected annually for consumption or industrial processing. Production could increase, especially in Europe (only 7% of the world's production), with more appropriate and efficient seaweed cultivation techniques, to match actual and future demands. This requires a step-change in knowledge of basic seaweed biology (currently almost non-existent), to prevent restricting future increases in seaweed production.

This COST Action will develop a European interdisciplinary platform integrating unique expertise, currently scattered worldwide, to (1) fill basic research gaps on seaweed development and reproduction, and (2) transfer this scientific knowledge to aquaculture end-users to support sustainable seaweed aquaculture. Academic partners highly skilled in seaweed basic research, and Research & Technological Development (RTD) and Innovation Institutes dedicated to the transfer of knowledge to end-users, will coordinate and promote research through 4 major scientific tasks:

1. Identifying how seaweeds become REPRODUCTIVELY PROFICIENT;
2. Defining mechanisms of FERTILISATION AND EMBRYOGENESIS;
3. Studying the kinetics and morphological principles of ADULT GROWTH;
4. Developing TECHNICAL TOOLS to drive Tasks 1-3.

This will be achieved via Workshops, Short-Term Scientific Missions, Training Schools and symposia, and deployment of communication tools optimising the transfer from basic research to innovation.

Keywords: seaweeds, growth and development, reproduction, knowledge transfer, aquaculture

B. BACKGROUND

B.1 General background

Seaweeds: an under-exploited bioeconomical feedstock

Seaweeds (marine macroalgae) are one of the main primary producers in the sea (over 50% of the oxygen released by oceans in the atmosphere is produced by algae), while in parallel their biomass forms the base of the food chain. They grow rapidly (some can reach several meters in length in one year), in a wide range of temperatures (from tropical to polar climates), using only sunlight, atmospheric carbon and naturally nutritious coastal waters. Hence, seaweeds do not compete for arable land, fertilizer and freshwater resources with terrestrial food and biofuel crops. Furthermore, several seaweeds produce more biomass per square metre than land plants (e.g. Saccharina latissima with 26 tonnes dry weight per hectare per year, compared to 2.1, 4.1 and 5.1 for soybean, wheat and maize respectively; Broch et al. 2012).

Seaweeds are used as:

- *Food*: seaweeds are an excellent source of proteins and vitamins/minerals and are low in fat. They are used extensively as food in coastal cuisines around the world and have been an important part of diets in China, Japan and Korea since prehistoric times. The growing globalization and adaptations of food culture worldwide give opportunities for seaweed consumption in Europe. One example is sushi, which has become a common and increasing part of European diet in the last 10 years (the Spanish sushi firm Sushita showed a 21% increase in sales in 2013). The seaweed industry produces 10 billion US$ per year (Rebours, J Appl Phycol 2014).

- *Feed*: seaweed flour meals bring mineral and vitamin complements to animal feed. They also substitute for animal proteins, as, although carbohydrates constitute the major components, red and green species may contain more than 40% dry weight of protein (see “Ocean Harvest- Animal nutrition & health » in Ireland at http://oceanharvest.ie/). The economic value of seaweed in feed is estimated at 5 million US$ per annum (McHugh: A Guide to the Seaweed Industry, Food and Agricultural Organization: 106, 2003).

- *Hydrocolloids in the food industry*: Polysaccharides (Alginates, Carraghenanes and Agar) are extracted from seaweeds to be used as texturizing or gelling agents, especially in low-fat food preparations. The estimated value is 1 Billion US$ per annum (Bixler & Porse, J Appl Phycol 2010).

- *A mineral source for cultivated plants and phytosanitary products*: seaweeds are used as fertilizers and as elicitors of plant defence systems in viniculture and arboriculture. Such fertilizers are worth over €10 million per year in Ireland, and €50M per year by Algea (Valagro group) in Norway.

- *A potential alternative feedstock for biofuel production*: some fast-growing seaweeds (e.g. brown alga Saccharina latissima) are rich in carbohydrates, which can be converted into ethanol, butanol or biogas by fermentation. The U.S. Department of Energy (DOE) reports a productivity of bioethanol from seaweeds approximately two times higher than from sugarcane and 5 times higher than from corn (from Wargacki et al., An Engineered Microbial Platform for Direct Biofuel Production from Brown Macroalgae. Science 2012). The Scottish Association for Marine Science is currently setting up seaweed biofuel pilot farms to contribute to the local gas supply.

- *Components of cosmetics*: France extracts 10% per year of its 500,000 - 1M tonnes of brown seaweeds present in the Brittany coasts, mainly for cosmetic and pharmacological products.

- *Bioactive components in pharmacological products*: sulfated galactans and other chemicals isolated from seaweeds have potential benefits to human health: preliminary studies report compounds with antibacterial, antiviral, anti-protozoal, anti-inflammatory, antioxidant, neuroprotective, anti-coagulant and antiproliferative properties in green and red macroalgae.

- *Diffusing agents in the textile industry*.

- *Biodegradable components in paper or plastics*.

In addition to their importance in the bio-based economy, seaweeds might represent significant environmental hazards. Because of eutrophication and habitat alterations, they are one important causative agent of green, red or brown “tides” that have harmed ecosystems worldwide, causing losses of biodiversity due to oxygen depletion, release of toxic chemicals, nutrient imbalances and ocean acidification. The green seaweed Ulva linza is also a biofouling agent, attaching to and accumulating on the surfaces of boats, power stations and bioreactors, reducing performance and/or fuel economy and costing the naval and marine transport industries billions of pounds per annum.

A need for the development of seaweed aquaculture

One of the current Societal Challenges Priorities of European Horizon 2020 strategy is “Food security, sustainable agriculture, marine and maritime research and the bioeconomy” implying “the sustainable use of marine resources, and the identification of innovative business opportunities in the maritime and coastal economy” (from the communication on the "Blue Growth" Work Programme Focus Areas, 2012-2016). Of the 16 millions tonnes (MT) of seaweeds used worldwide every year to provide the food and chemical industries, 14.7 MT (93%) are from aquaculture; the other 7% are harvested. Asia (China, Korea, Japan, Indonesia, Philippines, India) is the main producer, and 99.9% of its production comes from aquaculture. Seaweed cultivation is estimated at 7.4 billion US$, with brown and red seaweeds being the most exploited species. In 2008, the highest production of cultured seaweed was of Japanese kelp (Laminaria japonica, 4.8 MT), followed by Eucheuma seaweeds (Kappaphycus alvarezii and Eucheuma spp., 3.8 MT; 1.3. billion US$), Wakame (Undaria pinnatifida, 1.8 MT), Gracilaria spp. (1.4 MT) and Nori (Porphyra spp., 1.4 MT; 1.5 billion US$) (http://www.fao.org/docrep/013/i1820e/i1820e01.pdf). In contrast, only 0.1% of European production is covered by aquaculture. Consequently, Europe produces only 1% of the world production.

Therefore, today, there is a growing need for development, improvement and diversification of seaweed aquaculture practices, especially in Europe. First, the edible bioresource biomass will have to satisfy the 9 billion people predicted to live on the planet in the close future (2050), and Europe, with its large coastal territory and large range of climates, can contribute significantly to global food security. Secondly, new markets are emerging, requesting, in order to be economically profitable:

- A better quality seaweed stock, requiring the capacity to grow specific seaweeds (cultivars), especially those with high added-values.
- A better control of the feedstock production, to predict the activity of the downstream technological and commercial sectors over a long period of time.
- A larger panel of cultivated seaweed species, to diversify the offers to consumers (e.g. Polysiphonia in Greece)
- Traceability of the products: aquaculture, through a controlled seeding process, ensures the identity of the cultivated seaweed.
- Ease of exploitation: the choice of the aquaculture location site allows efficient management of collection and transportation means and minimisation of their costs. Automation is even conceivable.

In addition, a better knowledge of seaweed aquaculture practices will serve phytoremediation as seaweeds absorb excess nitrogen, phosphorus and heavy metals from water. They are also currently tested in integrated multitrophic aquaculture (IMTA) in several fin- and shellfish farming pilot-scale projects. Indeed, mass cultures of seaweeds in the sea or on land serve as a "nutrient extracting aquaculture" reducing eutrophication along e.g., the French coast or purifying outflow from intensive fish farms in Israel.

Current need for a coordinated research on seaweed development

Today, expert analysis concludes that the sustainable development of seaweed aquaculture and IMTA requires a better knowledge of the growth and reproduction of seaweeds, in lab conditions (controlled light intensity, light quality, photoperiod, temperature, inorganic and organic nutrients, osmotic stress, pH of the medium) and in response to environmental constraints (e.g. mechanical stress generated by sea currents or wave motion, seasons, pollution). In parallel, the environmental impact of seaweed aquaculture on biodiversity and water quality should be investigated in order to help policy makers to set regulation on availabilities of cultivable areas (Agrawal, 2012).

The CORDIS database demonstrates the importance of algae in funded European research

programs.
While some specialised projects aimed to use seaweeds as fertilizers (2FP-ECLAIR), sources of iodine (ANIS, 4FP-FAIR), biosorptive substances (4FP, BRITE / EURAM 3, SEAPURA), anti-inflammatories (SWAFAX, FP7-SME) and phycocolloids (HYFFI, FP7-SME), the latest projects assess seaweeds as potential biofuels (Seaweed biofuels for anaerobic fermentation SEAWEED-AD, Seaweed for fuel MABFUEL: FP7-PEOPLE; EnAlgae INTERREG-IVB; At~Sea, FP7-NMP, 2012-2015). However, no European program to date has supported basic research on seaweed development. Currently, the study of seaweed development is undergoing resurgence in the academic world, and is a timely topic, as verified by recent high-impact articles. However, the current research landscape is fragmented and scattered across research facilities, with research groups addressing different biological issues, while using different experimental approaches (genomics, genetics, cell biology and metabolomics) on different organisms (green, red and brown seaweeds).

Therefore, this COST Action will join the efforts of academics and R&D/Innovation Institutes to accelerate knowledge gain on the growth and development of seaweeds. It will (i) coordinate and galvanise multidisciplinary basic research on seaweed growth and reproduction (ii) increase the provision of efficient technical tools to this emerging field, (iii) strengthen and expand the field by organising meetings and facilitating knowledge exchange, and (iv) use this output to establish new, efficient and sustainable seaweed culturing techniques and subsequent wider use of seaweeds for societal benefit. COST is the ideal instrument to develop and manage such a multinational topic, which can be reinforced by additional groups joining the Action as this field continues to develop.

B.2 Current state of knowledge

Domestication of the oceans is widely regarded as a possible solution to increase food and energy production and could therefore be one of the next most important developments in human history. However, domestication of seaweeds is in its infancy compared to that of terrestrial plants. Currently, seaweed aquaculture practices rely mainly on empirical “seaweed gardening” techniques. An illustration is the preparation of production lines for the culture of Porphyra purpurea in France, for which blank lines are simply immersed in the sea, and are expected to be colonised by drifting naturally-produced Porphyra germlings. Therefore, while the requirement to improve aquaculture practices is increasing, major bottlenecks are evident, which must be solved before deploying seaweed aquaculture to a more specific and/or a wider range. Indeed, biological knowledge about seaweed life cycles will for the first time allow addressing of issues specific to seaweed aquaculture, e.g. better control of the different developmental stages to allow seaweed handling in an aquaculture setting. Likewise, identifying the molecular processes triggering the vegetative-to-reproductive shift will bypass the blockages in reproduction encountered in some cultivated seaweeds and will enable better management of the hatchery step necessary for rope-seeding. Progress on the vegetative reproduction of seaweeds must also be made, so that infinite propagation of a specific cultivar can be carried out, preventing the uncontrolled mass sporulation of valuable algal biomass. As an example, the intensive cultivation of “Nori” (red seaweed Porphyra yezoensis) for Sushi preparation currently depends on the capacity to trigger, through light and temperature management, a meiotic shift from the diploid “conchocelis” to produce the tiny unicellular meiospore (conchospore), which ensures the production of the haploid leafy thallus as the edible phase. A general consensus of seaweed producers is that increasing our knowledge of the underlying molecular basis of cell growth, development and reproduction in this species, and generally in economically important seaweeds, will improve aquaculture production yield. Unfortunately, this kind of knowledge is largely missing, because very little basic knowledge has been acquired concerning the biological mechanisms controlling seaweed growth and reproduction. Indeed, during the 20th and early 21st centuries, fundamental biological experiments to determine “how life works” in complex multi-celled organisms have focused on land plant model systems (e.g. tobacco, maize, rice, Arabidopsis.). Seaweeds, which constitute a large and significant group of multicellular organisms, have been generally left out of basic biological research, and studied largely from an ecological perspective. Nevertheless, a few attempts have been deployed to tackle the fundamental biology of seaweeds. Whilst electron microscopy produced a rather large number of descriptive studies, the application of immunofluorescence techniques gave new insights into algal morphogenesis. Mutants of the green freshwater macroalga Volvox (Kirk, 1998, in: Developmental and Cell Biology Series, Cambridge Univ Press) and of the green seaweed Ulva (Lovlie, in C.R. Trav. Lab. Carlsberg 1964) have been generated. The 1970s saw several pioneering studies on the modelling of red seaweed morphogenesis (Hardly-Halos, Rev. Gen. Bot 78 p.407). However, molecular genetic techniques, which were abundantly developed in animals and land plants from the 1980s, have only very recently started to be applied to seaweeds, partly facilitated by the falling cost of high-throughput sequencing. This creates a new impulse and a unique opportunity to understand the fundamental biology of seaweeds. In 2010, the first two multicellular algal genomes were published (the fresh water green alga Volvox carter, Prochnik et al., Science 2010; and the marine brown alga Ectocarpus siliculosus, Cock et al., Nature 2010). The continuation of these efforts was illustrated in 2013 by the publication of the first two red seaweed genomes (Chondrus crispus, Collen et al. PNAS 2013, and Pyropia yezoensis, Nakamura et al., PloS One 2013). The sequencing of the green seaweed Ulva mutabilis is underway. Falling sequencing costs also enable transcriptomic studies to be undertaken in any organisms, tissues, or even cell types (using laser microdissection). In addition, genetics is now possible in brown seaweeds (Ectocarpus as a genetic model: Charrier et al. New Phytologist 2008), complementing the work initiated in Volvox (Hallmann et al. PNAS 1997) and Ulva (Oertel & Wichard, unpublished results). Chemical technological advances have allowed progress also in the identification of molecules controlling seaweed morphogenesis (Spoerner et al. J Phycol. 2012) and reproduction (García-Jiménez & Robaina, J Phycol. 2012).

B.3 Reasons for the Action

The Action groups together two major nodes of the aquaculture field, i.e. the academic research community and the R&D and Innovation Institutes and SMEs. This Action is necessary and timely for two main reasons. Firstly, the worldwide academic community investigating seaweed growth and reproduction is small (~ 20 teams) and scattered (max. 2-3 teams per country). Each team is currently focused on specific projects, with no or little common/collaborative research shared between teams. Early-Stage Researchers are thus currently being trained only in specific topics, when this emerging research field requires broad-range capacities-building to ensure perpetual development of the biological knowledge and skills related to seaweed growth and reproduction. Secondly, the aquaculture stakeholders and academics investigating seaweed development do not work efficiently enough together, because of distinct short-term objectives. This Action is therefore a bottom-up initiative which will in the same time strengthen the academic community and link it to R&D and Innovation Institutes to define specific needs and the corresponding research to be undertaken, in order to improve, in the long term, efficient technological transfer of basic scientific knowledge to aquaculture end-users (industrials). Indeed, thanks to their accurate knowledge of the industrial expectations, aquaculture R&D and Innovation institutes/SMEs provide the capacity to rapidly transfer knowledge obtained by academics to industrial seaweed end-users, as they can both rank the concrete objectives to reach and translate them into scientific deliverables. In addition, aquaculture R&D and Innovation Institutes will increase the impact of this research on policy makers, regulatory bodies and national decision makers.
In more detail, the Action will enable:

- Reduction of the gap between academic labs working on different seaweeds with different techniques, and coordination of research to both strengthen the current community and promote synergistic production of basic knowledge on seaweed growth and development.

- Promotion of the expansion of the community by bringing more visibility and attracting Early-Stage Researchers: special attention will be placed on the organisation of Workshops and communication in worldwide conferences.

- Effective communication, interaction and transfer of knowledge between this academic community and the R&D institutes involved in the development and improvement of aquaculture practices. Among the high-priority objectives identified by aquaculture stakeholders are: (i) avoiding cross-breeding between wild and cultivated seaweed species, (ii) setting up in-lab cultivation protocols for new species, (iii) developing preservation/cultivation techniques to control and stabilise biomass production. The academic partners of the Action will therefore investigate the biological processes of seaweed development, and based on the skills and the high-technological equipment that are constantly developed in academic institutions, they will identify the chemical, genetic and physiological parameters at play in these processes.

B.4 Complementarity with other research programmes

There are currently no integrated multidisciplinary networking programmes focused on seaweed developmental research in Europe, even less at the international level. In a general way, this Action is highly complementary to the programmes in Marine Biology funded by the former EU FP7 and current H2020 programmes.

More precisely, because the Action aims at advancing knowledge on the biological processes of seaweed growth, development and reproduction required to improve and develop aquaculture activities, several EU-funded projects will benefit from it. First, the Action is complementary to the research project “AT~SEA” (FP7-NMP 2012-2015) which develops 3D multilayer textiles for increasing the yield of seaweed biomass in off-shore aquaculture plants. The recently accepted project “INTAB” (H2020), dedicated to an IMTA scheme combining seaweeds, abalone and finfish, will directly rely on knowledge advances in seaweed growth and reproduction, as seaweeds will be the central player of this scheme by both recycling the excretions of fin fishes and feeding the abalones in aquaculture conditions. The applications developed from the Action will be relevant to the “IDREEM” project activities (2012-2016, FP7-ENVIRONMENT), which develops tools and methods to help the European aquaculture industry adopt more environmentally and economically efficient practices of IMTA on a commercial scale, using modelling of seaweed growth.

Other programmes, based on the exploitation of seaweed biomass for biofuel production (“EnAlgae”- Interreg IVB, 2011-2015), crop protection (NatuCrop, FP7-SME, 2012-2014), taste enhancement ("TASTE", FP7-SME, 2013-2015) and food packaging (PLANTPACK, FP7-SME, 2012-2014) could turn in the close future to collecting seaweed from aquaculture plants, because of the numerous advantages it offers (see detailed reasons in the part B1: General background). The project "SEABIOPLAS" (FP7-SME, 2013-2015) has indeed, in its quest for alternative sustainable resources to produce plastic polymers, turned towards IMTA for the production of seaweed feedstocks.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The main aim of the Action is to unify a scattered European research landscape to enable a step-change in the basic knowledge of seaweed reproduction and development, and to ensure appropriate and efficient transfer to R&D and Innovation Institutes dedicated to the development of aquaculture techniques, in tune with current needs in Europe and worldwide. Consequently, the Action will undertake for the first time a strictly interdisciplinary approach, combining molecular/ developmental biology, genetics, and analytical chemistry.

C.2 Objectives

The principal objective of the Action is to increase fundamental knowledge about seaweed growth and reproduction, and to improve sustainable seaweed aquaculture. This will be performed by combining (i) our COST partners' academic understanding of the many biological processes that control seaweed development, with (ii) the know-how of Research & Development organisations dedicated to knowledge transfer and the creation of innovative seaweed industries. Ultimately, the Action will be a catalyst for further development and coordination of research dedicated to a better understanding of the physiological, cellular, molecular and genetic mechanisms that control seaweed growth and development, and further identification of the critical elements of aquaculture and bloom management.
Specifically, the Action will:

1. Identify the bottlenecks that impede further development of sustainable algal aquaculture. Among the technological issues which should be solved are:

o Avoid cross-breeding between wild and cultivated seaweed species.

o For specific species with economical values (e.g. Porphyra, Laminaria, Saccharina; see also the “Seaweed Species-Selection Index recently proposed by Kang et al., J. Ocean Univ China, 2013):

a. Set up in-lab cultivation protocols and develop recommendations for new candidate species

b. Provide standardized feedstock for predictable and robust biomass production

c. Decrease biofouling on the surface of seaweeds, which decreases the quality of the bioresource

and affects the production of algal natural products

d. Develop germling preservation techniques to control and stabilise the production in hatcheries

e. Control life cycle shifts that might jeopardize the biomass production through sporulation events.

2. Coordinate and combine the expertise of individual, high-skilled academic research groups in all areas of biology and chemistry to improve our understanding of fundamental processes related to seaweed fertility, growth and development (Task 1,2 and 3).

Among the biological issues which should be investigated are (responding to the goals above):

o Identifying the chemical and environmental factors to control seaweed fertility using e.g. comparative metabolite profiling along with chemometric data analyses.

o For specific seaweeds, acquiring a better knowledge of their life cycles and establishing cultivation conditions in lab.

o Controlling early life stages of different seaweeds in both tanks and natural environments, and characterizing the adhesion processes (e.g. biofilm formation) at the biological level.

o Identifying the seasonal environmental impact (including of nutrients, light, temperature, hydrodynamics), on seaweed growth and productivity (e.g. regarding bloom events).

o Acquiring a better knowledge of the seaweed surface to establish protocols to reduce biofouling.

o Setting up protocols to preserve seaweed spores, embryos or germlings (cryopreservation) in collaboration with the national curators of the algal collections (e.g. The Culture Collection of Algae at Goettingen University (international acronym SAG), Germany; Culture Collection of Algae and Protozoa, UK).

3. Develop technical tools to address new seaweed biological issues (Task 4).

4. Provide open workshops, such as “OMICS" workshops (e.g. "Functional Genomics" and "Comparative Metabolomics"), to gather together scattered expertise in the scientific community and disseminate it to a broader audience.

5. Train the next generation of innovative and interdisciplinary researchers through Short-Term Scientific Missions (STSMs), Workshops and Training Schools.

6. Ensure knowledge transfer to aquaculture industrial end-users (e.g. by listing our standardized protocols at the end of the Action, by directly interacting with industrials through the Action).

7. Provide recommendations to reduce the environmental impact of seaweed aquacultures to aquaculture stake-holders and policy-makers.

C.3 How networking within the Action will yield the objectives?

The Action is built on two initial actors of the seaweed sector:

i. the seaweed academic community investigating seaweed growth and reproduction, regrouping experts in seaweed genomics (leadership on brown, green and red seaweed genomes), seaweed genetics (on brown and green seaweeds, e.g. Ulva), metabolomics and cell biology. This community is used to communicating with large-audience public through interaction with schools and universities, or through general audience conferences and demonstrations;

ii. the Research & Development and/or Innovation Institutes/SMEs involved in the development and the improvement of seaweed aquaculture. These partners are used to interacting with aquaculture end-users (industrials, aquaculture SMEs) and national and European policy-makers.

The scientific objectives, agreed by all partners of the Action, will be reached by a combinatorial and concerted work, as each Action partner possesses specific skills and expertise. The general goals will be decided at the regular Action meetings (MC with WG Leaders). Implementation of these goals will be scheduled during workshops and STSM and Training Schools will contribute to their achievement.

The Action is composed of most European countries focused on the sustainable development of marine resource and more specifically in seaweed aquaculture. Altogether, this Action has the means to fulfil the full range of its objectives. Special attention will be paid to the capacity of the Action to generate a dynamic and productive network with entirely open lines of communication to enable efficient data sharing and knowledge transfer via an internet platform to ultimately be beneficial to the aquaculture end-users.

More precisely, the Action will (Table 1):

Main network objectives	How
1-Unify a scattered research landscape by creating an active network and solid and stable links	- Initial COST meeting to assemble and meet all members of the Action. - Organise meeting every 6 months, where biological and technological data will be presented, following the 4 scientific tasks of the Action (see D1). - Link members via dynamic website (already initiated). - Mining the community for “lost knowledge”. - Setting up novel collaborations between members.
2-Bringing synergy within the network by sharing methods and technical skills	- Organise Workshops, addressing the bottlenecks that impede further development of long-term sustainable seaweed aquaculture, focusing mainly on upstream biological limitations. Specific topics will be addressed, such as: * Advances in unialgal and axenic seaweed cultivation

	* Functional genomic approaches for seaweeds * Cross-kingdom interactions between seaweed and bacteria - Organise Workshops where possible in conjunction with high-impact meetings on plant- and developmental biology to contact and attract other potential new network members. Similar with aquaculture R&D institutions/SMEs in international meetings dedicated to algal aquaculture. - Train a next generation of innovative and interdisciplinary researchers by organising Short-Term Scientific Missions (STSMs) between partner labs. STMS will be particular important as PhD students with a specific background will broaden their understanding in the collaborative groups through hand-to-hand training. - Organise Training Schools focused on specific technical issues (3 during the Action). Early-Stage Researchers will be the priority for these Training Schools. The choice of the topic will be made after canvassing the members at the initial meeting, between: * basic knowledge of seaweed development and reproduction * bioinformatic analysis of high-throughput genomic/transcriptomic data * chemical identification from seaweed extracts (bioassay-guided approaches and explorative metabolic profiling) * cell biology techniques for seaweeds * modelling of seaweed development * advances in seaweed genetics (mutagenesis, crosses, genotyping) - Coordinate funding applications, at national or EU level, with a specific focus on doctoral or post-doctoral research opportunities (e.g. Marie Curie, EMBO, National doctoral training fellowships and research grants).
3-Establishing contact with industries, stimulate industrial development, application and commercial	- Evaluate the potential transfer of knowledge from the Action to aquaculture end-users

exploitation of the alga culture technologies	- Invite relevant industrial partners, previously identified by the R&D Institutes/SMEs of the Action, to mid-term Workshops to share the first deliverables - Share optimized protocols posted on the Action website - Promote transfer of expertise and technical skills between the Action and the industrial partners by writing optimized protocols and by posting them in the Action website
4- Dissemination of the results of the Action	- Write (collaboratively) authoritative basic review articles in the international academic literature to raise the profile of modern seaweed research - Publish (as letters in aquaculture journals) progress reports of the Action defining future research priorities and suggestion about possible future modification of seaweed aquaculture - Disseminate the main and final outcomes of the Action at a closing meeting to which stakeholders, end-users and policy-makers will be invited - Maintain the Action website active after the closure of the Action - Continue to perform outreach activities within local communities, as part of each partner's ongoing commitment to the public understanding of science - Further fructify the undertaken work by applying to programs funding research and networking

C.4 Potential impact of the Action

This COST Action will build upon novel research collaborations among several COST countries. It will be the first time that the partners have "officially" all joined forces to realize these common objectives. The COST Action will promote networking in the true sense of common EU legislation (e.g. COM/2004/101). The individual research projects all have the potential to make a strong scientific impact in this research field. This Action will coordinate and consolidate research on seaweed development at the European level, in order to reinforce this emerging academic field and create synergy by supporting capacity-building. This impact cannot be overestimated considering the current scattered expertise across Europe and further afield. The finding of the partners was that communication within the scientific community has been very limited, as their different research backgrounds mean the scientists tend to operate in different scientific networks and attend different conferences.

In addition to the national research laboratories, the direct beneficiaries of the network include (but are not limited to) aquaculture enterprises and previously funded scientific networks concentrating on growing seaweeds for biofuel, human consumption, animal feed, food technology, pharmaceuticals and cosmetics (i.e. 135 algal industries, 1277 phycologists in Europe according to the first European data collection; COST 49 Technical Report 1996). Integrated multitrophic aquaculture (IMTA; ESF Position Paper 15, 2010, Marine Biotechnology: A New Vision and Strategy for Europe) will benefit from the fundamental understanding of algal development resulting from this Action, which will become consequently an integral part of coastal regulatory and management frameworks.

The Action will further develop worldwide exchanges in core expertise in aquaculture and fundamental developmental algal biology.

C.5 Target groups/end users

The Action is primarily intended to integrate various research activities across Europe. The stakeholders and end-users include:

- Seaweed aquaculture industries: The R&D and Innovation Institutes partners of this Action are already competent platforms to interact with industrial companies (from SME to large companies) exploiting seaweed biomass for colloid extraction, biofuels generation and food (see part B).

- Fish aquaculture industries: The R&D and Innovation Institutes partners of this Action are already deploying research on Integrated Multi Trophic Aquaculture (IMTA, NFS Marine Biotech) which will benefit the fin-fish and shell-fish aquaculture industries (see part B).

- Biosensor design companies, for in situ monitoring of biological parameters as well as chemical biomarkers indicating the status of algal growth and/or position in the life cycle (e.g. nuisance blooms by green tides).

- Scientific communities studying developmental biology, who will gain knowledge about alternative molecular and cellular developmental mechanisms operating in seaweeds

- Scientific communities studying evolution of multicellular organisms, who will gain knowledge about genomics of organisms evolutionary distant from the current model systems, filling the gap between extensively studied taxons and unexplored taxons.

- Students and Early-Stage Researchers, who can use the technical advances and organisational frame of the Action to initiate challenging explorative projects in the so far underdeveloped field of seaweed development.

- Contacts are being made across Europe with institutions able to further coordinate the dissemination of the results of the Action

- The general public who will obtain accessible knowledge and understanding, through the website and outreach activities, about the economic potential and basic developmental biology of marine organisms such as seaweeds. Partners of the Action already have established ongoing links with local science museums, sea-life centres and schools.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

There are three main processes that must be better understood if we are to advance the state-of-the-art in seaweed growth: 1-Fertility induction; 2-Control of reproduction; 3-Growth mechanisms in adult seaweeds.

TASK 1: FERTILITY INDUCTION. A controlled shift of vegetative seaweeds to a fertile stage is usually a bottleneck in seaweed life cycles. Identifying the genetic and chemical factors involved in this process will enable researchers to control the production and propagation of seaweed biomass, and enable selective breeding.

TASK 2: REPRODUCTION AND INITIATION OF NEW GENERATIONS. Correct embryonic development depends on gamete fusion and the sensing of environmental cues. The chemical and molecular factors involved in male and female gamete chemotaxis and fusion (pheromone secretion, cell surface recognition) are unknown in most seaweed species. Their identification will enable better control of the cross-fertilisation necessary to produce genetically improved seaweed strains. Parthenogenesis (asexual reproduction without fertilization characteristic for certain seaweeds) will also be explored as a way of maintaining and propagating strains of interest selected by cross-breeding. Knowledge of the molecular and cellular mechanisms involved in embryogenesis will allow control of seaweed germination, polarisation, and early development, and will help guide the development of embryonic cryopreservation techniques for cross-bred strains. Finally, the factors involved in vegetative reproduction (e.g. fragmentation of seaweed blades in ship ballast).

TASK 3: TOWARDS ADULT GROWTH. Investigations into morphogenesis (cell division, elongation, differentiation and death) will define the developmental checkpoints to use as targets for the controlled production of seaweed biomass by vegetative growth and sub-culturing. Chemicals with morphogenetic activities will be identified using metabolic profiling (exo/endo metabolome fingerprinting). “Bioassay-guided” approaches and "comparative metabolic profiling" will be combined to identify diffusible molecules involved in morphogenesis. Furthermore, the survival of seaweeds in harsh conditions (e.g. in ship ballast, without renewed sea water and light for several months) will be particularly investigated, as this contributes largely to the propagation of exotic invasive species.

To achieve these scientific tasks, upgrade of the palette of available tools is foreseen.

TASK 4: TECHNICAL TOOLS. The currently available palette of techniques for the study and control of seaweed growth and reproduction will be increased. First, standardized experimental designs to improve seaweed cultivation at lab- and pilot-scale will be established. Second, “-OMICS” approaches will be implemented to understand seaweed development, including systems-level data analysis. Genetic and epigenetic signatures of seaweed development will be linked to environmental conditions. Third, inspired by molecular biology advances in land plants, reverse genetic and transformation protocols will be developed in seaweeds. This Task will identify genetically tractable seaweeds and cell types (e.g. germ cells), using the skills that the COST partners have in producing transgenic green or brown seaweeds. Finally, cell biology (state-of-the-art imaging, in situ localisation, reporter transgenics) will complement “-omics” and genetics to define spatio-temporal molecular expression patterns during the different steps of seaweed development. Investment in the conservation techniques enabling long-term maintenance of a specific developmental stage will also have to be developed.

D.2 Scientific work plan methods and means

The 4 scientific objectives of the Action are sub-divided into a panel of Deliverables (DL), which is deliberately large, with the view to enlarge the Action with future partners. Current members of the Action have the means to deliver the DL marked with asterisks. DL priority will be ranked at the first Action meeting with all the partners present.

The following deliverables (DL) are :

TASK 1: FERTILITY INDUCTION.

DL1-1*- Identify the overall biological (e.g. age, size) and environmental (e.g. temperature, tides, day length, dehydration, tearing, wounding) parameters triggering the shift to the reproductive phase.

DL1-2*-Identify the chemical compounds and signalling molecules (morphogens) mediating the differentiation of the reproductive cells (gametes or spores)

DL1-3- Identify the mode of action of the signalling molecules within the whole seaweed tissue: localisation of biosynthesis, transport and receptors

DL1-4*- Characterize the cell differentiation steps leading to the development of reproductive organs, at both the cellular (microscopy) and the transcriptional level (microdissection followed by transcriptomics)

DL1-5*- Identify cell markers (transcripts and proteins) allowing early identification of reproductive cells prior to morphological differentiation. This will generate tools capable of speeding up the reproductive shift (to be developed in Task 4)

TASK 2: REPRODUCTION AND INITIATION OF NEW GENERATIONS.

DL2-1*- Identify the parameters triggering the release of reproductive cells into seawater.

DL2-2*- Characterize the physiological parameters of germ cells' motility within the seawater: velocity, survival, phototaxis.

DL2-3*- Characterize the chemo-attraction of female and male germ cells and identify the molecular factors enabling physical recognition and contact between the female and male germ cells. Describe their fusion mechanisms at the cellular and molecular levels.

DL2-4- Identify the processes of cytoplasmic heredity in the first steps of zygotic cell division (contributing to improved seaweed selection for algoculture).

DL2-5*- Characterize the establishment of the cell polarity axis at the sub-cellular level prior to and after the first cell division (cytoskeleton, cell nucleus position and orientation of the division plan). This will impact on the further developmental pattern of the seaweed.

DL2-6*- Identify the molecular factors involved in determining cell fate at the embryo stage and during sporulation events by e.g. cell wall determinants and external factors.

DL2-7*- Characterize the expression pattern (overall transcript composition) of the zygote prior to its entry into mitosis or meiosis; Seaweeds have complex and diverse life cycles and some skip the diploid stage as the zygote immediately enters into meiosis: a better knowledge of this process might allow generation of artificial life cycle stages useful in aquaculture (e.g. haploid / diploid stages).

TASK 3: TOWARDS ADULT GROWTH.

DL3-1- Characterize whether cell-cell communication occurs within the embryo (apoplastic or symplastic communication). This will allow practice of excision of seaweed parts, which might be necessary in aquaculture processes.

DL3-2*- Assess the impact of external and internal forces (mainly mechanical) on embryo fate. Most seaweed embryos develop directly in the sea, exposed to strong mechanical forces (such as sea current, waves and tides). In addition, growth and cell multiplication generate compression and shearing forces, which cells need to account for and respond to.

DL3-3*- Identify bacterial chemicals used as external seaweed morphogens. This will lead to possible control of seaweed developmental steps by external application of morphogens present in natural compounds (in hatchery).

DL3-4- Characterize seaweed tissues or cellular structures enabling long-range transport through the seaweed body (differentiation of sieve elements and/or plasmodesmata, transport velocity). The intention would be to eventually manipulate the size of seaweed whole-body or specific organ to optimise yield should account for these knowledge.

DL3-5*- Determine the existence of processes such as apical dominance, leading to the possibility of modifying overall seaweed morphology by promoting branching, thereby increasing seaweed biomass or production of reproductive organs, similarly to crop plants on land (e.g. “Green Revolution” breeds of wheat and rice).

TASK 4: DEVELOPMENT OF TECHNICAL TOOLS.

DL4-1*-: Establishment of cultivation protocols enabling the whole seaweed life-cycle to occur in laboratories conditions. This will be developed on specific seaweeds with aquaculture interests.

DL4-2*-: Establishment of cryopreservation protocols. Different stages of the life cycles (zygote, embryo, germlings, specific tissues/organs of the adult body, such as reproductive organs, gametes or spores), will be tested for cryopreservation (-120°C, -80°C, with different cooling processes). Alternatively, shorter-term storage systems (cold room for only a few months) will be developed.

DL4-3*: Identification of detectable markers (RNA, proteins, chemicals) used to identify the

reproductive cells prior to morphological (visible) differentiation. That will allow definition of the vegetative-reproductive shift, and hence anticipation of further steps in the aquaculture process.
DL4-4*: Implementation of high-throughput “-OMICS” tools, already established in some seaweeds by academic partners, which will be transferred to and developed in other seaweeds more specifically dedicated to aquaculture (upon requirement to achieve other Deliverables).
DL4-5*: Development of reverse genetic and transformation protocols in seaweeds. First, a selection of genetically tractable seaweeds and cell types (e.g. germ cells) will be performed, relying on COST partners skilled in green or brown seaweed transgenics.
DL4-6*: Develop cell biology (state-of-the-art imaging, in situ localisation, reporter transgenics) in relevant seaweeds. This will complement “-omics” and genetics to define spatio-temporal molecular expression patterns during the different steps of seaweed development.

E. ORGANISATION

E.1 Coordination and organisation

The Action consists of 21 partners from 10 COST countries and 6 partners from 4 non-COST countries. Among COST partners, 14 are from academic institutions, and 7 are Research & Development and Innovation Institutes or SMEs. While all focusing on a better knowledge of seaweed development, the range of competencies within the Action is large. It ranges from “in-field” aquaculture and knowledge transfer to industry, to basic seaweed biology and the development of cutting-edge technical tools. Furthermore, some partners are also land plant biologists sensitive to agricultural issues.
General organisation: To ensure the optimal execution of the Action, the management structure will be composed of a Management Committee (MC) embracing partners spanning the full range of scientific or technical cultures present in the network (see above); they will be elected at the outset of the Action. The elected MC Chair will act as a contact between the Action and the COST Association. The MC Vice-Chair will act for the MC Chair, when s/he is unavailable. These representatives will be designated at the first meeting of the Action along with the representatives of each country to the MC. A Leader for each Working Group will be nominated by the MC to coordinate and develop WG-specific tasks throughout the Action. Each WG Leader will prepare a detailed work programme, which will be approved by the MC taking into account (i) the objectives of the Action, (ii) the scientific strategy deployed to reach the objectives, (iii) the availability of relevant expertise and facilities provided by the members of the Action. The MC will meet every 6

months and the WG Leaders as often as required for the ongoing successful work programme.
Additional regular contact between group members will be via internet conferences.
One manager of both Short Term Scientific Missions and Training Schools will be appointed at the first meeting.
To disseminate the outcomes of the Action, a Dissemination Coordinator will also be appointed and will be additionally responsible for the development, updating and maintenance of the website.
A Board for Gender/Career Issues will take care that all guidelines and EU strategies with respect to hiring and invitation of scientists are followed (e.g. diverse interview panels, members trained in unconscious bias), and that where possible meetings are arranged to enable the participation of members with family/caring commitments, etc.
The Management Committee will:

- Organise the election of COST Action Chair, Vice-Chair, Working Group Leaders, and Steering Committee.

- Perform meetings every 6 months (except at the beginning of the Action when it is more frequent).

- Organise scientific Workshops, Training Schools (TS) and the final conference.

- Evaluate progress of the scientific tasks every 6 months, from WG reports

- Evaluate progress of other deliverables (Training School, Workshops) every year (6 months after TS and workshops have taken place), reported by WS and TS managers

- Prepare the Annual Reports.

- Coordinate the work between the different WGs, in order to fulfil the Action objectives

- Maintain the public Website, whose aim is:

    i. To strengthen links between members of the Action (sharing technical protocols, publications, reminder of important events, forum of discussion, etc.),

    ii. To advertise the existence of the Action to other interested experts who are not yet members of the Action,

iii. To disseminate the events of the Action (meetings open to the wider research community).

• Promote contacts and combined activities with the appropriate ongoing COST Actions and other relevant national, European and international initiatives (e.g. EU projects).

• Ensure interaction and communication with the COST Office on regular basis.

Working Group (WG) Leaders will:

• Plan specific WG activities, including Training Schools.

• Coordinate WG activities, in relation to the WG objectives.

• Evaluate WG progresses through the achievement of the deliverables. In case of delay, WG Leaders will contact the MC to discuss potential solutions (e.g. contact additional experts)

• Prepare WG progress reports to the Action Chair and MC every 6 months

Workshop (WS) Manager and Coordinator:

• WS will be the open and necessary context to discuss specific topics as related to the Action tasks, new methodologies, etc. Along with network members and stakeholders, Early-Stage Researchers will be encouraged to attend.

Along with the Workshops, the Action will also organize Short Time Scientific Missions and Training Schools, all of them associated with the 4 WG and producing the deliverables described in details above (see sections C.2 and D.2) and summarized in Table 2 below. These are important parts of the Action.

Short Term Scientific Missions (STSM) Manager and Coordinator:

• STSM will be a very important tool to integrate and develop research activities. They will strengthen the collaborations among partners and will allow the development of novel research projects related to the tasks. Importantly, they will promote new coordinated applications for research funding in the EU. Furthermore, Early-Stage Researchers and promising scientists will be involved and the Action will promote their mobility for advanced training. The work performed during visits will complement the results achieved at their home institution and will be an integral part e.g. of their PhD dissertation or post-doctoral project. TS will make new equipment and methods familiar to the Action members, and will allow the standardization of experimental and analytical approaches. One Manager/Coordinator of STSM will be appointed in the first meeting (MC).

Network-wide Training Schools (TS) Manager and Coordinator:

• TS will provide advanced training. The TS will focus on interdisciplinary training based on the specific partners' research expertise within the 4 WGs. These Schools will address topics beyond the scope of the project and will rely on additional invited senior members of the scientific community outside the network interested and willing to participate in this advanced training approach. In particular, scientists outside the EU, with whom the Action members are already in contact, will be invited, to broaden the expertise available for Action members. This enhances the quality of the training and gives the Trainees the opportunity to discuss their work with senior scientists from outside the Action. The schools will consist of both lectures and advanced "hands-on" practical training in novel methodologies and instrumentation addressed by the WGs. Training Schools are an essential tool to inspire the next generation of scientists.

International symposium organizer:

• In the final year of the Action a high-profile, widely advertised Conference will be organized under the general theme of this Action: "Advancing seaweed development from molecules to morphology". The scientific achievements of the Action will be communicated and future prospects will be envisaged. An Editorial Board will be created to publish the proceedings of this conference. This will be the final module of the Action. Individual sessions will highlight the central topics and research projects performed in the Action.

Dissemination Coordinator:

• To successfully disseminate the outcomes of the Action, a Dissemination Coordinator will be selected among MC members. The Dissemination Coordinator will guide the dissemination activities and will be responsible for the development and maintenance of the Action website. An important achievement will be the establishment of standardized protocols to which scientists, the general public and aquaculturists have access and may contribute.

Table 2. Major Milestones of Action and Deliverables:

Month	MC meeting	Other organisational level	Deliverables
1	+	- First meeting of the Action: setting up the organisation (MC, SC, WG Leaders) of the Action	
3	+		Approval of detailed Work Programme of Action: - coordination of ongoing national research - organisation of Short-Term Scientific Mission - coordination of application for research funding
4		- Launch of the Action website	Open and restricted platforms/blog for the scientific community and the Action members.
6	+	– Workshop 1 - Training School (TS, Summer Schools)	- Evaluation of the Scientific Task progresses. - Associated with WG4: DEVELOPMENT OF TECHNOLOGICAL TOOLS. - Workshop 1 **“Axenic and unialgal cultures: novel and forgotten approaches”** - Training School 1: “**Cultivating seaweeds in vitro”**
12	+	Preparation of the annual report with WG Leaders	- Meeting with all members of the Action - Presentation the achieved deliverables (Workshop, TS and scientific Deliverables) top the members of the Action - Evaluation by the MC and WG Leaders - Potential Co-authored publication to academic/aquaculture journals
18	+	- Workshop 2 - STSM (at any time after the workshop 2)	- Evaluation of Scientific Tasks progresses - Coordination of the Workshops - Associated with WG4: DEVELOPMENT OF TECHNOLOGICAL TOOLS. - Workshop 2: ”**Functional genomics and transcriptomic using model seaweeds**” - STSM to train network-wide techniques and protocols on **next generation sequencing** and data management. - Updating the Dissemination plan
24	+	- Preparation of the annual report with WG Leaders	- Meeting with all members of the Action - Presentation the achieved Deliverables (Workshop, TS and scientific Deliverables) top the members of the Action - Evaluation by the MC and WG Leaders

		- MC meeting with industrial stakeholders	- Potential Co-authored publication to academic/aquaculture journals - Evaluation of Workshop 2 and STSM 1. - Reports on the Action main results will be presented to the industrial end-users and further development will be discussed.
30	+	- Workshops 3 - Training School 2 - STSM	- Evaluation of the Scientific Task progresses. - Associated with WG4: DEVELOPMENT OF TECHNOLOGICAL TOOLS. - Workshop 3: "**Crossing the kingdoms: Seaweed substances and interaction with bacteria that promote seaweed growth"** - Training School 2: **Mass spectrometry** enabled elucidation of **infochemicals** - STSM: Metabolic platform: application to basic and applied phycology
36	+	- Preparation of the annual report with WG Leaders	- Meeting with all members of the Action - Presentation the achieved deliverables (Workshop, TS and scientific Deliverables) to the members of the Action - Evaluation by the MC and WG Leaders - Potential Co-authored publication to academic/aquaculture journals - Evaluation of Workshop 3 and TS 2 and STSM2 - Co-authored publication presenting the results of the Action
42	+	- Workshop 4 - Training School 3	- Evaluation of the Scientific Task progresses. - Associated with WG4: DEVELOPMENT OF TECHNOLOGICAL TOOLS. - Workshop 4 **"Imaging seaweed cells and tissues"** - Training School 3 « **State-of-the-art of modern techniques for imaging the cell and tissues** »
48	+	- Preparation of the final report with WG Leaders - MC meeting with industrial stakeholders - Meetings with other research programmes / science	- Evaluation of Workshop 4 and TS 3 - Closing meeting of the Action - Final international symposium on « Advances in seaweed growth and development » - Co-authored publication grouping the 4 scientific Tasks - Final evaluation and final report to the COST Association - Reports on the Action final results will be presented to the industrial end-users and future common projects will be discussed.

		societies to transmit the outcomes of the Action.	-Discussion about the possibilities/relevance to expand the network to other scientific fields

E.2 Working Groups

The scientific objectives of the Action will be reached following a work plan involving 4 Working Groups (WG), based on the 4 tasks:
WG1: FERTILITY INDUCTION.
WG2: REPRODUCTION AND INITIATION OF NEW GENERATIONS.
WG3: TOWARDS ADULT GROWTH.
WG4: DEVELOPMENT OF TECHNICAL TOOLS.
Each WG will be managed by a WG Leader. Each Working Group Leader will monitor and coordinate the achievement of Deliverables of WG (corresponding to each task) by deploying relevant actions if necessary (e.g. contact additional experts) upon approval by the MC. They will be in close contact with the different partners of the Action, and will supervise work coordination to ensure achievement of each task. Supervision of work progress will be made through an internet server, on which partners will regularly and frequently load their results.
WG 4 will organise Training Schools and the different STSMs and Workshops programmed for this Action (to be specified at the first Action meeting).
The WG Leaders will prepare WG progress reports to communicate to the Action Chair and MC every 6 months.

E.3 Liaison and interaction with other research programmes

The Action is dedicated to the acquisition of basic knowledge on seaweed development and reproduction, and to its transfer to aquaculture activities.
Members of the Action have individual membership to national, European and International science societies dedicated to the basic or applied study of macroalgae. Meetings of the Action MC with these societies will allow discussion of potential association to future and common funding applications.
Members of the Action (especially Research & Technological Development Institutes) have business links with several seaweed industries and aquaculture SMEs for biofuel production or IMTA development. This will likely result in future involvement in several related H2020 research

programmes.
Some partners of the Action are also members of other European funded research programmes, such as “EnAlgae” (Exploitation of algae for Energy production; Interreg IVB, 2011-2015), or the “INTAB” project (Multi-trophic aquaculture involving shell-fish, fin-fish and seaweeds; H2020, 2014-2017). Possible interaction with the “AT~SEA” (FP7-NMP) project involved in new generation textiles as material for offshore cultivation of seaweeds will be studied, as the attachment of seaweed germlings to support material will gain from a better knowledge of biological cell adhesion mechanisms.

E.4 Gender balance and involvement of Early Stage Researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve Early-Stage Researchers. This item will also be placed as a standard item on all MC agendas.
The gender balance of this Action is about 30% women and 70% men. Following the gender Action plan (GAP, 2010-15) of the EU, a board of gender issues will be established by the MC with three elected members. The Board´s task is to counsel all partners with respect to gender issues.
STSMs for young-scientists to visit other research groups will be encouraged and a career-mentoring programme for both men and women will be implemented. Experienced female scientists will act as role models and will mentor Early-Stage Researchers and provide support and career advice for them.
The Action is fully committed to the education of the next generation scientists and will in particular take care to involve Early-Stage Researchers in the participation, organisation and evaluation of the workshops and training schools. Their involvement will also be very important in all WGs via the instrument of STSMs.

F. TIMETABLE

The Action is planned for 4 years.
Table 3: Time table for the achievement (A) and evaluation (E) of the main Action Deliverables by the MC.

		YEAR 1		YEAR 2		YEAR 3		YEAR 4	
Scientific Tasks	1. Fertility	+	+	+	+	+	+	+	+
	2. Reproduction and new generations	+	+	+	+	+	+	+	+
	3. Towards adult growth.	+	+	+	+	+	+	+	+
	4. Technical tools	+	+	+	+	+	+	+	+
	Evaluation by the MC of each Task from WG leader reports	E	E	E	E	E	E	E	E
Other deliver-ables	Workshop 1 :	A	E						
	Workshop 2 :			A	E				
	Workshop 3 :					A	E		
	Workshop 4 :							A	E
	Training School 1	A	E						
	Training School 2					A	E		
	Training School 3							A	E
	STSM 1			A	E				
	STSM 2					A	E		
	Annual report		+		+		+		+
Other actions	Initial Action meetings (with all partners)	+							
	MC approval work programme	+							
	MC meetings	+	+	+	+	+	+	+	+
	Launch of Action website	+							
	MC meeting with industrial end-users				+				+
	Final conference								+
	Possible large-audience communications/publications		+		+		+		+
	Meetings with other research programmes/science societies related to seaweed aquaculture or developmental biology							+	+

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, DE, EL, ES, FR, IE, NL, NO, PT, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 40 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

The Target audiences for the dissemination of the results of this Action are:

- Aquaculture industries, needing predictable, traceable and quality seaweed biomass (for the production of high-value products, and robust production planning).

- Members of the European Community and politicians concerned with the sustainable cultivation of algal aquacultures. They will be better informed to argue the issues of sustainable aquaculture.

- European and international researchers involved in seaweed research (via Phycological Societies).

- The broader scientific communities studying developmental biology (in higher plants), who will gain knowledge about both the alternative and the conserved molecular and cellular developmental mechanisms operating in seaweeds.

- Scientific communities studying evolution of multicellular organisms, who will gain knowledge about the genomics of organisms evolutionarily distant from commonly used model species, filling the gap between extensively studied taxons and unexplored taxons.

- Students and early-career researchers, who can capitalise on the technical advances and organisational frame of the Action to initiate challenging explorative projects in the so far undeveloped field of seaweed development.

- The general public, who will obtain accessible knowledge and understanding about basic developmental biology of marine organisms such as seaweeds.

- Biosensor design companies for in situ monitoring of biological parameters as well as chemical biomarkers indicating the status of algal growth and/or status in life cycle.

- Socioeconomically affected coastal regions (Brittany, France; Ria Formosa, Portugal; Lagoon of Venice; Italy) by e.g. green Ulva tides.

H.2 What?

In order to maximise the usefulness of the basic knowledge for the further development of aquaculture, a special attention will be given to the deployment of a scheme to ensure a narrow and responsive communication between the different partners, and especially between the Academics and the Innovation groups.

To members of the COST Action:

Posting data on a regular and frequent basis (to be defined by partners) on a dedicated server with access restricted (password protected) to the members involved in the different WGs of the COST Action. This will allow sharing of data on a real-time basis to allow the highest reactivity from the R&D partners.

To the scientific community:

- Peer reviewed publications in scientific journals.
- Non-restricted website:
- Posting of specific information publicly available
- News section, to inform about meetings and workshops, on the website.
- Regular e-mail based newsletter to which the Action and other researchers can subscribe.
- A special issue of technical protocols and guidelines will be published e.g. in “Methods in Molecular Biology”.
- A volume of “Frontiers in Plant Science” is currently prepared on the topic of seaweeds development and reproduction (COST Action Coordinators as editors).
- Workshops dedicated to the morphogenesis of marine macroalgae will be included in major multi-disciplinary international conferences such as the Annual Moss International Conference and the Society for Experimental Biology annual meeting. The workshops will be organized by the MC.
- Attendance and presence at other appropriate plant and phycology conferences: some members of the Action are members of land plant community and are in an ideal position to provide a cross-disciplinary presence.

To the large public audience:

- Posting of general information on a publicly available website.

- Wider outreach using existing links and networks: Public conferences targeting large audience: Schools, Museums. The COST Action will be present at the “Night of Science” (e.g. in Jena Germany, or in Brest France) and other local activities of the participating cities. Presentations will be made in High Schools of European regions particularly concerned by seaweed bio-economy (e.g. Brittany in France).

H.3 How?

- The specific dissemination plan will be evaluated by the MC on a yearly basis depending on the progress within the Action network. The MC will also discuss the potential platforms to communicate the research of the Action via workshops at international conferences.

- Where appropriate, MC meetings will take place within EU-wide meetings such as EuroMarine.

- Specific multidisciplinary journals will be selected for publication (PLoS Biology, PLoS One, PNAS, BioEssays, ChemBioChem) to increase the visibility of COST Action.

- Where possible, the Action meetings will be integrated into international/European conferences on both plant morphogenesis and phycology (e.g. International conference on Phycology, European conference in Phycology in 2015 in London).

- Review and open letters in academic journals will be written to attract and to increase the visibility of the Action to the academic community.

- Visit aquaculture meetings in order to bridge the various scientific communities.

- Press and media will be invited to the meetings and workshops. Articles about the Action activities will be sent to local newspapers.