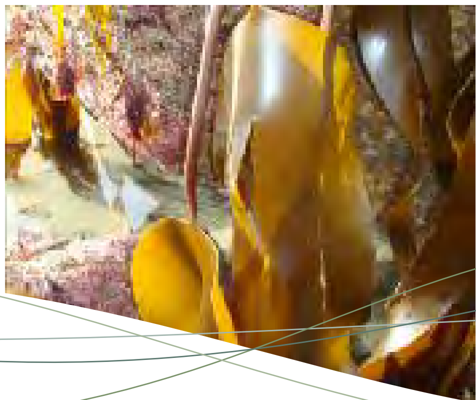
Marine Research Sub-Programme (NDP 2007–'13) Series

SeaChange
Casadh na Taoide

Development and Demonstration of Viable Hatchery and Ongoing Methodologies for Seaweed Species with Identified Commercial Potential Project-based Award

Lead Partner: Bord Iascaigh Mhara



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Project-based Award

Development and Demonstration of Viable Hatchery and Ongrowing Methodologies for Seaweed Species with Identified Commercial Potential

(Project reference: PBA/SW/07/001)

Lead Partner:	Bord Iascaigh Mhara (BIM)
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Project Duration:	01 February 2008 to 31 May 2011

Bord Iascaigh Mhara Irish Sea Fisheries Board

OÉ Gaillimh NUI Galway

Queen's University Belfast

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EXECUTIVE SUMMARY

This project was initiated with a proof of concept approach. The project aim, as set out in the terms of reference, was to develop and trial industry-scale hatchery and ongrowing methodologies for identified seaweed species, and to provide a platform for transferring the technology to create new business opportunities in seaweed aquaculture in Ireland. The defined research objectives included: the development of viable, industry-scale hatchery and ongrowing methodologies for *Palmaria palmata*; the investigation of pilot-scale hatchery methodologies and the implementation of a programme of ongrowing trials for *Laminaria digitata* and *Porphyra* spp.; the provision of a species-specific, desk-based assessment on the criteria for optimum site selection for seaweed ongrowing operations; and the development of an economic model for viable, industrial-scale production of *P. palmata* based on proven aquaculture methodologies. The objectives included an economic assessment of the potential for viable industrial-scale production of *L. digitata* and *Porphyra* spp., a market analysis and finally, the development of an appropriate technology-transfer strategy and associated training tools to facilitate an interest in, and uptake of, seaweed aquaculture as an emerging business opportunity.

In achieving the aims of the project trials of industry-scale hatchery and ongrowing methodologies for four species of seaweed (*Palmaria palmata, Laminaria digitata*, *Saccharina latissima* (an additional species), and *Porphyra* sp.) were completed in Ireland. Intensive studies were conducted at hatcheries in counties Cork, Galway, and Down, and material was deployed to sea for ongrowing at five separate inshore sites on the South-West, West, and North-East coast of Ireland. The cultivation of *Palmaria palmata* (dulse) relying on vegetative propagation in tanks on land was also tried and this yielded consistent growth results. *Palmaria* proved difficult to cultivate at sea on a large scale, and the economic analysis of the hatchery and ongrowing operations did not suggest that it could provide the basis of a viable industry. By modifying techniques that had been developed in Europe for related kelp species (especially *Alaria esculenta* and *Saccharina latissima*), *Laminaria digitata*, and *Saccharina latissima* were successfully cultivated in the hatchery and grown-out at sea. *Porphyra* from the British Isles *(P. leucosticta,* sourced from the Natural History Museum in London*)* was cultivated in the hatchery for the first time in Ireland and small scale on-growing trials were carried out at sea. These trials were successful, but considerable further work is needed before commercial cultivation can be attempted. A market and business analysis of *Palmaria palmata*, *Laminaria digitata,* and *Saccharina latissima* indicated that the optimal hatchery set-up is a combination hatchery; i.e. one that is capable of producing both bivalve spat and seeded collectors for grow-out at sea. A fully integrated seaweed hatchery and grow-out unit was analysed for its

viability. In examining four different business case studies for sensitivity and break-even, the seaweed and scallop hatchery and existing mussel site option was found to be the most viable, indicating a break-even price of €1.12/kg for seaweed from the farm. This price is at the higher end of the market for seaweed but indications are that it is achievable for material which meets the requirements of the high end functional food and beverage markets. Seaweed is an extremely versatile natural resource used in a variety of products. Ireland's seaweed and biotechnology sector is currently estimated to be worth €18 million per annum.

The results of the work carried out during this project have been written up into six publications. The guides and manuals listed below are designed to support promoters of seaweed aquaculture in their decision making. Each publication is available from BIM.

Edwards, M. and Watson, L. (2011). Aquaculture Explained No 26. Cultivating *Laminaria digitata*. BIM. 71pp.

Watson, L. and Walsh, M. (2011). A Market Analysis towards the Further Development of Seaweed Aquaculture in Ireland. BIM. 49pp.

Watson, L. and Dring, M. (2011). Business Plan for the Establishment of a Seaweed Hatchery and Grow-out Farm. BIM. 38pp.

Werner, A. and Dring, M. (2011a). Recommendations for optimal techniques for obtaining spores of *Palmaria palmata*, settling and maintaining them prior to outplanting at sea. BIM. 7pp.

Werner, A. and Dring, M. (2011b). Recommendations for optimal ongrowing and harvesting techniques for *Palmaria palmata* in different Irish sites with indications of yield. BIM. 8pp.

Werner, A. and Dring, M. (2011c). Aquaculture Explained No 27. Cultivating *Palmaria palmata.* BIM. 74pp.

1. Project Description

1.1 Project Objectives

The main objectives of this project were to develop and conduct trials of industry-scale hatchery and ongrowing methodologies for three seaweed species with commercial potential. These included two edible red algae, *Palmaria palmata* and *Porphyra sp*., and the large brown kelp *Laminaria digitata*. During the project the large brown kelp *Saccharina latissima* was added to the work programme. In addition to developing ongrowing methodologies for each of the seaweed species, the project aim was to provide a platform for transferring the results and knowledge gained during the project, which would support the creation of new business opportunities in Ireland's seaweed aquaculture sector.

The project goals were both scientific and industry-focused, and included:

Scientific goals

- To establish the optimal hatchery culture conditions for each seaweed species
- To develop settlement techniques for each seaweed onto suitable substrates for deployment at sea
- To monitor and improve the yield of cultured seaweeds on culture equipment at various licensed sea sites
- To develop seaweed harvesting strategies

Industry-focused goals

- To produce a seaweed marketing strategy
- To conduct economic analyses for the three seaweed species
- To develop training courses in algal cultivation techniques
- To publish cultivation manuals under BIM's '*Aquaculture Explained*' series
- To identify the requirements for locating seaweed cultivation sites, using Bantry Bay as a study area.

1.2. Partners and Industry Associates

In addition to the three institutional partners (BIM, NUI Galway, and QUB), seven seaweed industry firms were also involved in the project as outlined in Table 1.

Table 1: Seaweed companies and their role within the project

Participant	Role within Project
Cartron Point Shellfish Ltd.	Active participation in cultivation of *L. digitata* and *P. palmata* (hatchery and sea sites)
Tower AquaProducts Ltd.	Tank cultivation of *P. palmata*
Irish Seaweeds Ltd.[1]	Provision of licensed sea trial site
G + B Barge Operators Ltd.	Industry partner
Roaringwater Bay Seaweed Co-operative Society Ltd.	Provision of licensed sea trial site
Cleggan Seaweeds Ltd.[2]	Provision of licensed sea trial site
Dingle Bay Seaweeds Ltd.	Provision of licensed sea trial site

During the project, two new sea- sites were made available; a one-hectare site in Ard Bay, Co. Galway (licence held by Mr. Michael Ward), and one of 18 hectares that was operated by Dingle Bay Seaweeds Ltd in Ventry Harbour. The total sea-area available to the project was 85 hectares.

1.3. Project Hatcheries and Licensed Seaweed Trial Sites

Three licensed hatchery facilities, QUB Marine Laboratory at Portaferry, Co. Down, NUI Galway Carna Research Facility, Carna, Co. Galway, and The Daithi O'Murchu Marine Research Station, operated by Cartron Point Shellfish Ltd. and BIM, Gearhies, Co. Cork, were made available to the project. Each hatchery was able to provide seeded seaweed collectors for deployment at nearby sea sites.

Most of the grow-out sea sites were located in the West and South-West of Ireland. Longlines were also deployed at two sites in Strangford Lough, Northern Ireland. Site conditions at all locations varied, with depths between 6m and 18m, and substrate types ranged from boulders and bedrock to silt, sand, and mud.

[1] Formerly Dolphin Sea Vegetables Ltd.
[2] Cleggan Seaweeds Ltd subsequently disengaged from the project.

2 RESULTS FROM CULTIVATION AND ON-GROWING TRIALS

2.1 Cultivation of *Palmaria palmata* on Land and at Sea

2.1.1 Cultivation – hatchery techniques

Fertile material for spore release was collected between January and March/April. The start of the cultivation process involved the freshly collected reproductive material being placed on top of the collectors or on the net (both made of Kuralon string). Environmental conditions influence spore release, which should occur in three days under low light and low temperature conditions (5-10 μmol m^{-2} s^{-1} at 10˚C), and incorporating a light: dark period of 12:12 hours. UV-filtered seawater was used at this stage. The successful release of spores should result in settlement of 100 or more spores per cm of culture string length. A high spore mortality is to be expected (60-80%). Filtered, UV-sterilised, nutrient enriched (e.g. f2 medium) seawater is used to grow-out the *Palmaria* in the nursery. For autumn/winter deployment seeded Kuralon string collectors will need to be maintained in the hatchery for 6-9 months. Tanks should be cleaned and the water exchanged every 2-4 weeks.

2.1.2 Deployment and ongrowing of seeded collectors at sea

For successful ongrowing in the sea, Kuralon string collectors should be deployed from October to early December with a culture string that is evenly and densely seeded with *Palmaria* sporelings, the largest of which are typically 5 mm – 8 mm in length. The maximal yield of *Palmaria* achieved during the project was 1.2 kg m^{-1} on 2 m droppers after five months (Strangford Lough, 2011) and a total of 25 kg from a 3 m x 1.2 m net after four months (Ard Bay, 2010). The growth of young plants was found to be adversely affected by fouling. Summer deployments are likely to be less successful than autumn deployments.

2.1.3 Land-based tank cultivation of *Palmaria palmata*

Trials with tank cultivation were conducted as an alternative to cultivating *Palmaria palmata* at sea. The advantage of this cultivation method is the omission of the nursery phase (2.1.1 above). Harvestable biomass of *Palmaria* was grown vegetatively in a tank, from an initial stock of *Palmaria* collected from the shore. Once the initial biomass has started growing in the tanks, the surplus material can be harvested at frequent intervals throughout the year. In this approach to land-based tank cultivation, there is no need for a hatchery or for on-growing structures in the sea, and the limitations imposed by boat availability and weather are also avoided.

2.1.4 Harvesting methods

The timing of harvest is just as critical as the timing of deployment for obtaining a high quality crop, and is best after 5-6 months in the sea. Fronds may deteriorate if the stock is left at sea for longer than six months. During the trials multiple harvests of one culture string (i.e. 3-4 harvests from a net or dropper at monthly intervals from early spring until early summer) yielded the highest biomass (e.g. a net deployed in Ard Bay in 2009 and harvested in 2010 resulted in 25 kg of material). The prerequisite for multiple harvests is a high quality of seeded culture string with an even and dense cover of *Palmaria* sporelings.

In harvesting *Palmaria* from tanks all material which exceeds the initial stocking density should be removed from the tanks at appropriate intervals. With decreasing day length growth rates reduce significantly, and there is very little growth during the winter months. Therefore the frequency of harvests must be adjusted to growth rates. In the summer because of increased day length there is maximum growth, and up to 40-60% of the initial stocking weight should be harvestable every two weeks. The remaining fronds should be screened and any older, damaged or fouled material should be removed.

A specially equipped vessel, such as a mussel harvesting barge with a lifting derrick and flat work area with a conveyor belt and hopper, can be used to harvest *Palmaria* at sea (see also 2.2.3). It may be necessary to use an overhead lifting device when harvesting material from tanks.

Culture methods for *Palmaria palmata* developed during this project are described in Werner, A. and Dring, M. (2011c).

2.2 Cultivation of *Laminaria digitata* and *Saccharina latissima* at Sea

2.2.1 Cultivation – hatchery techniques

Fertile material for spore release was collected between April and November around the Irish coast. The hatchery phase can be divided into two: establishment and maintenance of gametophyte cultures; and development of sporophyte cultures. Reproductive sori were cleaned with sterile seawater and partially dehydrated. The prepared sori were placed in the dark at 10˚C for 18-24 hours and immersed in cool sterilised seawater, covered and left to release zoospores. Subsequently, these zoospores were cultured in nutrient-enriched (e.g. f2 medium) seawater for 3 to 5 months. When the gametophyte cultures have developed a sufficient biomass, fertility may be induced by refreshing the nutrients and adjusting the light regime. Once numerous reproductive structures are observed, the culture is prepared for spraying onto culture string.

2.2.2 Deployment of *Laminaria* and *Saccharina* cultures at sea

The collectors (Kuralon string) are deployed to sea, preferably in October or November, either as droppers suspended from a longline or along the horizontal header rope of the longline. If deploying horizontally, the boat is pulled down the length of the header rope, hand over hand. The collector (Kuralon string) is also pulled down the length of the header rope, the culture string spiralling around the larger diameter header rope. Once each cohort of seaweed is deployed, it is advisable to visit the cultivation site once per month for maintenance and monitoring of growth. By April or May the yield of seaweed per linear metre should average 7 kg.

2.2.3 Harvesting methods

A suitably equipped vessel, such as a mussel harvesting barge, can be used to harvest the stock. Typically a vessel would come alongside the longline; using a fore and aft derrick hook the longline is raised to a safe workable height. The seaweed is cut away from the longline by hand and carried on a conveyor belt into a one-tonne bag suspended from a suitable crane. Once filled, these one-tonne bags can be stored on deck until harvesting is completed, drawn ashore, and loaded on to trucks for delivery to the processing unit.

Culture methods for *Laminaria digitata* developed during this project are described in Edwards, M. and Watson, L. (2011).

2.3 Cultivation of *Porphyra* spp. at Sea

2.3.1 Cultivation – hatchery techniques

Cultures of conchocelis (the microscopic phase in the life history) of different species of *Porphyra* from the British Isles were sourced from the Natural History Museum in London, and an apomyctic strain of *P. leucosticta* was selected for further work. This was necessary because it was not possible to isolate and culture conchocelis from Irish material. Difficulties in isolating and culturing conchocelis from Irish material and the lack of previous work on the environmental factors that trigger reproduction in such cultures meant that it was unlikely that sufficient string would have been produced for field trials. The different life-history stages (thalli and conchocelis) were cultured in the hatchery to increase their volume using conchocelis cultures sourced from the Natural History Museum in London. Germination of spores released from reproductive blades started about 7 days after spore release, and was greater under neutral day lengths than in short or long day length. Kuralon string was seeded using spore suspensions obtained after the release of spores from reproductive blades.

2.3.2 Deployment and on-growth of seeded collectors at sea

Blades were put to sea on string in October, after 6 weeks in the hatchery. At this stage the blades were sufficiently well established (5 mm) on the string to allow deployment at sea. By November most blades were between 10 mm and 30 mm in diameter with a maximum of 50 mm. This was the first successful cultivation of *Porphyra* in the sea in Ireland. Although the cultivation technique proved successful, the biomass generated was not sufficient to warrant any harvesting trials.

3 Optimum Site Selection for Seaweed Ongrowing

The geographical distribution of seaweeds can be regulated by abiotic factors, with many species restricted to certain oceans, or latitudes. While the most important factor controlling the dispersal of algae is often temperature, seaweed populations develop in response to a complex set of local environmental conditions. With this in mind, it is important to choose on-growing sites for cultivated seaweeds that possess optimal environmental parameters for the best growth and productivity. While environmental suitability is the key to the success of a seaweed farm, the site must also be suitable from an economic, physical, and legal perspective. Table 2 summarises the most important parameters that must be met for the cultivation of *Laminaria digitata* and *Palmaria palmata* within inshore waters around Ireland. These parameters are divided into requirements for good algal growth, and those parameters affecting the farm (e.g. deployment, maintenance, and harvesting).

Table 2: Parameters that affect the choice of site for seaweed cultivation

Parameter	Optimal Conditions (where known/ appropriate):	Affects		Notes
		Seaweed growth	Farm	
Depth	6-30 m	✓	✓	Depth and combination of factors (e.g. temperature, substrate) affects seaweed growth; max. depth determines suitable deployment site.
Surface seawater temperature	Max. ≤ 16 °C	✓		During deployment months October to December
Salinity	Min. ≥ 34	✓		
Current velocity	Min. ≥ 0.8 cm s^{-1}	✓	✓	Velocity at very high speeds may damage plants; makes site work more difficult
Turbidity	low	✓		
Nutrient availability		✓		
Wave action	moderate	✓	✓	Greater wave action damaging to plants and site – see current velocity
Substrate type	Sand, rock	✓	✓	Substrate type affects turbidity, and therefore growth; may determine choice of most suitable anchor system
Protected/ Restricted Areas			✓	Subject to licensing, farms can be located in Natura 2000 sites, SPAs and SACs. However, restricted areas may include shipping lanes or recreational areas.
Obstructions			✓	Physical obstructions such as ship wrecks, reefs, other licensed aquaculture sites
Access to road network			✓	
Access to workforce			✓	

Site selection of seaweed ongrowing was analysed in a desk-based assessment, using Bantry Bay as the study site. This bay has an existing aquaculture community (mainly shellfish) and, with the exception of Glengariff Bay, is not classified as a Natura 2000, SAC or SPA site (Special Area of Conservation or Special Protected Area). Modelled temperature, salinity, and current data were made available from the Marine Institute's ROMS model (Regional Ocean Modelling System). Hydrospatial data and information on licensed aquaculture sites were made available from Seazone Solutions Ltd. and the Department of the Agriculture, Food and the Marine, respectively. Spatial analysis techniques of Arc GIS software were used to choose areas with optimal growth conditions that did not coincide with physical or anthropogenic obstructions.

While ground-truthing would be necessary to validate the results of the desk study, the results indicate that the best places to cultivate *L. digitata* and *P. palmata* amount to 5.1% of the total area of Bantry Bay (Figure 1). These areas are concentrated in the straits behind Bere Island, around the northern tip of Whiddy Island, and in scattered locations along the southern shoreline of the bay.

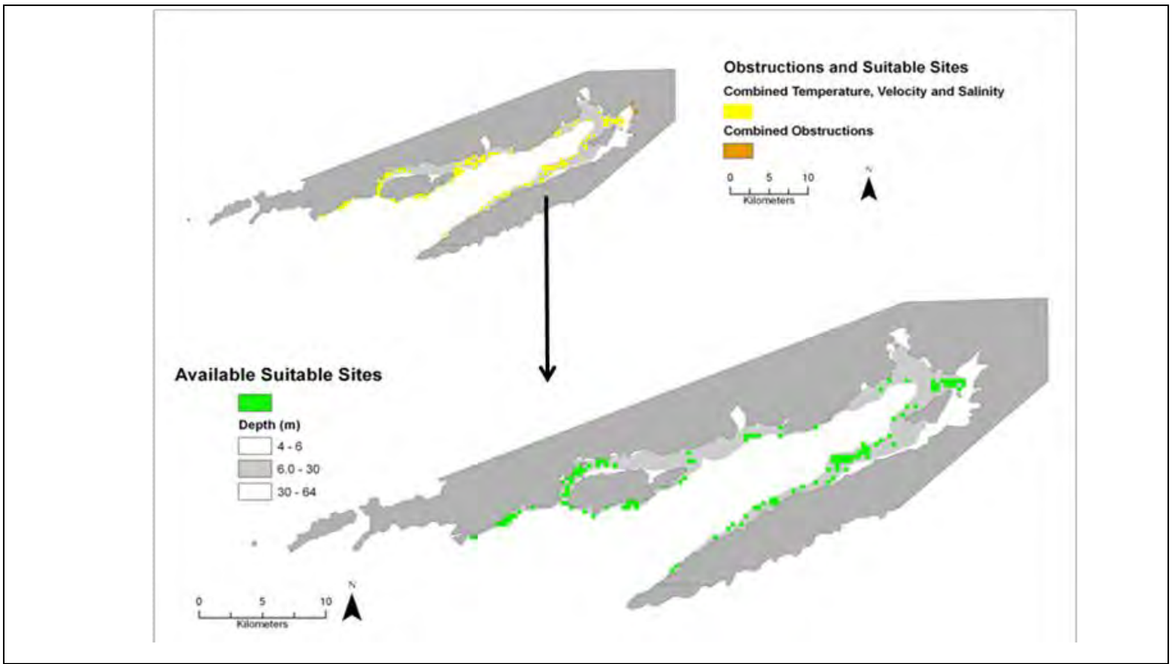

Figure 1: Biologically suitable areas for seaweed farms in areas with no obstructions in Bantry Bay, within the depth range of 6-30 m

4 SEAWEED AQUACULTURE MARKET ASSESSMENT

According to FAO (2010a and 2010b), the world seaweed industry is estimated to be worth US$5.5-6 billion annually, with US$5 billion being generated from products destined for human consumption, the remainder being generated from hydrocolloids and miscellaneous products. The global seaweed industry uses 7.5-8 million tonnes of wet seaweed annually. Over 90% of the seaweed used is cultivated; the rest is wild harvested. China and Japan are some of the main centres of world seaweed activity supplying product for human food and a variety of advanced applications. Ireland's seaweed and biotechnology sector is currently worth €18 million per annum. In contrast to global trends, Ireland processes 36,000 tonnes of seaweed which is all wild sourced. There are 185 full time equivalents employed in the seaweed sector here (Morrissey et al., 2011). The product range offered by Irish companies is generally high volume, low value products such as animal feeds, plant supplements, specialist fertilisers, and agricultural products. There are also some firms producing higher value products such as foods, cosmetics, and therapies with seaweeds increasingly used in spas. Various agencies have funded seaweed research projects and the potential exists for Irish firms to benefit from the results of this work. The NutraMara project, funded jointly by the Marine Institute and the Department of Agriculture, Food and the Marine, aims to identify novel marine food ingredients and products from marine waste streams, underutilised marine species, aquaculture, and seaweed. The work programme includes *inter alia* the complete extraction, biological and chemical characterisation of polyphenols, peptides, polysaccharides, amino acids, polyunsaturated fatty acids, protein hydrolysates and materials with antioxidant, probiotic or prebiotic properties. The results from this research programme will be made available to Irish industry.

Irish seaweed companies are also engaged in research and development activity; this includes firms seeking to develop applications for seaweed by the pharmaceutical, cosmetic, and food sector.

Laminaria digitata and *Palmaria palmata* were identified as offering an opportunity for cultivation in Ireland. The market study found the current wholesale price for good quality wild dried *Palmaria* for human consumption varies between €16/kg and €19/kg for bulk quantities, whereas *Laminaria* wholesales from €10/kg to €16/kg for bulk quantities. These figures reflect prices which may be realised at the higher end of the wholesale market for Irish seaweed. Most of the edible seaweed produced in Ireland is consumed in Ireland, although a small proportion is exported to Spain and the UK. There is increasing demand from Spain and France for *Palmaria* for human consumption. *Laminaria* and *Palmaria* can also be fed to abalone. The combined requirement for these two seaweeds from the current macroalgivore sector in

Ireland at full licensed production capacity is 1,500-2,000 tonnes per annum. Farmed seaweed has a number of defined benefits. Farming provides a guaranteed quality, clean product at a defined period of the year. Farming allows for product accreditation and certification. Farming allows for harvest to order. Farmed seaweed necessarily commands a higher price in the marketplace and it needs to be pushed into higher value products. As our knowledge of seaweed and its uses in a range of high value products improves, it is hoped that farmed seaweed production can increase to supply raw material. At the same time as production capacity increases, processing capability must improve.

New product development work is under way and a number of exciting products are currently being worked on in the functional food and beverages areas, and in the use of seaweed extracts for human medicine. To capitalise upon new market opportunities, more information and in-store promotional material is required to improve the profile of seaweed amongst retailers and consumers. Branding, product differentiation, and organic accreditation are all important elements in marketing seaweeds. New seaweed-based food products can be marketed using the 'Ireland Brand'. This brand stands for provenance, truth, good value, and quality. Such an approach could support producers to access national and international markets for seafood products.

The results of a market research study carried out during this project are described in Watson, L. and Walsh, M (2011).

5 Economic Analysis of Seaweed Aquaculture

5.1 Tank Grown *Palmaria palmata*

5.1.1 Tank cultivation set-up and operational costs

The approximate cost of the capital equipment required for a 40 tank-farm of 1,000 litres each is €13,804, with the capital costs for an 80-tank farm approximately €28,000.

The maximum growth rate which can be expected is 2 kg fresh weight m^{-2} 14 $days^{-1}$. At a stocking density of 4 kg m^{-2}, *Palmaria* doubles in weight every 4 weeks (i.e. the growth rate is 4 kg m^{-2} $month^{-1}$). If this rate can be maintained throughout the year, the annual production will be 48 kg m^{-2}, and the total production from 40 tanks will be 1.92 tonnes.

5.1.2 Commercial considerations

The current value of wet *Palmaria* in Ireland is €2.50 per kg; hence the total value of full production at maximum growth rates from a 40-tank farm would be €4,800. This return would be just enough to cover the electricity costs and the depreciation on the equipment (20% of value per year); the labour associated with harvesting would be an additional operating cost. Doubling the output of the farm, by adding an additional 40 tanks and other ancillary equipment to agitate the seaweed, would still not cover all the operational costs even with sales of €9,600 per annum.

This economic analysis points to the absolute need to obtain a higher price for the cultivated material. An example of where such an approach worked is that of a small company in northern Spain (Cultivos Marinos del Cantábrico). This firm started to sell *Palmaria* directly into restaurants in 2000 and was able to demand at least 5 times the price that was being paid in Ireland at that time. A similar strategy of obtaining a premium price by selling directly to restaurants is currently operated in Germany by Sylter Algenfarm. Such prices would clearly transform the prospects for tank cultivation of *Palmaria* (or any other similar seaweed) at the scale envisaged here.

5.2 Sea Site Grown *Laminaria digitata* and *Saccharina latissima*

5.2.1 Hatchery set-up and operational costs

In a hatchery, there is a requirement for certain pieces of equipment regardless of the species to be cultivated or the level of production (e.g. a cold room, autoclave, and microscope). The cost of the equipment for a hatchery with a capacity to produce 14,400 m of string seeded is €48,130. The running costs (electricity and labour) amount to €90,000 per annum. The hatchery can produce *Laminaria* or *Saccharina* in two batches for sea deployment from November to February. Alternatively, the tankage could be divided to allow shared production of the two species. This hatchery can also be multi-purpose with a capability to produce seaweed and bivalve spat such as scallop (up to 1.5 million at €0.05 each.).

The total potential harvest volume from 14,400m of seeded *Laminaria* or *Saccharina* is 100 tonnes wet weight product (15 tonnes dry product).

5.2.2 Sea site set up costs

To deploy the full amount of *Laminaria* collectors (14,400 m) will require, for example, 32 grow-out units, each with a 30 mx30 m grid system, and 450 m of continuous rope on which the collectors will be deployed. The total cost of such a grid system is €84,128.

5.2.3 Commercial considerations

In considering the viability of the seaweed hatchery and grow-out operation, four different options were considered as follows:-

1. A new seaweed hatchery with a new grow-out site.
2. A new seaweed hatchery and an existing mussel site partially used for seaweed grow-out.
3. A new seaweed and scallop combined hatchery with a new seaweed grow-out site.
4. A new seaweed and scallop hatchery with an existing mussel site partially used for seaweed grow-out.

The analysis identified the fixed costs associated with both the hatchery and sea site set-up and operation. In addition, there are variable costs which depend on the type of farm option chosen. The variable costs are labour in the hatchery and at sea, vessel hire, and also bank interest which itself is dependent on the capital required for the undertaking. The results of a sensitivity analysis and break-even point for each of the above options are given in Table 3 based on fresh weight.

Table 3. Sensitivity analysis: Three-year break-even point for *Laminaria digitata* or *Saccharina latissima*

Case Study	Description	Break-even price (€/kg)
1	Seaweed hatchery and grow out farm	€2.15
2	Seaweed hatchery and existing mussel site	€1.65
3	Seaweed and scallop hatchery and grow out farm	€1.63
4	Seaweed and scallop hatchery and existing mussel site	€1.12

It is clear from the analysis presented in Table 3 that the opportunity for profit lies in increasing the sales price above €1/kg and/or including an alternative income stream from sales of scallop spat (€0.05 each). The scenarios presented show substantially improved cash flows at €2/kg wet weight of product. Any economies of scale to be achieved by increasing the size and capacity of the farm are likely to be in the costs of labour both in the hatchery and at sea, and in the co-use of vessels, in particular where a combined mussel / seaweed farm type activity is carried out. It is unlikely that any other economic benefits will be found, since additional scale of production will result in a proportionate increase in costs for capital items, such as the bespoke grow-out seaweed grids and associated moorings. In the hatchery, increased capacity will require additional hatchery units plus associated fit-out costs, together with extra costs for electricity and consumables.

The results of an economic analysis carried out during this project are described in Wason, L. and and Dring, M. (2011).

6 Conclusions

- *Laminaria digitata*, *Saccharina latissima* (brown weeds), and *Palmaria palmata* (red weed) can be targeted for farming in Irish ambient conditions.
- *L. digitata* and *S. latissima* are easily manipulated in the hatchery and can be grown out at sea achieving a density of at least 7kg/linear metre.
- *Palmaria palmata* can be grown in tanks on land and can double in weight every four weeks.
- Difficulties with establishing the conchocelis stage of *Porphyra* mean that it is not viable to grow this species commercially at present.
- Subject to licensing, Irish seaweed farmers potentially have access to plenty of suitable sea sites, and mussel farms provide a ready opportunity for those wishing to switch to seaweed or even combine seaweed with mussel aquaculture.
- New seaweed sites can be identified using a GIS type system whereby key environmental parameters are mapped electronically allowing for interrogation of data for suitable site identification.
- Undertaking this project has highlighted the difficulty that industry can have with securing an aquaculture licence in Ireland.
- A hatchery capable of producing 14,400 m of seeded string and 1.5 million scallop with a grow-out farm (existing) mussel site offers the best alternative from the point of view of break-even sales price for seaweed (€1.12 / per kilo wet weight).
- Seaweed farmers must target niche markets in order to ensure profitability.
- Functional foods, cosmetics, and pharmaceuticals are some of the product areas in which high-value farmed seaweeds can be used.

7 Recommendations

- Establish a forum for discussion to include seaweed farmers and the research and development agencies (e.g. Department of Agriculture, Food and the Marine, Bord Iascaigh Mhara, Marine Institute, Teagasc, Department of Agriculture and Rural Development, Northern Ireland Environment Agency, and others) to agree a common approach to seaweed farming and product development in Ireland.
- Subject to sufficient support funding, hatchery production of seeded collector string to increase to 5,000 m in 2011 and 15,000 m in 2012 to cater for increased demand from existing licensed project partners.
- Using existing project partner licensed sites, and subject to sufficient support funding, scale-up farmed production of kelps to take production capacity at sea to 20 t in 2012 and 80 t in 2013.
- Best practice techniques in handling, drying, milling, and packaging quality farmed seaweed to be established by BIM in conjunction with project partners, including the design and construction of a proprietary drying unit with a 2 tonne/day drying capacity.
- Further development of speciality products to be undertaken with project partners to include processing techniques, production roll-out, business mentoring, and market development.

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Morrissey K., O' Donoghue C. and Hynes S. (2011). Qualifying the value of multisectoral marine activity in Ireland. Marine Policy 35 (2011) 721-727.

APPENDIX - LIST OF PUBLICATIONS AND COURSES

Publications

Edwards, M. and Watson, L. (2011). Aquaculture Explained No 26. Cultivating *Laminaria digitata*. BIM. 71pp.

Watson, L. and Walsh, M. (2011). A Market Analysis towards the Further Development of Seaweed Aquaculture in Ireland. BIM. 49pp.

Watson, L. and Dring, M. (2011). Business Plan for the Establishment of a Seaweed Hatchery and Grow-out Farm. BIM. 38pp.

Werner, A. and Dring, M. (2011a). Recommendations for optimal techniques for obtaining spores of *Palmaria palmata*, settling and maintaining them prior to outplanting at sea. BIM. 7pp.

Werner, A. and Dring, M. (2011b). Recommendations for optimal ongrowing and harvesting techniques for *Palmaria palmata* in different Irish sites with indications of yield. BIM. 8pp.

Werner, A. and Dring, M. (2011c). Aquaculture Explained No 27. Cultivating *Palmaria palmata.* BIM. 74pp.

Training Courses

September 2008. BIM FETAC accredited seaweed training course.

September 2009. BIM FETAC accredited seaweed training course.

March 2010. BIM FETAC accredited seaweed training course.

March 2012. BIM FETAC accredited seaweed training course.

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