BIM Ireland's Seafood Development Agency

TECHNICAL REPORT **ON SEAWEED HATCHERY AND SEA GROW-OUT** SITE DESIGN

Rialtas na hÉireann
Government of Ireland

Có-mhaoinithe ag an Aontas Eorpach
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Overview

Global macroalgal production and demand began to take off in the 1950's, increasing exponentially in the past 30 years and reaching over 35 Mt in 2019 (FAO, 2021). Global production is mainly based on aquaculture cultivation (97% in 2019) (see Fig 1, Table. 1). When compared with China and the rest of Asia, Europe still lags behind in terms of seaweed production. However, there is considerable potential for European, and particularly Irish seaweed production to contribute to world demand and bridge the gap. All marine waters in the European EEZs have been assessed as "high opportunity" to develop seaweed aquaculture (Theuerkauf *et al* 2019) (Fig 2). Across the globe macroalgae are harvested from wild stocks or produced in aquaculture systems. According to an FAO report, in 2019, over 97% of the world's macroalgae production came from Asia and only 0.8% originated from Europe (www.fao.org).

The largest macroalgae biomass volumes in Europe are produced by Norway, France and Ireland. Ireland's share of the world total was 0.08% or 29,542 tonnes of which only 0.14% was farmed, in contrast with Asia where over 99% of their seaweed was aquaculture based (Table 1).

This report describes and costs the set-up of two sample kelp hatchery scenarios; (1) using 120L boxes (herein referred to as the 'box system') and (2) using 500L tanks (herein referred to as the 'tank system'), the hatchery will have the capacity to produce both 50kms of seeded string and 250kms of seeded string.

Both hatchery scenarios additionally allow for red seaweed research and development work.

Further to this, the report describes and costs three sample grow-out site scenarios; (1) a 20 hectare grow-out site in a near shore, relatively shallow bay using mooring system 1 (MS1), (2) a 20 hectare grow-out site in a more exposed, deeper water site using mooring system 2 (MS2) and (3) a larger 100 hectare more exposed, deeper water, grow-out site also using MS 2. The report also sets out a summary analysis of the co-location opportunities for seaweed and offshore wind energy production.

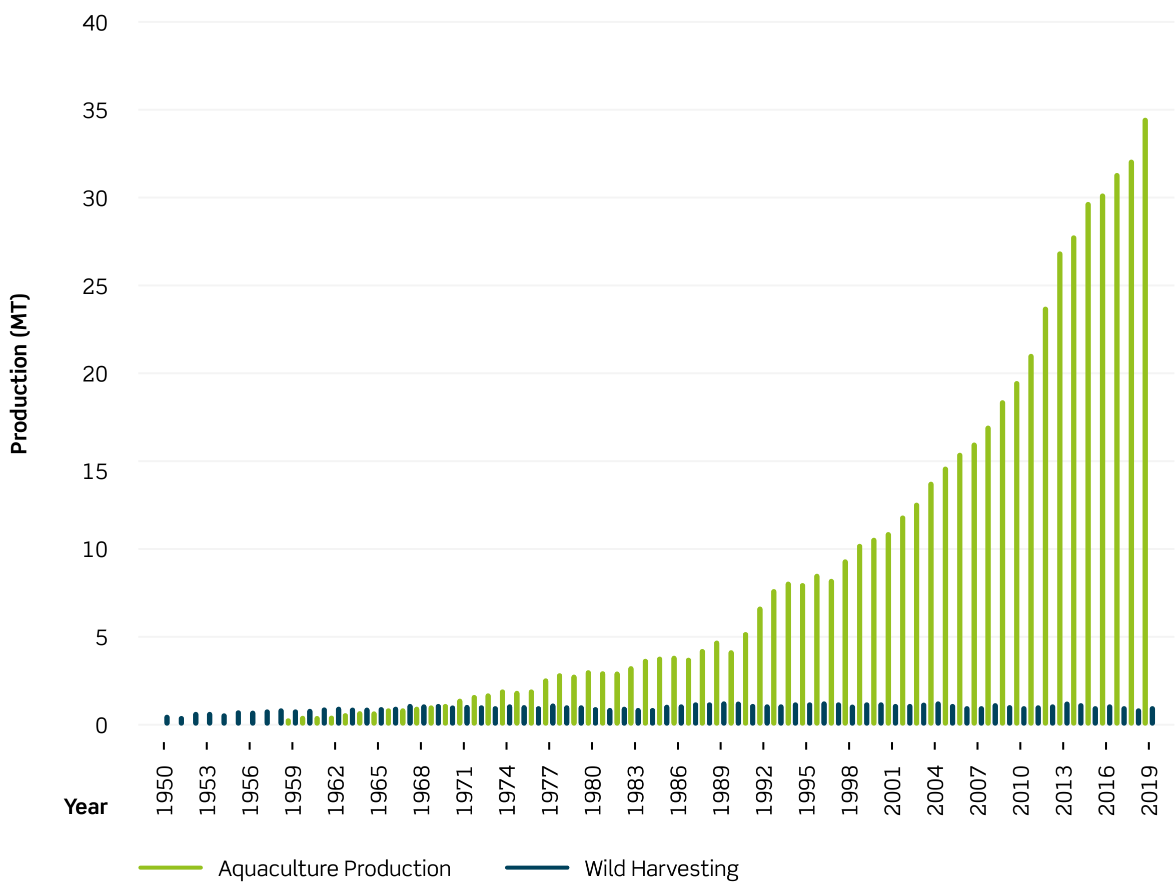


Figure 1. Global production (Mt) of cultivated and wild harvested algae between 1950 and 2019 (from FAO, 2021).

Table 1. Global seaweed production 2019
(FAO 2021; FAO Global Fishery and Aquaculture Production Statistics).

Country/Area	Total (farmed & wild) production (tonnes)	Share of world total (%)	Aquaculture share in total production (%)
World	**35 762 504**	**100.00**	**96.97**
Asia	34 826 750	97.38	99.10
Europe	287 033	0.80	3.88
Norway	163 197	0.46	0.07
France	51 476	0.14	0.34
Ireland	29 542	0.08	0.14
Russian Federation	19 544	0.05	54.10
Iceland	17 533	0.05	0.00
Africa	144 909	0.41	81.29
Americas	487 241	1.36	4.69
Oceania	16 572	0.05	85.32

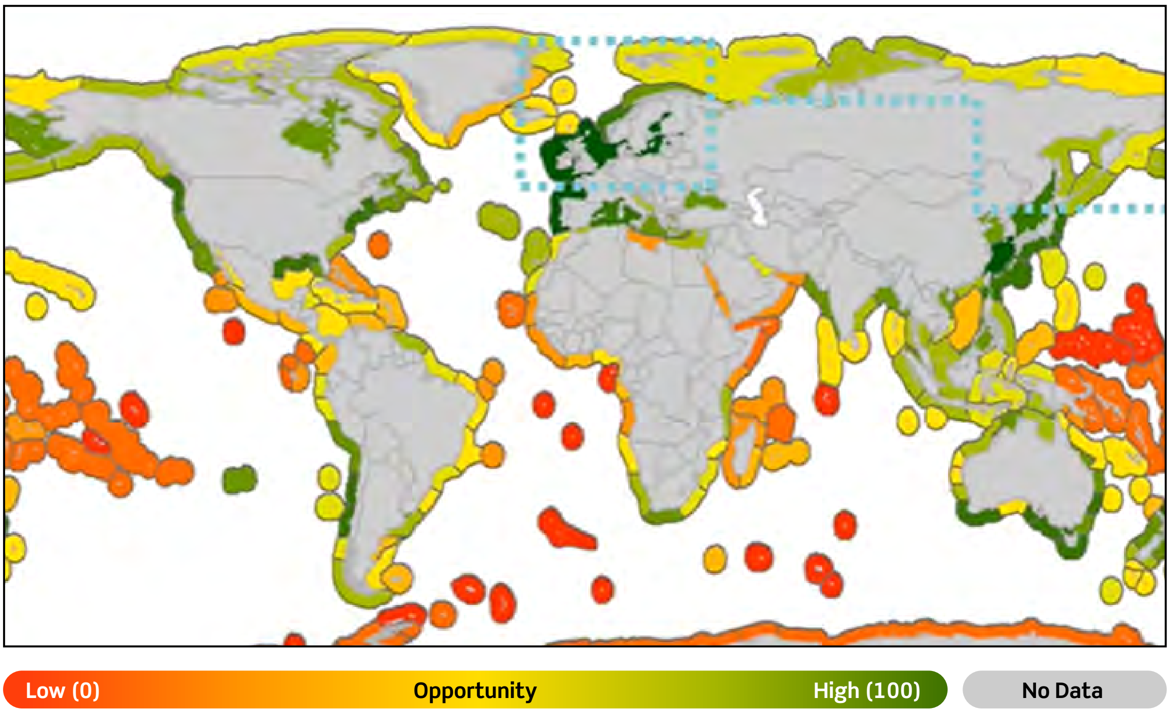


Figure 2. Global potential for development of seaweed aquaculture (Theuerkauf** et al **2019).

The Irish Seaweed Industry – a perspective of seaweed growers in Ireland

There is clearly an opportunity for Irish seaweed growers to upscale production, however, there seems to be some constraints on the development of this industry. A survey was carried out amongst Irish seaweed growers in attempt to understand their opinions, particularly in relation to hatchery and grow-out services.

Of the largest seaweed farmers in Ireland who responded to the anonymised survey, 70% of licences have been issued since 2018, covering almost half of the 189 Ha licensed areas owned by those involved in the survey. Of the 11 sites surveyed, only one grower is using their entire licensed area, while another has opted to forego growing seaweed and use their multi-species licence to grow mussels instead (Fig. 3). Only 16% of the overall area licensed to grow seaweed are being utilized, however most famers plan to apply for a licence to increase their acreage, three of whom currently have applications to do so with Department of Agriculture Food and Marine (DAFM). It could be surmised that growers are waiting for a market to fulfil their potential.

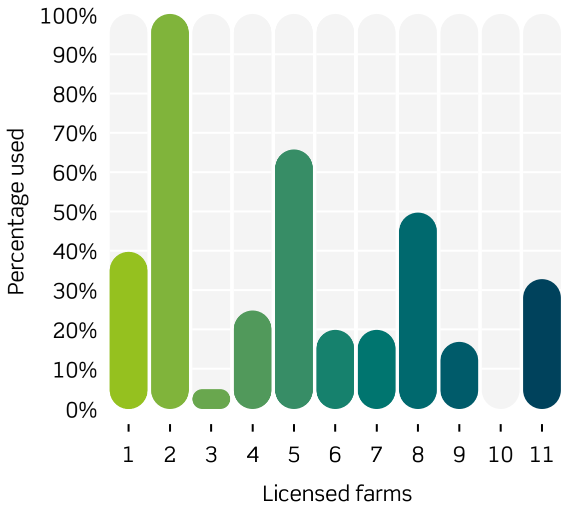


Figure 3. Percentage of licensed area currently used by seaweed growers in Ireland 2022.

In terms of seaweed biomass and the choice of species cultivated by all the licensed farms surveyed, winged kelp (*Alaria esculenta*) dominates the results (Fig 4). Reasons proposed for this popularity include: 1) the ready availability of *Alaria* seed from the EMFF funded BIM R&D Programme, 2) the well-established and proven growing methods, and 3) efforts already made in establishing a market for sale of *Alaria*. Also, as some of the growers are commercial businesses, they cannot afford to trial other species and will wait for further research to be carried out before cultivating them. Other farmers believe it is a question of supply and demand, if there is a market it will drive innovation and research into growing different seaweeds. Some are currently trialling sugar kelp (*Saccharina latissima*) through the summer months to extend the growing season of the licensed area to 12 months as opposed to the regular six or seven months. According to one farmer the demand for *Saccharina* is increasing, with one customer requesting 134t wet weight to be grown in 2023. The yield of *Alaria* grown in 2022 ranged between 5 and 17 kg/m, averaging at 8kg/m, while the average yield for *Saccharina* in the same period was 14kg/m. However, the weight of biomass harvested greatly varied according to how soon it was weighed after being harvested.

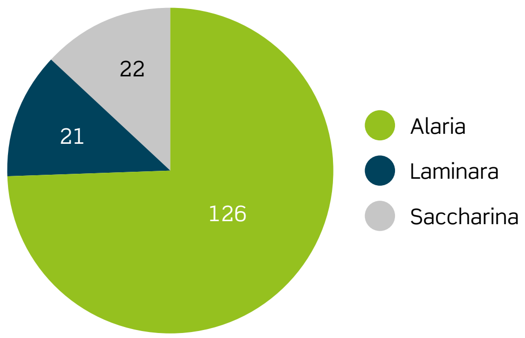


Figure 4. Approximate weight (tonnes) of kelps harvested in Ireland in 2022.

When asked what they would be willing to pay for *Alaria*-seeded collector string, answers varied between zero and €3/m. For other farmers, the outlay would depend on the potential sale price approximated from previous seasons. One farmer who received €1/kg wet weight for their *Alaria*, does not believe they could afford to pay for the seeded collector string as the profit margin would be too small. Another grower who received €7/m for *Saccharina* seeded collector string, believed that charging anything less would not have covered their costs. As a comparison, a European-based hatchery charges €15/m, however they provide deployment and grow-out assistance along with the collector string. Six of eight of the interviewees have intentions of setting up a commercial hatchery, three of whom are currently establishing a design concept and costings.

Seaweed Hatchery

Any hatchery needs to be designed to produce a variety of species based on environmental sustainability, best practice technology and market demand. The priority at this time is to supply seeded lines with various kelp species. Currently, kelps are produced in two stages: 1) hatchery laboratory conditions and 2) at-sea grow-out sites. This report looks at the infrastructure required to fulfil both stages and costs same. For a step-by-step guide on the hatchery production of kelp see the BIM publication; Aquaculture Explained No. 26 – Cultivating *Laminaria digitata* (Edwards *et al.,* 2011). The hatchery set-up needs to be versatile enough to accommodate production of both kelp and non-kelp species, based on market demand.

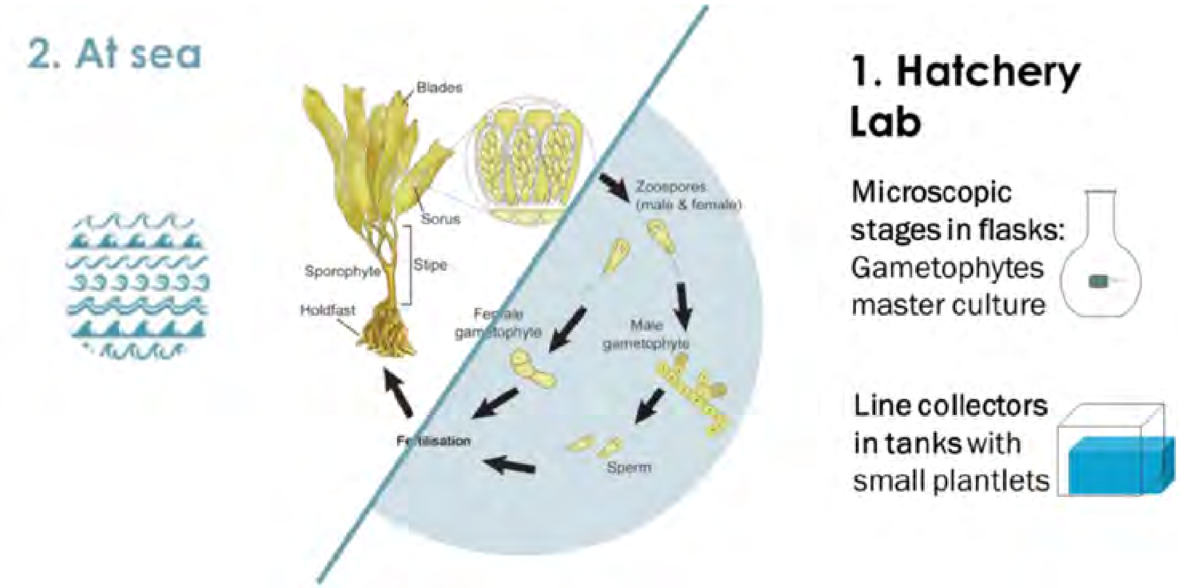


Figure 5. Two stage cultivation of kelps in the hatchery and at sea (credit: Sara Barrento.)

Overview of hatchery techniques for kelps

The main species cultivated in Ireland currently are *Alaria esculenta*, *Saccharina latissima* and a small amount of *Laminaria digitata*. The cultivation of these species is found in detail in BIM's publications; Aquaculture Explained No. 21 *Cultivation of brown seaweed Alaria esculenta*. (Arbona & Molla, 2006), and Aquaculture Explained No. 26 Cultivating *Laminaria digitata*. (Edwards *et al.,* 2011).

There is also a growing interest in the cultivation of the red seaweed *Palmaria palmata,* with investment into its expansion by BIM in Bantry Bay, see BIM publication, Aquaculture Explained No. 21 – Cultivating *Palmaria palmata* (Werner *et al.,* 2011) for information on growing red seaweeds. The timing of seaweed cultivation is governed by its biology. Kelp production can only be done by completing the life cycle of the species (see Fig. 6), not by vegetative propagation as is the case with other species.

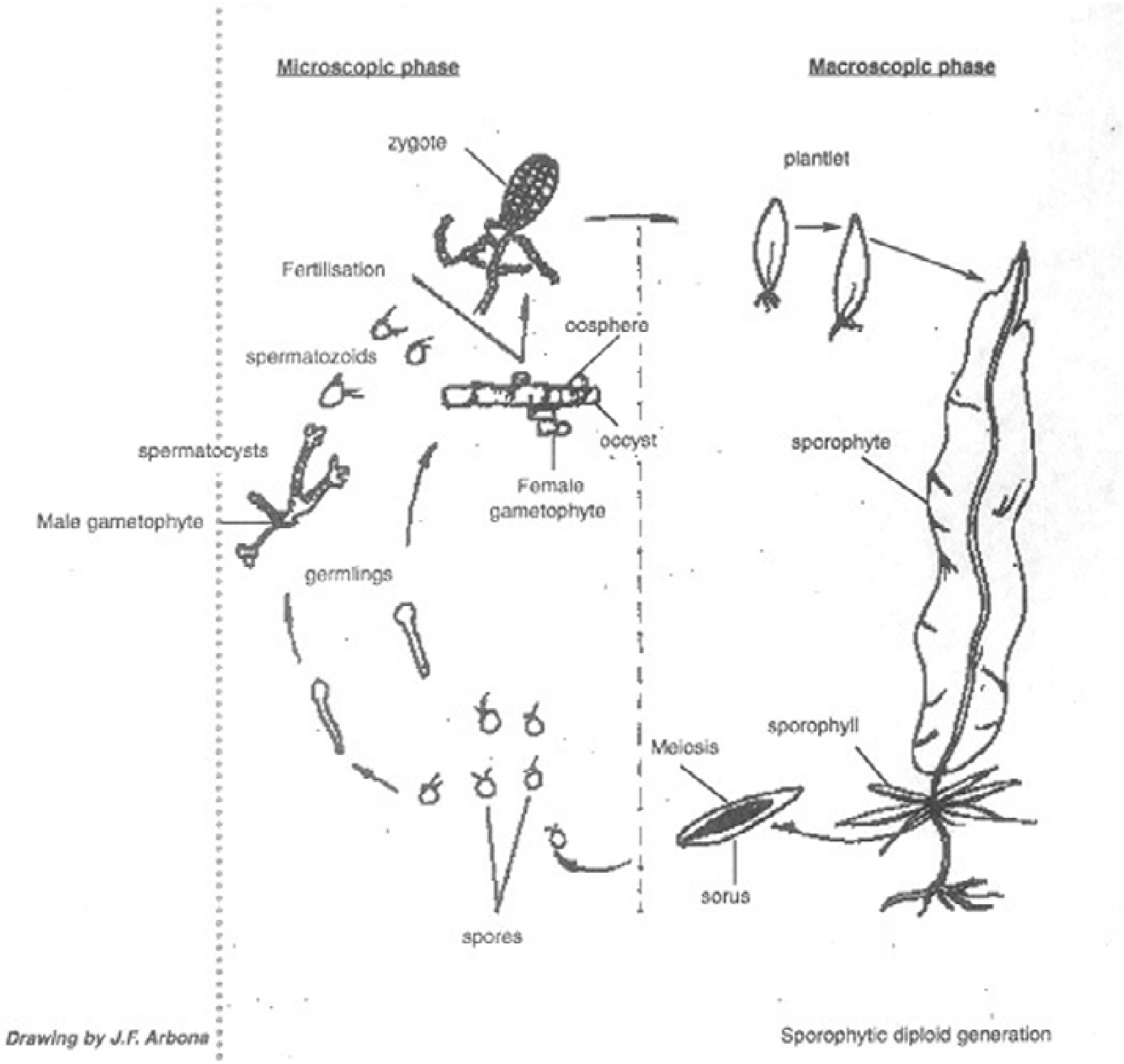
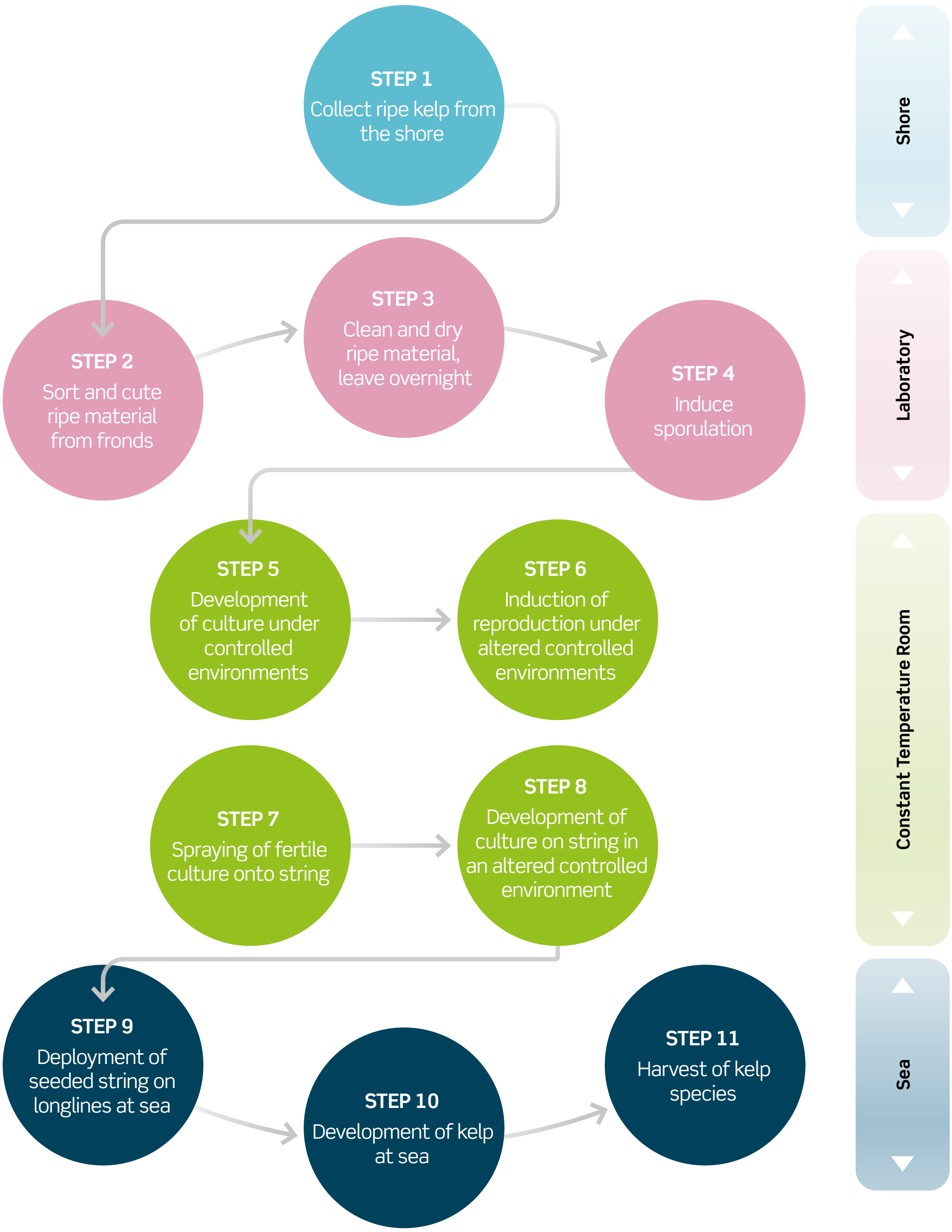


Figure 6. The life cycle of** Alaria esculenta **(Credit: J. F Arbona).

Brief outline of steps involved in the cultivation of kelps (Traditional seeding system)



Overview of the cultivation of kelp species

The production steps are best illustrated in picture format and include brief descriptions.

Figure 7. Collecting ripe* Alaria *sori from the shore.

Step 1: Optimal selection of the best parental individuals from wild stock between March and May for *Alaria* and *Saccharina*¸ and July to September for *Laminaria*. This is generally carried out on days of the lowest tide in the months corresponding to presence of fertile material in the wild.

Figure 8. Ripe* Alaria *sori sorting back in the dry laboratory.

Step 2: The best sori are chosen based on darkness of colour, indicating maturity, and absence of epiphytic growth on the ripe material, The goal is to separate out the mature sorus tissue with minimal fouling organisms attached to its surface.

Step 3: The ripe material is cleaned, dried, and stored at 10°C for 18-24hours.

Step 4: Once the ripe material is reintroduced to sterile seawater, release of spores should occur. Nutrients are added. These are then held in 24hr light at a temperature of 10°C increasing to 14°C in daily increments of 1°C

Figure 9. Building up stocks of gametophytes in the light and temperature-controlled culture room. (Photo credit: Freddie O'Mahony)

Step 5: The biomass increases over time and requires splitting between flasks once a carrying capacity has been reached. The cultures also require a medium change every 10 days. This stage requires autoclaved water and flasks, and a filtered air supply to each flask. At this point the culture can be maintained for years.

Step 6: The next stage is carried out six weeks before deployment. Fertilisation of gametophytes can be induced by adjusting light from 24 hours light to 12 hours light and temperature reduction from 14°C to 10°C over an 8-day period.

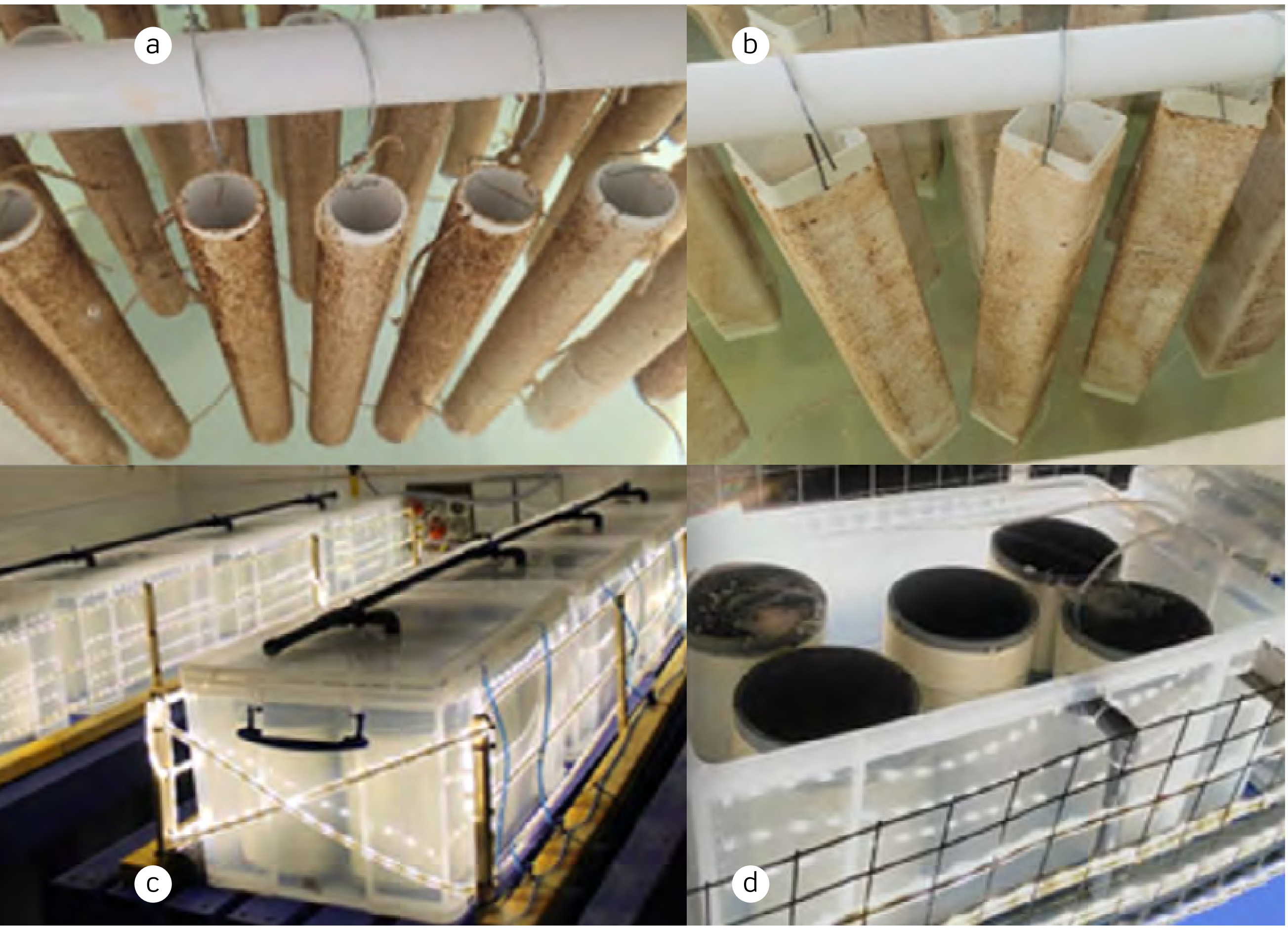


Figure 10. juvenile** Alaria **sporophytes sprayed onto Kuralon string wrapped around collectors, in 500L tanks using a) cylindrical collectors, b) cuboid collectors, and (Figures c & d) 120L boxes/aquariums

Step 7: Most of the kelp grown on lines in Ireland originate from juvenile sporophytes sprayed onto string and wound onto plastic collectors. The string generally used is 1 or 2mm, short cut, twisted twine such as Kuralon. Twisted twine made from polyvinyl alcohol (PVA) or twine surface treated by corona discharge prior to seeding, has been shown to be the optimal substrate for juvenile sporophyte attachment (Kerrison *et al.*, 2019). Suitable twine can be sourced online from companies such as Kuraray or Technored in Spain. Using a spray gun, fertilised gametophytes are sprayed onto collectors wrapped in twine. These collectors are generally cylindrical (Fig. 10a) or cuboid (Fig. 10b) PVC piping, cut into 30cm lengths. The collectors are then held in 500L tanks (also seen in Fig 10 a & b) or 120L boxes until they are mature enough to go to sea, juvenile sporophytes of 1-2mm max in length are ideal for transfer to sea. This grow-out method is reliable and allows for site-specific spore selection as the mature plants can be harvested from predetermined locations. however, it requires significant dedicated temperature-controlled space over time, as discussed further in the document.

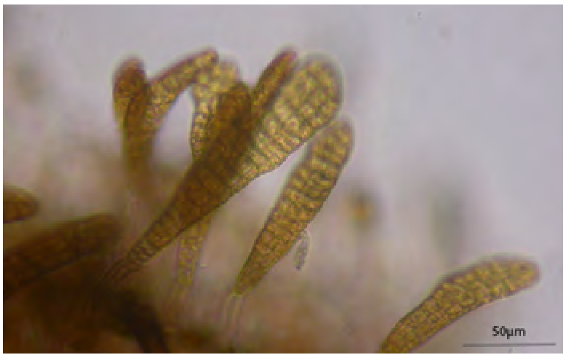


Figure 11. Developing *Alaria* ***juvenile sporophytes on the string using an electron microscope (Photo credit: Freddie O'Mahony)***

Step 8: The sprayed collectors are routinely checked for growth and contamination during the period prior to going to sea (Figure 11). *Ectocarpus* sp. is the contaminant most threatening to the growth of the sporophytes at this stage.

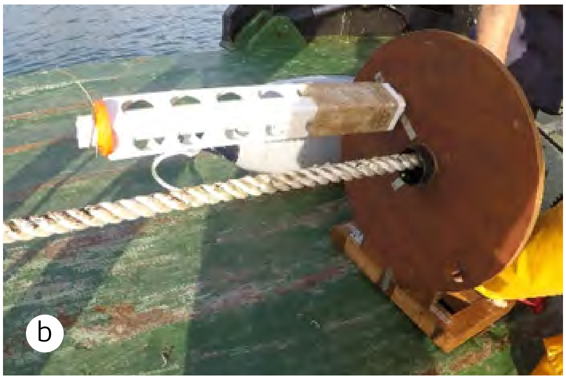


Figure 12a (manual) & b (mechanical) deployment of seeded string on long lines at sea in October from a collector.

Step 9: The transfer of juvenile sporophytes to the long-line system at sea occurs between October and December for kelps in Ireland. The collector is wound around long-line either by hand or using a specially designed machine for which a number of prototypes exist. Incorrect coiling is the main cause for poor development of sporophytes on the long-line (Arbona & Molla, 2006). Figure 13 shows the long-line post deployment.

Figure 13. A submerged longline using LD2 flotation buoys spaced at 13 m on an 32mm polyester longline in Bantry Bay (a near shore site). See also the required Navigation buoy which must be placed at each of the four corners of the site as a safety measure for passing vessels.

Figure 14. *Alaria* ***in January, halfway through the growth cycle (2.5 months post deployment at sea) approximately 6 kg/ linear m.***

Step 10: Monitoring growth and maintenance of the line (Fig 14) occurs throughout the growing season and particularly after swells and storms have passed through the on-growing sites.

Figure 15. *Alaria* ***in April, final harvest (5 months post deployment at sea) approximately 12kg/linear m.***

Step 11: Once the seaweed has reached peak growth and prior to the development of epiphytes which cause degradation of the fronds, the biomass should be harvested. This generally occurs between March and May (Fig. 15).

As quickly as possible post-harvest, the seaweed must be stabilised. This is generally achieved by drying at a commercial drying facility, though other post harvesting methods are being explored such as fermentation, see Zhu *et al.,* (2020) for a review on post processing methods and effects.

Direct Seeding

In recent years, direct seeding of lines is being explored to optimise production methods. Direct seeding differs from the traditional deployment of seeded string in a number of ways. Where traditional methods are employed, juvenile sporophytes attach to the string fibres and after 6 weeks in controlled hatchery conditions they are deployed to sea. At that point the sporophytes will have developed a firm attachment to the string and thus the majority are immediately able to withstand open sea conditions. Direct seeding is a method used where juvenile sporophytes, gametophytes or meisospores are mixed with a specific biological glue and applied directly to the cultivation rope, string, ribbon or tape immediately before deployment. The requirement for holding tanks for developing sporophytes on string-wrapped collectors is therefore redundant, along with the need for temperature and light control rooms. However, the developing kelp have less time to form an attachment to the rope or other growing substrate before going to sea. When using direct seeding technologies available at this time, detachment and morphological differences have been noted and thus yield decreased (Mols- Mortensen *et al.*, 2017).

Using the direct seeding method, seeding can occur at three different development stages: meisospores, gametophytes or juvenile sporophytes. (Note: seeding with sporophytes has been shown to be most effective of the three stages (Kerrsion *et al.*, 2018)). Binder/glue solutions are used to allow the gametophytes and sporophytes time to attach to the twine or rope once seeded. Theoretically, the binder's high viscosity inhibits the sporophytes from being washed away when placed at sea. The holdfast of the sporophytes embedded in the binder must then develop and attach to the string/rope before they are detached at sea. The binders are generally made of calcium alginate. A proprietary binder, AtSea, is also on the market.

The substrate on which the seaweed cultures are sprayed, or otherwise attached, also affects how the developing plantlets attach. Kerrison *et al.* (2020) showed promising results using the binder-seeding method on AlgaeRibbon and AlgaeRope compared to traditional seeded string on longlines when cultivating *Alaria* and *Saccharina*. The binder-seeding methods they employed produced similar *Alaria* yields and higher *Saccharina* yields when compared to traditional seeding methods using twine. However, they cautioned the morphology of the *Alaria* plants differed between populations, with approximately 23% displaying shorter fronds and 42% narrower fronds on the binder-seeded ribbon.

Umanzor *et al.* (2020) demonstrated that the AtSea binder retained more sporophytes on Kuralon string than any of the three formulations of calcium alginate-based binder used in the study. This was observed where the cultures were maintained in complete stillness in laboratory conditions. However, a 70-80% detachment rate was observed when aeration was added. Poor attachment of developing sporophytes once deployed at sea is currently the main inhibitor to the widespread use of direct seeding methods. This method possibly does not allow for holdfast development onto the rope or twine prior to deployment, potentially resulting in unequal population densities on the substrate (Mols- Mortensen *et al.*, 2017). While the initial stages of development of direct seeding are showing potential, there are still some technical challenges to be overcome before efficacy is consistent with traditional methods. If a reliable and consistent direct seeding method was developed, it would negate the space requirement for almost half of the hatchery building and the plant required for both the box and tank systems. This represents a potential saving of almost €169,000 in building costs, associated equipment and labour to maintain the system (see Table 5). Direct seeding would therefore save a significant amount on hatchery set-up and ongoing operational costs, thereby making it a more economically viable business (van den Burg *et al.,* 2016).

Design and costs of hatchery systems

Two hatchery systems were considered for this report; (1) using 120L boxes and (2) using 500L tanks, both hatcheries will have the capacity to produce both 50kms of seeded collector string and 250kms of seeded collector string for brown seaweeds. The report outlines the design and costs associated with both systems. The blueprint for the hatchery design is shown in Fig 17 (box system) and 18 (tank system). Filtered and UV water is essential to produce clean contaminant free sporophytes; from the cleaning of sporophylls prior to sporulation to the deployment of the developing sporophylls access to clean seawater is essential. The water flow diagram common to both systems is outlined in Fig 19 and the hatchery equipment requirements are outlined in Table 4.

The main space constraint in the hatchery is maintaining the seeded string. This can be done in boxes (Fig. 16a) or in tanks (Fig. 16b). The design of the hatchery in figures 17 and 18 allow for the use of either 120L boxes on shelves or 500L tanks. Each collector needs to be housed in these vessels for at least one month. The level of infrastructure required to produce 250Km of seeded string in one batch would be cost prohibitive, therefore the collectors would be housed, and string deployed in consecutive batches. In the main, deployment of the seeded string takes place from October to December, so it is possible to maintain three to four batches of seeded string consecutively toward the end of the year to maximise output. Various options to maximise use of the 4 tank rooms in the designs are outlined for growing seeded string in 120L boxes (figure 17) or 500L circular tanks (figure 18) and are shown in Tables 3 and 4.

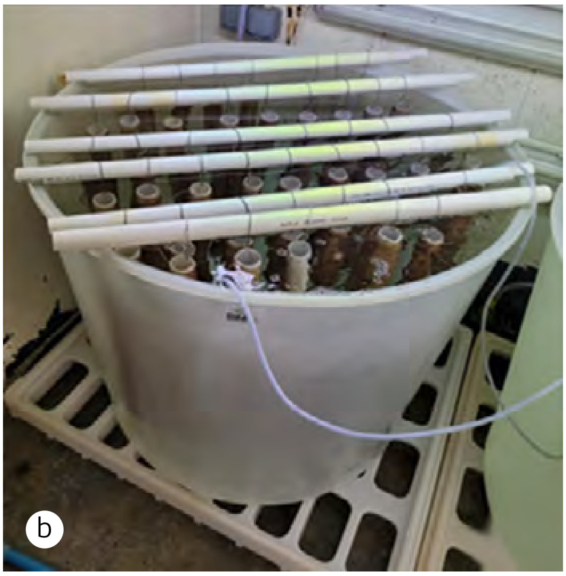


Figure 16. (a) Plastic boxes on shelving unit holding seeded collectors (photo credit: Alaska Fisheries Development Foundation.) and (b) 500L tank holding seeded collectors

The building footprint for the boxes (287m^2) is slightly less than the tank system (308m^2) though considerably more infrastructure will be required to fit out the box system than the tank system, for example shelves, pipework for air and water to each tank along with sumps for drainage thus a cost analysis would work out similar. The box system room holds 8 shelves, each stack of shelves contains 3 shelves, the bottom shelf contains the drain or sump, the top two shelves contain the boxes. There are four stacks of shelves per room, two different length shelves (4m in the centre of the room and 4.8m for the shelves on either side of the room). Each tank room has the capacity to hold 44 boxes. As seen in table 2, the number of constant temperature (CT) rooms (tanks rooms) required varies according to the number of batches produced. If 50km of string was to be produced in one go, 3 CT rooms would be required, if it was split into two batches, then 2 CT rooms would be required. The additional rooms in the hatchery could be used for further research and development on red algae cultivation, as referred to later in the document. If 250km of string was to be produced in the same set up, it would require 4 CT rooms to produce 3 batches of seeded collector string or 3 CT rooms to produce 4 batches of seeded collector string. The most that could be produced in the box scenario at any one time, using all four tank rooms is 88Km. The number of CT rooms required to produce both 50km and 250km of seeded collector string is the same when 500L tanks are used (see table 3).

Table 2. Space requirements for different amounts of seeded string grown in batches in ***120L boxes (box system).***

Length of seeded string required	**Number of collectors required where 1mm string is used and holds 100m string**	**Number of boxes required** (5 collectors per box)	**Number of Constant Temperature rooms required** (8 usable shelves with 44 boxes in each room*)
50 Km (one batch)	500	100	3
50 Km (two batches)	250	50	2
250 Km (three batches)	833	167	4
250 Km (four batches)	625	125	3

Table 3. Space requirements for different amounts of seeded string grown in batches in **500L tanks** ***(tank system)***

Length of seeded string required	**Number of collectors required where 1mm string is used and holds 80m string**	**Number of tanks required** (20 collectors per tank)*	**Number of CT rooms required** (14 tanks per room)
50 Km (one batch)	625	32	3
50 Km (two batches)	313	16	2
250 Km (three batches)	1041	52	4
250 Km (four batches)	781	39	3

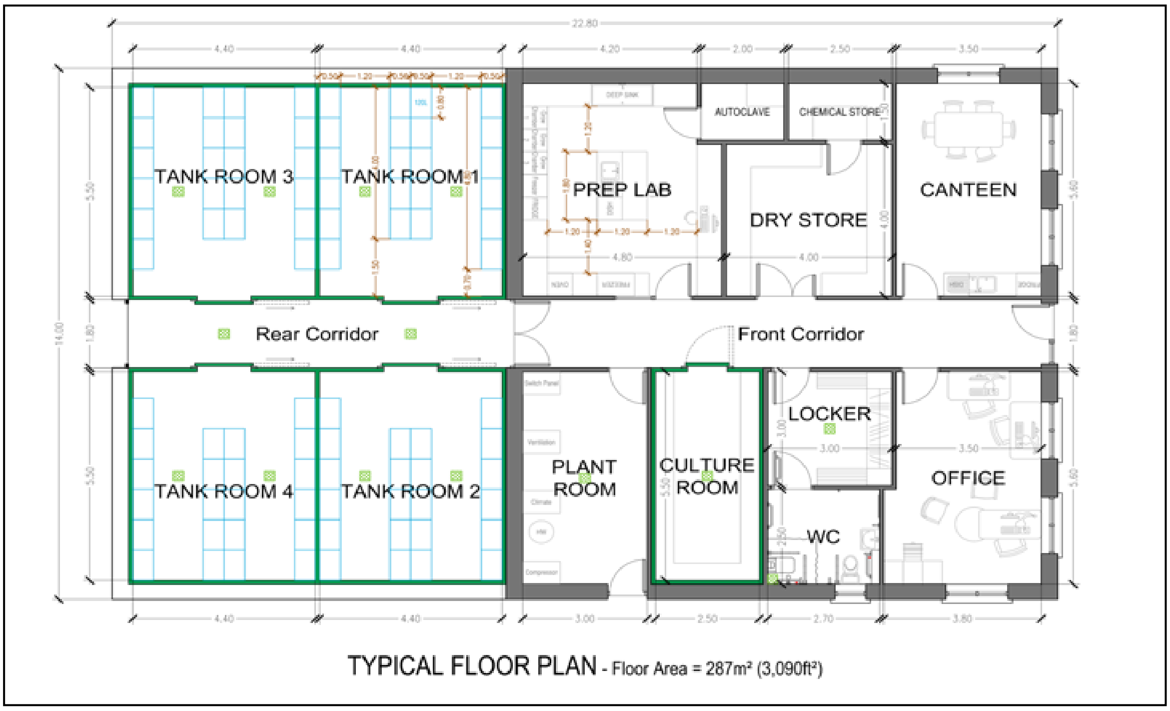


Figure 17. Box system- Blueprint of a hatchery with four tank rooms using boxes for the seeded string.

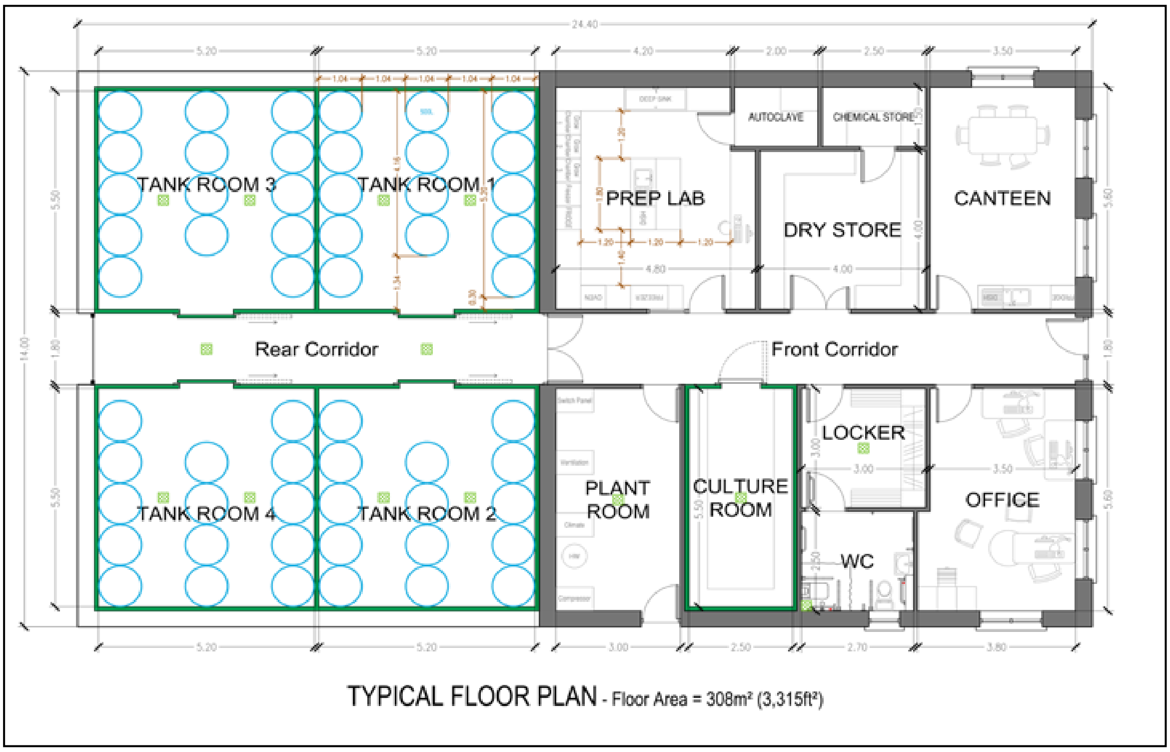


Figure 18. Tank system - Blueprint of a hatchery with four tank rooms using tanks for the seeded string.

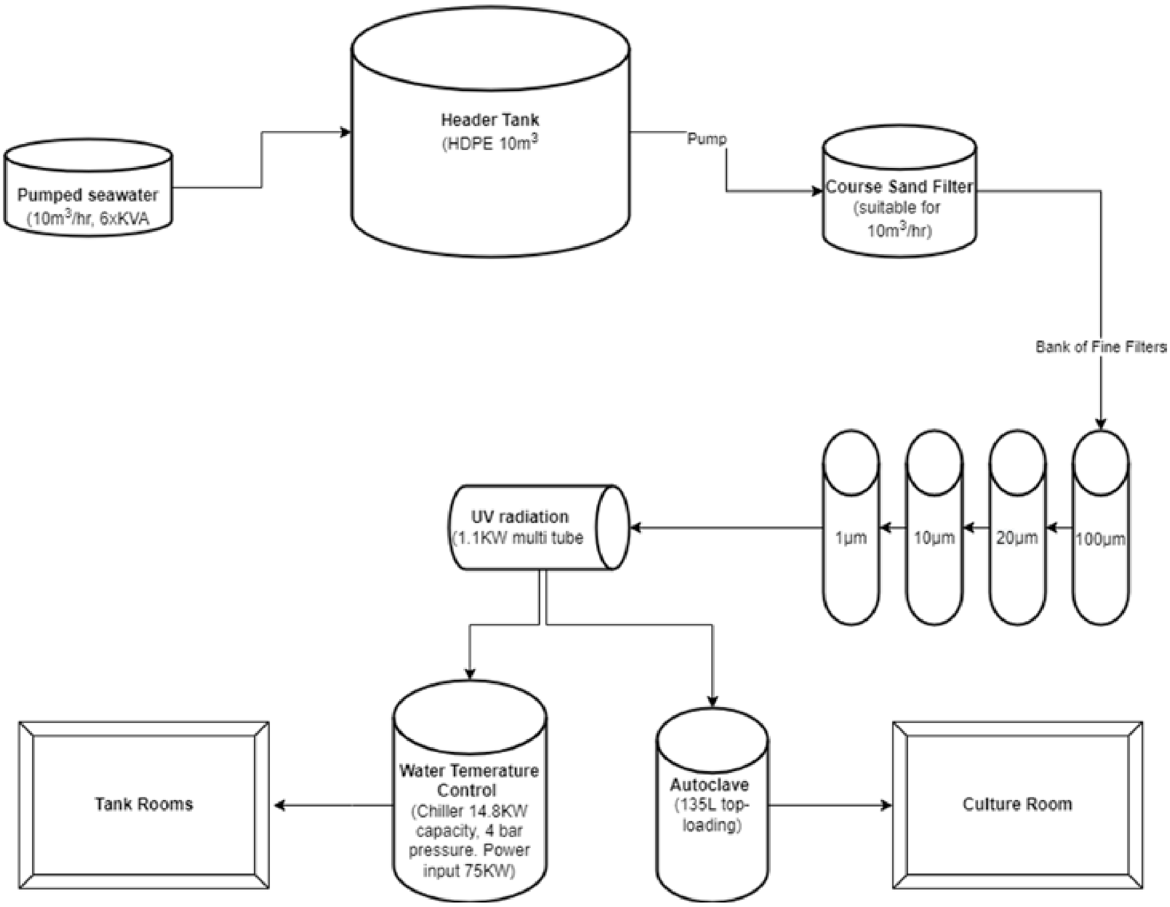
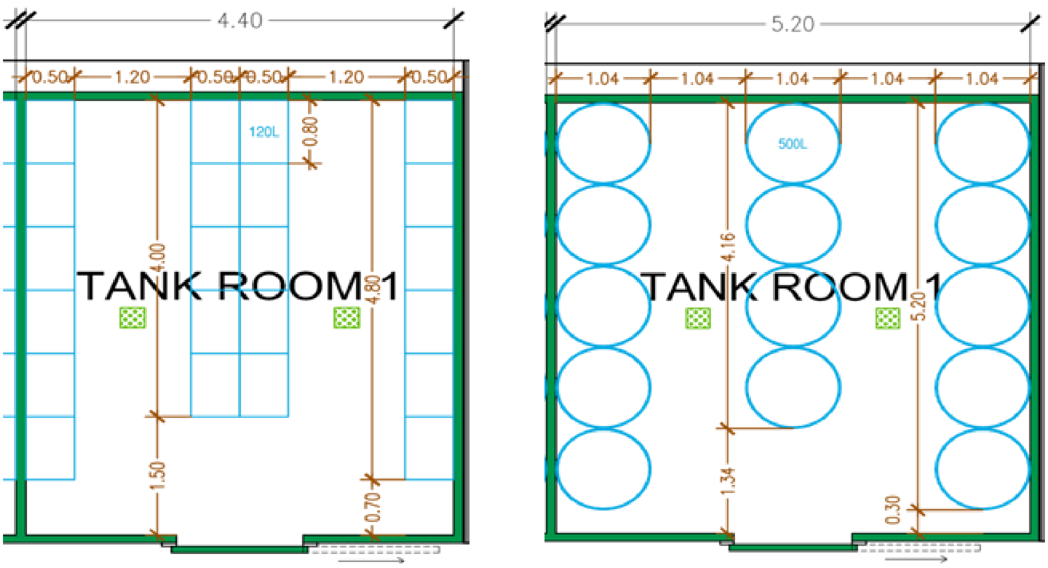


Figure 19. Flow diagram illustrating seawater flow through the hatchery with the capacity of producing a maximum of 88km of seeded collector string at any one time.

Table 4. Equipment and materials required for each room of the hatchery capable of producing a maximum of 88km of seeded collector string at any one time.

TANK ROOMS

(insulated constant temperature rooms containing either 14 500L tanks or 44 boxes)
x 2 (50 km of seeded string assuming 2 batches are made)
x 4 (250km of seeded string assuming 3 batches are made)



Used for:
- Maintaining seeded string on collectors (kelp) in tanks or boxes prior to deployment at sea
- Tank cultures for other species e.g. Palmaria palmata

Furniture required	Equipment required	Consumables required
• Heavy duty shelves • Ventilation duct • Access to - Freshwater - hot and cold • Access to filtered and UV seawater • Access to air compressor	• Seaweed tanks (500L) x 13 (50km in 2 batches) or 32 (250km in 4 batches) **OR** • Boxes (120L) x 50 (50km in 2 batches) or 125 (250km in 4 batches) boxes • Sump tanks (1 for every 10 boxes) OPTIONAL • 1000L IBC tanks x 20 for red algae spore settlement	• Lights with timers • Air tubing • Collectors • String

CULTURE ROOM

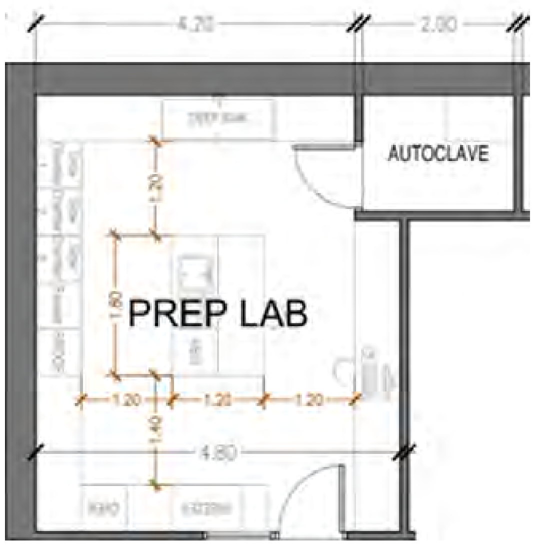
(insulated constant temperature rooms)

Used for:

- Maintaining gametophyte cultures in flasks

Furniture required	Equipment required	Consumables required
• Heavy duty shelves • Ventilation duct	Glassware • 5L flasks x 15 (50km seeded string) or x 30 (250km seeded string) • 10L flasks x 24 (50km seeded string) or x 70 (250km seeded string) • 5L beakers x 10	• Adjustable lights with timer • Air tubing

PREPARATORY LAB



Used for:

- Cleaning of kelps
- Spore release
- Set up flask cultures to go in constant temp room/grow chambers
- Weighing of biomass
- Microscopic inspection of cultures
- Nutrient preparation
- Seeding collectors

Furniture required

- Epoxy lab sink ca. 150cm
- Regular size sink
- 3 big taps with hose:
  - Cold freshwater tap
  - Hot freshwater tap
  - Seawater tap
- Bench
- Chairs and stools
- Cabinets with shelves

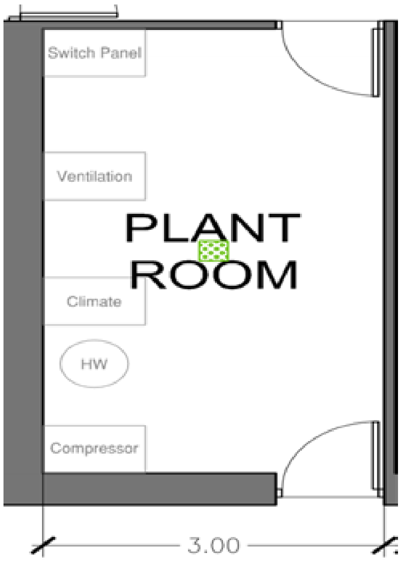
Equipment required

- Microscope with camera and computer
- Dissecting microscope
- Portable scales
- Weighing balance
- 4 growth chambers
- undercounter freezer
- Fridge
- Dishwasher (for glassware)
- 1L Reagent bottles
- Gas blow torch
- Metal cabinet for chemical store
- Autoclave (in own room by the Prep lab) containing metal shelves

Consumables required

- Lights with timers
- Air tubing
- Collectors
- String

PLANT ROOM



Used for:

- Housing for water and aeration systems and electricity panels

Equipment (internal) required	Equipment (external) required
• Switch panel • Ventilation/air compressor • Climate systems • Hot water system • UV system • Sand filters • 100, 20, 10 & 1 µm filters • Sensor systems	• Generator • Seawater pump • Header tank

Dry Store

Used for:
- Storage of chemicals in the chemical store and equipment when not in use such as flasks and collectors

Furniture required	Equipment required	Consumables required
• Lockable chemical storeroom • Cupboards • shelving	• Waste disposal bins	• Glassware • Collectors • Non-hazardous chemicals • Plastic wear • PPE

Common Rooms (Canteen, office, WC and Locker)

Used for:
- Office work, meeting room/canteen, toilets (accessible) and locker

Kitchen requirements	Office requirements	Toilet and locker requirements
• Fridge • Sink • Microwaves • Seating area	• Chairs • Tables • Projector • Filing cabinets	• Shower • Toilet • Sink • Lockers • Storage for wellies, wetsuits etc.

Summary cost assessment of hatchery set-up

The budget estimate (Table 5) is based on the drawings prepared in Figures 17 and 18 and was conducted by a chartered quantity surveyor. Estimated costs include for civil, structural, architectural, mechanical and electrical costs to construct a single storey 287m² facility capable of producing 50kms or 250kms depending on the tankage/shelving installed and the production cycle chosen. The estimate provides for a Kingspan cladded façade and roof, with Kingspan cladding or equivalent roof. Walls to the tank area are assumed insulated panel walls to maintain constant room temperatures. Walls and structure to the balance of the areas (prep lab, dry store, plant room, offices and canteen) are assumed blockwork and paint finish. Internal finishes are assumed basic with vinyl floors, painted plasterboard ceilings, LED light fittings and natural ventilation. Given the specific site location is to be identified – a provisional allowance has been included for site development and external works, based upon normal site conditions.

Table 5. Budget estimate for basic building costs associated with hatchery design above (Box and tank systems).

	Area (m2)	Unit cost (Ex Vat)	Total (Ex Vat)
Tank/box rooms	125	€1,350	€168,750
All other rooms	162	€2,350	€380,700
TOTAL	287		**€549,450**
GRAND TOTAL (ex VAT)			**€618,450**

* External works includes – prepared site, roads, paths, site services piped and ducted, electrical installations and landscaping

Assumptions, qualifications, exclusions and notes

- Estimated building costs are based upon current rates as of September 2022. Estimate excludes escalation. Current construction price inflation at present is pertaining at approximately 14% per annum. This level of price inflation is largely attributed to the war in Ukraine, coupled with material price volatility due to increased supply chain requirements, alongside labour shortages and energy cost inflation.
- Estimate does not include construction preliminaries; main contractor supervision and co-ordination, PSCS (Project Supervisor Construction Stage) duties, insurance, site cabins and compound area, site administration, lighting and power for works, temporary works design, post building cleaning. This has been estimated at €75,000.
- Estimate excludes design team fees - €69,345, calculated at 10% of the basic building cost and main contractor preliminaries, insurances and management (additional €75,000).

- Estimate excludes VAT items charged @ 13.5% and 23%
- Estimate excludes equipment costs (these can be found in Appendix I).
- Estimated costs exclude site specific abnormalities.
- Estimate based upon works being completed during normal working hours, with no allowances for overtime, weekend work or shift work.
- Estimate does not allow for expedition of the contract or stoppages.
- Estimate does not include planning, fire cert & DAC (Disability Access Certification) Application fees
- Estimate does not include Aquaculture and Foreshore Licence and Effluent Discharge Licence Fees
- Estimate excludes utility fees
- Estimate excludes ESB substation, outbuildings and any works outside the site boundary

The detailed cost of two hatchery scenarios and three farm site scenarios are given in Appendix I and II. Table 6 and 7 give a summary of the total cost involved. The cost of set-up and electricity is almost €187,000 for 50km of string when using the 500L tanks, whereas when boxes are uses for holding the collectors the cost is €5000 less. Although 250,000Km of seeded collect string is five time that of 50,000Km, the cost is less than half, the cost of production of 250Km of seeded collector string is over €272, 000 when using the tanks and €8,000 less when using the boxes. This cost analysis indicates there's an economy of scale in effect, the greater the amount of seeded string produced, the cheaper it is for the producer to supply it and thus the cheaper it should be for the on-growing farmer to buy.

Table 6. Summary costs associated with hatchery production

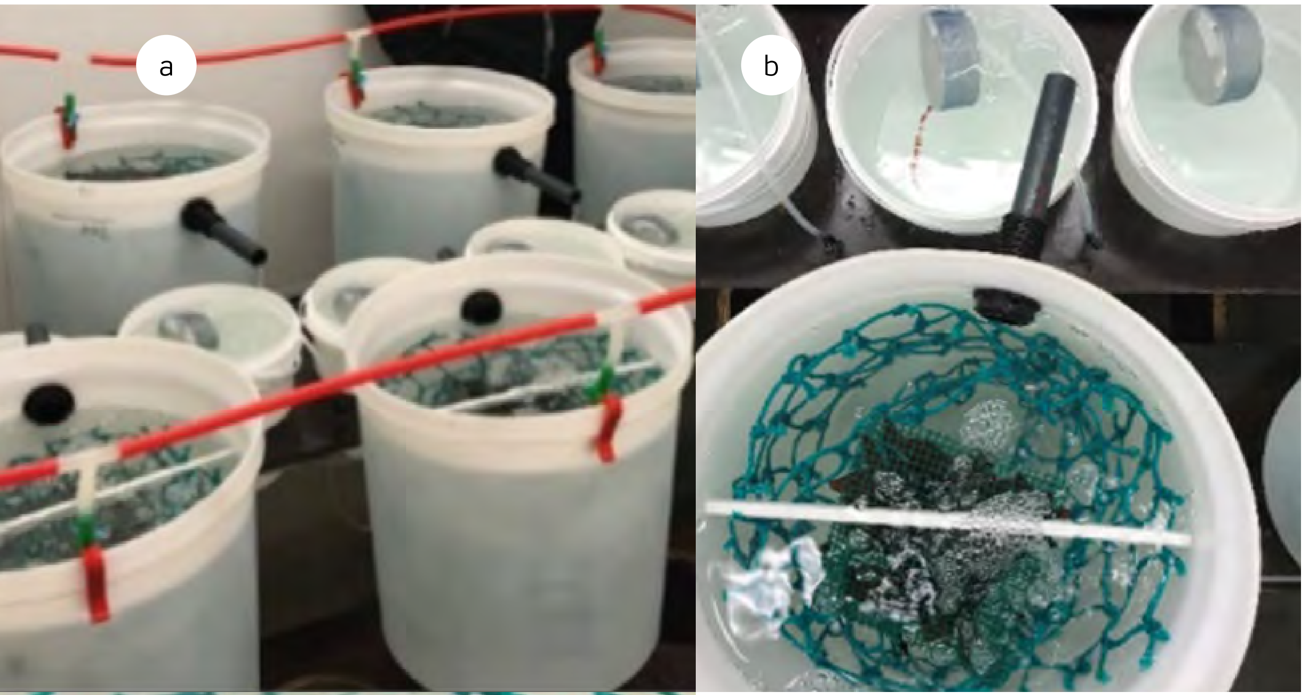
Room/Area	Equipment and Consumables	For 50km seeded string	For 250km seeded string
All	Electricity (running cost)	€15,000	€22,500
Total with tanks		€186,868	€272,406
Total with boxes		€181,888	€260,174
Total without optional extras		**€169,608**	**€246,894**

• Does not include labour costs.

Research and Development Capacity Space for Red Algae Cultivation in the Hatchery

In both hatchery design scenarions costed in this report an area was set aside for tank trials focussing on the cultivation of red algae (e.g. *Palmaria palmata* & *Porphyra* spp). For a step-by-step guide on the hatchery production of *Palmaria* see the BIM publication; Aquaculture Explained No. 27 – Cultivating *Palmaria palmata* (Werner *et al.*, 2011).

This research area should include tanks dedicated to holding stocks for spore release and seeding onto 20 nets (5m x 2m). The development of new cultivation methods for red seaweeds will require control over reproduction, hence the tanks will be placed in temperature control rooms. The polyethylene tanks will be large enough (2m x 1m) to accommodate 5m x2m vertically folded nets (Fig. 20). The net seeding methods developed by Schmedes *et al.*, (2019) would be employed for optimising the hatchery production of red algae by using vertical seeding tanks, with agitation during the seeding phase.



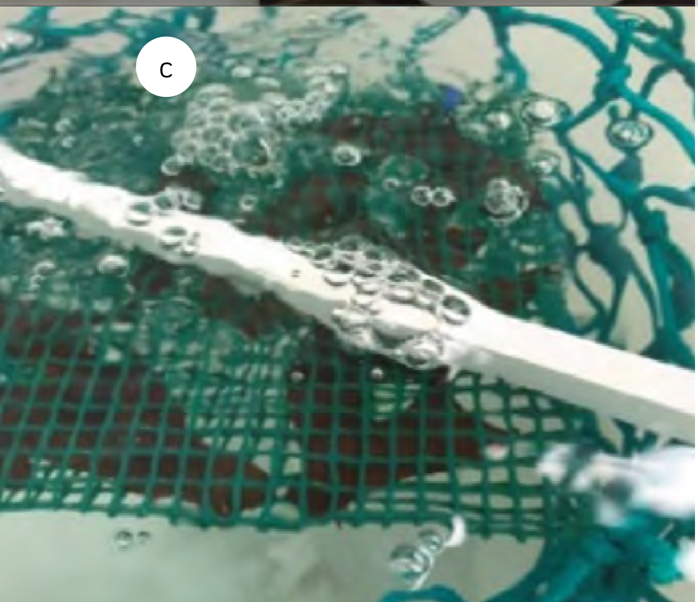


Figure 20.
a) Parallel flow-through setup of 30L conical seeding tanks.
b) Sori packages were fixed centrally above the net spirals and 2 cm below surface. Effluent spores were detained in spore-detaining tanks (SDTs).
c) Aeration (1.2 L min^{-1}) from the bottom provided hemispherical water circulation and dispersal of released spores (from Schmedes** et al.**, 2019).

At-sea grow-out sites

Of the farms currently in operation in Ireland, 80% are located in exposed or semi-exposed sites. Exposure can be defined in terms of wave exposure, Visch *et al.,* (2020) defined them as follows: 500,000–800,000 m^2s^{-1} (exposed), 100,000–200,000 m^2s^{-1} (moderately exposed) and 10,000–30,000 m^2s^{-1} (sheltered). Three grow-out site systems were reviewed and costed based on their exposure level. MS1 is used in semi-exposed or sheltered areas, (see figure 22) it uses fewer mooring blocks and anchor lines. The growing lines still run parallel to each other however they are attached to a header line at each end of the growing line which runs perpendicular to the growing lines. The header lines are held in place with anchor lines attached to 4T mooring blocks at each corner of the site and 9 x 2.5T mooring blocks running along the length of each header line. All but one of the growers surveyed use a 2-mooring block per growing line system, that is MS2, (see figure 23), as the growers believe their sites are too exposed to employ MS1 or consider the infrastructure and logistics is lacking to trial an alternative layout. MS2 uses a mooring block on each side of each growing line, making it a more dependable system in exposed sites however the cost is considerably greater than MS1, (€50,000 ca.) (see Table 7). The report considers the use of MS2 in a 20Ha farm and a larger 100Ha farm, both located in more exposed sites.

The following items are the base requirement for successfully growing-out macroalgae at sea. Figures 22 and 23 highlight how the items link together to secure the growing line and maintain it in sunlit surface waters. Appendix II provides the details of the costs involved in setting up three variations of a farm, 20Ha site using MS1, a 20 Ha site using MS2, and 100Ha parallel lines, using MS2.

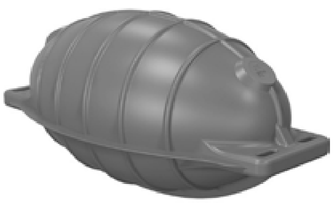
Growing lines

Both polyester and nylon rope are employed for growing lines. Both materials are strong and synthetic but differ in many ways; nylon is stronger and more flexible and has a higher stretch resistance. However, nylon's strength is compromised when wet, causing it to sag while polyester retains its strength when wet. However, polyester has low stretch properties. Both nylon and polyester growing lines should have a lifespan of at least 4 years. The diameter of line used varied from 15mm to 32mm. For this study, **32mm polyester rope** will be used for the growing lines.

Buoys

Buoys are required to ensure the growing line remains high enough in the water column to allow the kelp to photosynthesise (i.e. 1-2m below the surface). To minimise the visual impact of the farm, grey **LD 2 buoys** will be employed at a frequency of one buoy every 13m of growing line, which is the optimal spacing to maintain the kelp in the sunlit section of the water column. The buoys are bullet shaped and designed to reduce drag when used in strong currents and tides. The buoys should be spliced into the growing lines using **12mm polysteel rope**, to ensure they maintain their position along the line.

Barrels



Barrels (also known as fenders and mussel floats – see Fig 13) mark the ends of each growing line and mooring block, while also serving as a sturdy, buoyant point of attachment and connection for the mooring, extension and growing lines. The barrel is formed from solid plastic so there is no risk of deflation, however they can fill with water if not maintained correctly. The barrels used in the current set-up are **MF130 Mussel Floats.**

Aids to navigation

Aids to Navigation (AtoN) are required for all seaweed sites due to risk of collision and/or entanglement. All AtoN require statutory Sanction from Irish lights prior to their establishment, alteration or disestablishment. Provision and maintenance of AtoN Markings are the responsibility of the licensee. Further advice on the suitable marking scheme for each site is available from the Navigation and Maritime Services Department. Tel: +353 1 271 5400. Email: info@Irishlights.ie, website: www.irishlights.ie. See Figure 12 for a typical AtoN.

Mooring blocks

Concrete mooring blocks serve as anchoring points at the end of each growing line. The weight of each mooring block will depend on the exposure of each site and the setup of the lines. Although 1T mooring blocks are commonly used, it is recommended that 2.5T or 4T blocks be employed due to the extreme climatic conditions experienced in exposed sites off the coast of Ireland.

Anchor lines

Anchor lines are generally a combination of heavy chain and polysteel mooring rope, linking the mooring block on the seabed to the barrel at the surface. The chain (38mm), which is shackled to the eye of the mooring block, dampens the wearing effect of large sea swells on the ropes. The mooring line connecting the chain to the barrel will be 32mm or 40mm polysteel rope, depending on the level of exposure. The mooring lines require annual cleaning from fouling material (Fig. 20) and replacing every 2-3 years. Failure to maintain the mooring lines will result in line breakages and loss of gear.

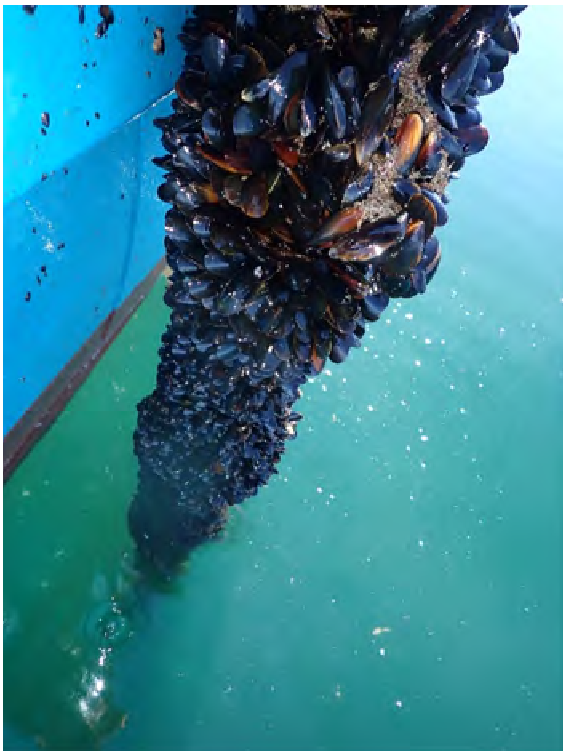


Figure 21. Extensive fouling of a mooring line by the annual growth of mussels.

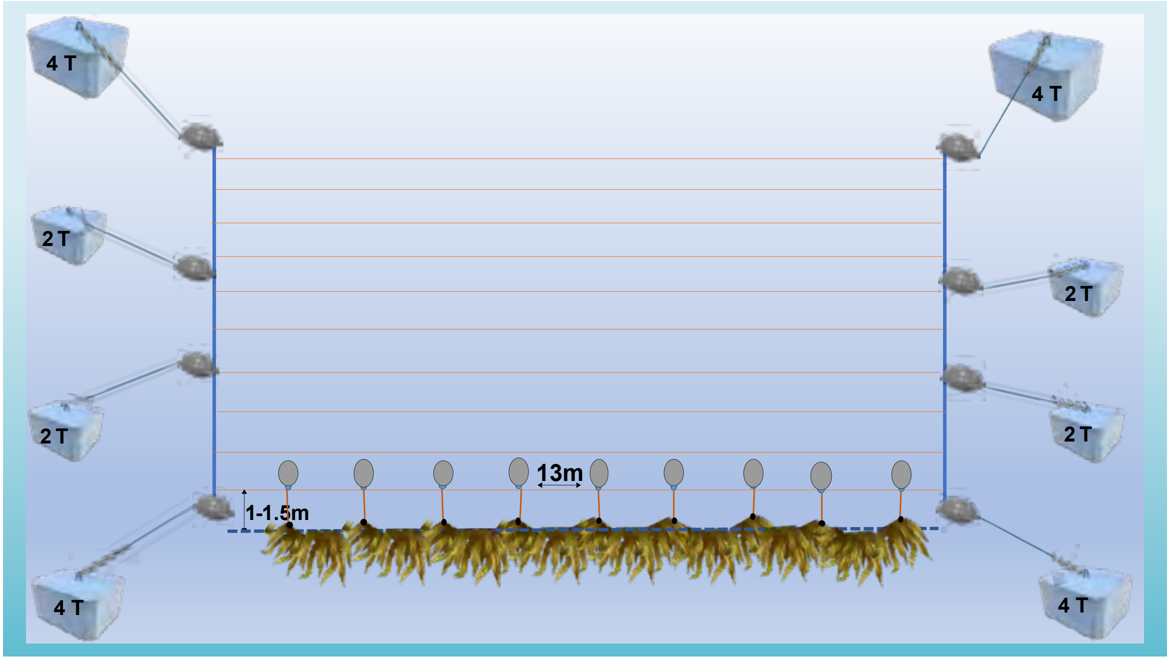


Figure 22. Plan view of set up for more sheltered locations (mooring system 1)

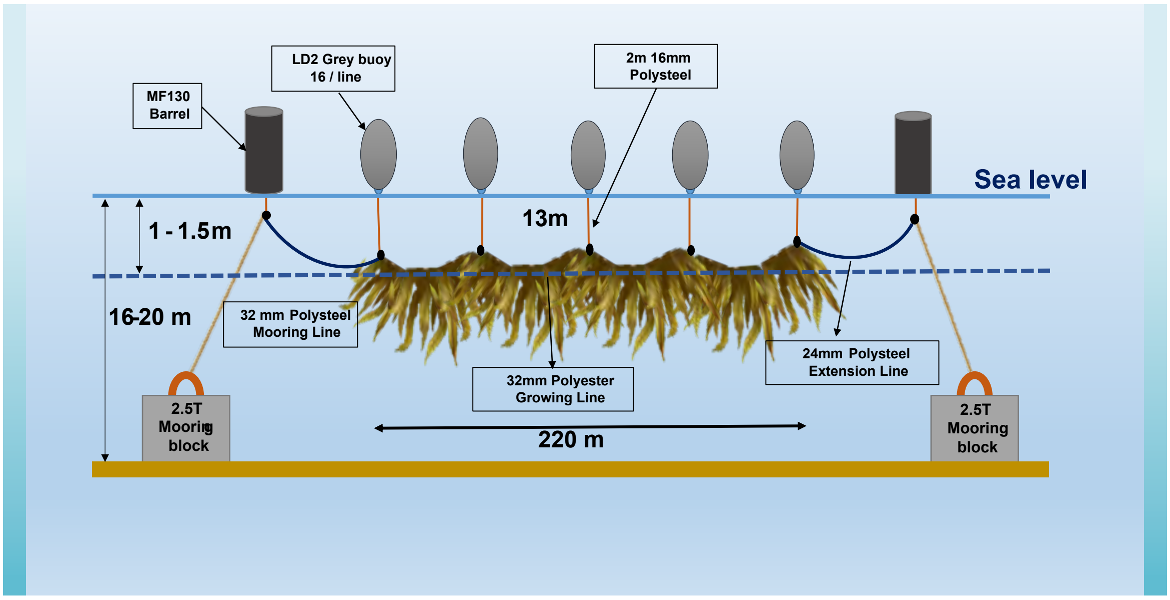


Figure 23. Side view of a single line set-up for an exposed site (mooring system 2)

Inventory of equipment required for grow-out sites

Inventory of equipment required for 20 Ha farm (500m x 400m) in a near shore relatively shallow, protected bay e.g., Bantry Bay using mooring system 1 (MS1)

A 20Ha site using MS1, is comprised of one column of 47 Lines, 220m each spaced 10m apart (see appendix II for cost of farm set-up, appendix III for site layout plan and figure 24 for snapshot of the plan). This system uses fewer mooring blocks, anchor lines, chain, barrels, and shackles and is thus much cheaper to set up, however the system may be less stable than the individual line style system.

- 4 x 4T mooring blocks for each corner of the farm to stabilise the whole system
- 18 x 2.5T Mooring Blocks, 9 located along the lengths of the header line to stabilise the growing lines
- 47 x 220m growing lines, along which the seeded string will be deployed
- 2 x 460m length of header line to ensure the growing lines maintain an equal distance apart
- 94 x 10m lengths of rope for use as an extension line between the header line and the growing line (the purpose of the extension line is to enable tightening of the growing line as the biomass increases by pulling both sides of the extension line.
- 800 x LD2 grey buoys, spaced at 13m
- 22 x Mussel floats/Barrels, one attached to the end of each anchor line and header line
- 22 x 48m lengths of anchor line, one line attached to each chain and barrel
- 22 x 12m lengths of chain, one chain shackled to the mooring block and tied to the anchor line
- 22 x shackles
- 822 x 2m lengths of rope attaching buoys and barrels to growing line and header line, also used for linking ropes.

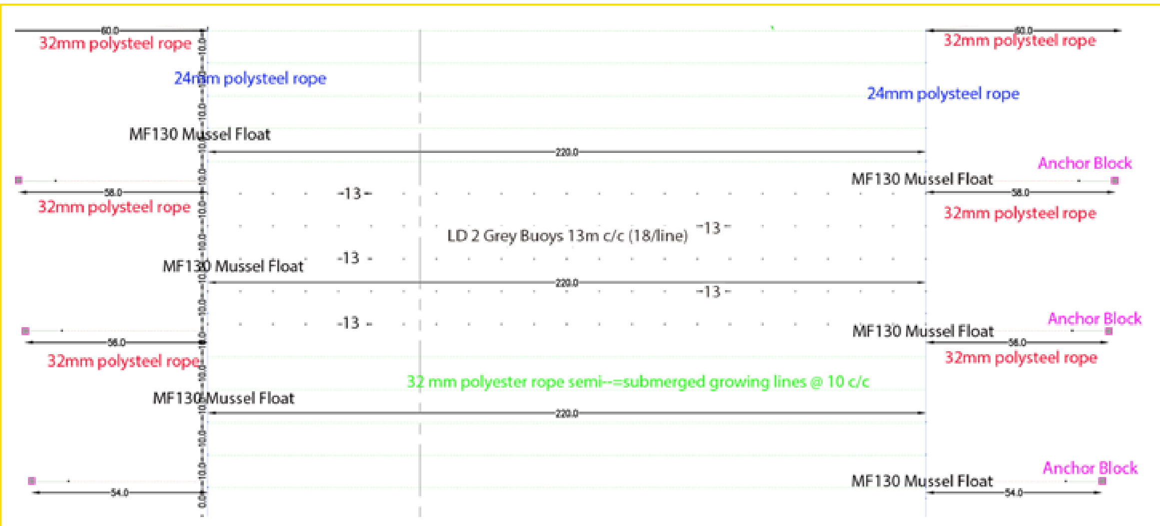


Figure 24. Snapshot of structural requirements for a 20-hectare MS2 licensed area (see appendix III for full version)

Inventory of equipment required for 20 Ha individual line style farm (690m x 290m) in a near shore relatively shallow bay e.g., Bantry Bay, using mooring system 2 (MS2)

A 20Ha site using MS2 is comprised of two columns of 25 Lines, 220m each spaced 10m apart (see appendix II for cost of farm set-up, appendix III for site layout plan and figure 25 for snapshot of the plan). This system uses two mooring blocks and associated equipment per line, making it a more expensive system to set up than the MS1. However, it may be a more stable set up particularly in exposed sites.

- 100 x 2.5T mooring blocks, located at each end of the growing lines
- 50 x 220m growing lines
- 100 x 25m lengths of rope for use as an extension line between the barrel and the growing line
- 900 x LD2 grey buoys, spaced at 13m
- 100 x Mussel floats/Barrels, one attached to the end of each anchor line and extension line
- 100 x 48m lengths of anchor line, one line attached to each chain and barrel
- 100 x 12m lengths of chain, one chain shackled to the mooring block and tied to the anchor line
- 100 x shackles
- 1000 x 2m lengths of rope attaching buoys and barrels to growing line, also used for linking ropes.

Figure 25. Snapshot of structural requirements for a 20-hectare individual line system licenced area, (see appendix III for full version)

Inventory of equipment required for 100 Ha individual line farm (1024m x 980m) in a more exposed, deeper water grow-out site e.g., Galway Bay, using mooring system 2

A 100Ha individual line system site is comprised of three columns of 94 Lines, 282 lines in total, 220m each spaced 10m apart (appendix II for cost of farm set-up, see appendix III for site layout plan and figure 26 for snapshot of plan). This system uses two mooring blocks and associated equipment per line, making it a more expensive system to set up than the MS1. However, this system may be required in exposed sites to avoid movement of mooring blocks and thus growing lines.

- 564 x 2.5T mooring blocks, located at each end of the growing lines
- 282 x 220m growing lines
- 564 x 25m lengths of rope for use as an extension line between the barrel and the growing line
- 5076 x LD2 grey buoys, spaced at 13m
- 564 x Mussel floats/Barrels, one attached to the end of each anchor line and extension line
- 564 x 48m lengths of anchor line, one line attached to each chain and barrel
- 564 x 12m lengths of chain, one chain shackled to the mooring block and tied to the anchor line
- 564 x shackles
- 5640 x 2m lengths of rope attaching buoys and barrels to growing line, also used for linking ropes.

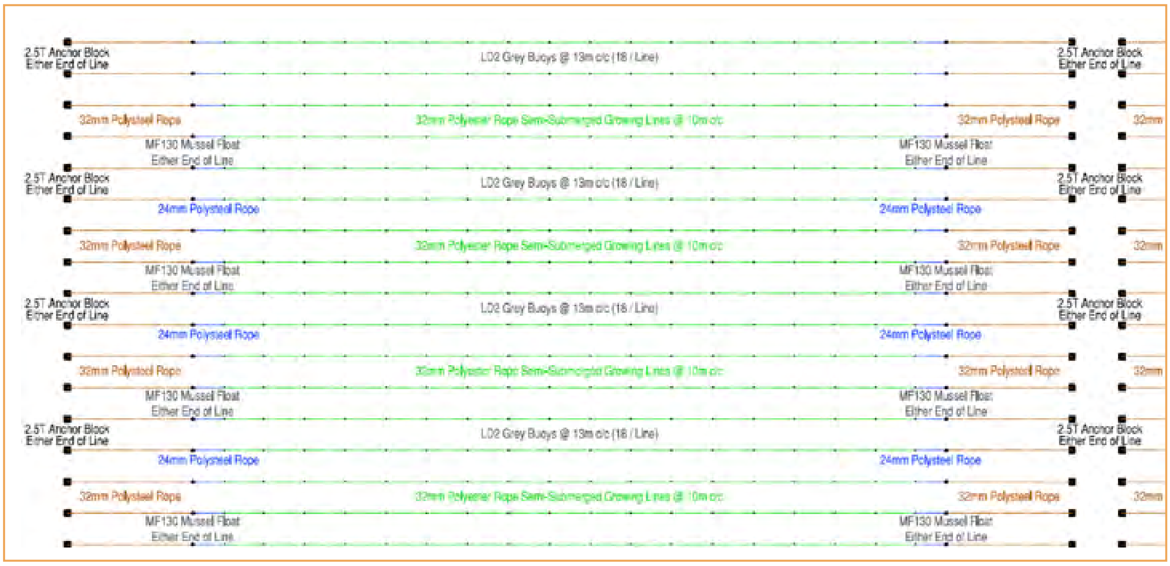


Figure 26. Snapshot of structural requirements for a 100-hectare licenced area (see appendix III for full version)

Summary cost assessment of at sea farm set-up

The costs associated with setting up the 20Ha MS 1 is significantly lower than that associated with the 20Ha MS 2. The total cost per line is €1,357 for the 20Ha MS1 and €2,322 per line for the MS2, in total the parallel line system cost almost €60,000 more to set-up than the MS1. However, the latter system is not well established as yet and using existing technology is only suitable in sheltered or semi-exposed sites. Trials using this system should be explored. Setting up a 100Ha farm in an exposed area would take considerable infrastructure to keep the grow lines secure. At €1.2 million to establish a 100Ha seaweed farm, Irish seaweed farmers would need reliable markets to ensure sale of the seaweed and return on investment.

Table 7. Summary costs associated with grow-out site establishment

Farm item	Equipment and Consumables	20 Ha farm sheltered & shallow site (MS1) 47 lines @ 220m (Ex VAT)	20 Ha farm exposed site (MS2) 50 lines @ 220m (Ex VAT)	100 Ha site exposed & deep (MS2) 282 lines @220m (Ex VAT)
Total cost		€63,767	€116,105	€731,987
Total cost per line		€1,357	€2,322	€2,982
Total cost infrastructure		€72,767	€125,105	€740,987
Labour for deployment		€49,800	€49,800	€302,400
Labour for harvest		€33,200	€33,200	€153,550
Overall Total Cost of Farm (Ex Vat)		€155,767	€208,105	€1,196,937

• Does not include cost of seeded collector string.

Co-location of seaweed cultivation with offshore wind energy installations.

Introduction

Competition for space for seaweed aquaculture in the near shore is driving the industry to move further away from the coastline. In parallel, the rapid growth of offshore wind farms in Europe has led to the concept of multi-use platforms where seaweed could be grown alongside wind parks (Wever *et al*., 2015; Jansen *et al*., 2016, Van de Berg *et al*., 2020). However, the development of offshore seaweed aquaculture is gaining momentum but is reliant on realistic and cost-effective infrastructure and solutions to withstand the exposed conditions and overcome issues related to deeper offshore waters. Seaweed requires sufficient nutrients and light to grow so long-lines must be set close to the surface (<8m deep), which raises logistical issues due to the exposed nature of the site.

Two projects that are currently investigating multi-use offshore platforms that combine the harvesting of wind energy and seaweed along with other low trophic aquaculture species are **UNITED** and **Wind and Weir**. A subsequent Horizon Europe project **ULTFARMS** will start in 2023.

UNITED - Multi-Use offshore platform demonstrators for boosting cost-effective and eco-friendly production in sustainable marine activities.

The UNITED project, funded under Horizon 2020, will provide evidence for the viability of ocean multi-use activities through the development of five demonstration pilots. Three of the offshore pilots include a seaweed culture element that are based in the North Sea off Belgium, the Netherlands and Germany. The aims of UNITED are to:

- Address current bottlenecks relating to the large-scale installation of ocean multi-use activities;
- Demonstrate business synergies and benefits of ocean multi-use; &
- Provide a roadmap for deployment in future multi-use sites and potential scaling barriers to be addressed through best practices and lessons learnt.

The mid-project conclusions of UNITED suggest that offshore seaweed cultivation is possible, however, adaptation of existing cultivation techniques is necessary. The choice of seeding technique was crucial to its success, with direct seeding techniques being less successful than treatments that had a traditional nursery stage. A s explained in the report, direct seeding method needs to be developed further to be a practical and reliable choice for growers. Also, deployment and harvesting were hampered by weather conditions. Other challenges, including biotechnical, legal, safety, and administrative considerations, will also need to be overcome if offshore seaweed farming is to be a viable option.

Wind and Weir

This INTERREG funded project aims to develop a large-scale, automated seaweed production system that is safe, sustainable, ecologically sound and offshore-proof and suitable for functioning within offshore wind farms.

Preliminary trials have been successful. The next objective is to seed 4.9 acres at the Northern Wind Farm, which lies 23km off the Belgian coast. North Sea Farmers aim to build the first commercial large-scale ocean farm (160Ha) in a wind park in 2023.

ULTFARMS - Circular Low Trophic offshore aquaculture in wind farms and restoration of marine space.

The primary aim of ULTFARMS will be to demonstrate a profitable, sustainable, and eco-friendly low-trophic food (molluscs & seaweed) production from offshore aquaculture activities shared within wind farms in the North Sea and Baltic Sea. Six sites were chosen offshore from Belgium, the Netherlands, Denmark and Germany. The project will start in 2023 and will build on previous projects and create new cultivation structures and techniques for deployment and harvesting to cope with the demanding environment.

Conclusions

Seaweed cultivation in conjunction with wind parks is still under development. Although demonstrated in a small-scale scenario, innovations in engineering, automation and monitoring are still required to support cultures in these hostile environments.

This proposed support would include:

- Re-enforced long-line systems with automated submergence based on oceanic conditions;
- Mooring and line attachment systems;
- Seeding methods;
- Seaweed strains suitable for exposed sites;
- Monitoring systems using sensors and satellites;
- Regulation and governance landscape; &
- Marketing and social engagement strategies.

In conclusion, the optimised and carbon neutral use of offshore marine space will relieve the pressure on overburdened coastal zones. In doing so, it will increase production of European seaweed, while safeguarding the environment and add value to wind farm green energy ethos.

References

- Araújo, R., Lusser, M., Sanchez Lopez, J., and Avraamides, M. (2019). Brief on Algae Biomass Production. Luxembourg: Publications Office of the European Union.
- Arbona J-F, Molla M (2006) Cultivation of brown seaweed *Alaria esculenta*. In: Aquaculture Explained No. 21 (ed. Watson L), p. 50. Bord Iascaigh Mhara, Dublin.
- Edwards, M., Watson, L., O'Mahony F., Connellan I., Dring, M., Werner A. (2011). Cultivating *Laminaria digitata*. Aquaculture Explained No. 26 72 pages. www.bim.ie
- FAO (2021). FAO Global Fishery and Aquaculture Production Statistics (FishStatJ; March 2021; www.fao.org/fishery/statistics/software/fishstatj/en).
- Fish Stat J. (2021). www.fao.org/fishery/statistics/software/fishstatj/en.
- Jansen, H.M., Van Den Burg, S., Bolman, B. (2016). The feasibility of offshore aquaculture and its potential for multi-use in the North Sea. Aquacult Int 24, 735–756 https://doi.org/10.1007/s10499-016-9987-y
- Kerrison, P.D., Innes, M., Macleod, A. *et al* (2020). Comparing the effectiveness of twine- and binder-seeding in the Laminariales species *Alaria esculenta* and *Saccharina latissima*. J Appl Phycol 32, 2173–2181 (2020). https://doi.org/10.1007/s10811-020-02069-5
- Kerrison PD, Twigg G, Stanley M, De Smet D, Buyle G, Pina AM, Hughes AD (2019) Twine selection is essential for successful hatchery cultivation of *Saccharina latissima*, seeded with either meiospores or juvenile sporophytes. J Appl Phycol. https://doi.org/10.1007/s10811-019-01793-x
- Kerrison PD, Stanley MS, Hughes AD (2018) Textile substrate seeding of *Saccharina latissima* sporophytes using a binder: an effective method for the aquaculture of kelp. Algal Res 33:352–357
- Mols-Mortensen. A, E.Á.G. Ortind, C. Jacobsen, S.L. Holdt (2017) Variation in growth, yield and protein concentration in *Saccharina latissima* (Laminariales, Phaeophyceae) cultivated with different wave and current exposures in the Faroe Islands. J. Appl. Phycol., 29, pp. 2277-2286, 10.1007/s10811-017-1169-4
- Schmedes, P., Søndergaard; N., M. Møller (2019). New hatchery methods for efficient spore use and seedling production of *Palmaria palmata* (dulse). Journal of Applied Phycology, (), doi:10.1007/s10811-019-01998-0
- Theuerkauf S.J., Morris J.A. Jr, Waters T.J., Wickliffe L.C., Alleway H.K., Jones R.C. (2019). A global spatial analysis reveals where marine aquaculture can benefit nature and people. PLoS ONE 14(10): e0222282. https://doi.org/10.1371/journal.pone.0222282
- Umanzor, S., Li, Y. & Yarish, C. Effect of direct "seeding" binders and embryonic sporophyte sizes on the development of the sugar kelp, *Saccharina latissima*. J Appl Phycol 32, 4137–4143 (2020). https://doi.org/10.1007/s10811-020-02277-z

- Van den Burg S.W.K., M. F. Schupp, D. Depellegrin, A. Barbanti, S. Kerr (2020). Development of multi-use platforms at sea: Barriers to realising Blue Growth. Ocean Engineering, Volume 217. https://doi.org/10.1016/j.oceaneng.2020.107983.
- van den Burg SWK, Van Duijn AP, Bartelings H, van Krimpen MM, Poelman M (2016) The economic feasibility of seaweed production in the North Sea. Aquac Econ Manag 20:235–252
- Visch, W., Nylund, G.M. & Pavia, H. Growth and biofouling in kelp aquaculture (*Saccharina latissima*): the effect of location and wave exposure. *J Appl Phycol* **32**, 3199–3209 (2020). https://doi.org/10.1007/s10811-020-02201-5
- Werner A., Dring, M., Watson, L., Edwards, M., O'Mahony F., Connellan I., Maggs C. (2011). Aquaculture Explained No. 27 – Cultivating *Palmaria palmata*. 76 pages. www.bim.ie
- Wever L., G. Krause, B. H. Buck (2015). Lessons from stakeholder dialogues on marine aquaculture in offshore wind farms: Perceived potentials, constraints and research gaps. Marine Policy, Volume 51, Pages 251-259. https://doi.org/10.1016/j.marpol.2014.08.015.
- Zhu, X.; Healy, L.; Zhang, Z.; Maguire, J.; Sun, D.; Tiwari, B.K. (2020) Novel postharvest processing strategies for value-added applications of marine algae. J. Sci. Food Agric. Volume 101, Issue 11 Pages 4444-4455

Appendix I.
Hatchery - plant and equipment cost (September 2022

Room/Area	Equipment and Consumables	For 50km seeded string (Ex Vat)	For 250km seeded string (Ex Vat)	Notes
External	Generator	€25,000	€25,000	110 KVA - 3 phase. 88KW
	Seawater pump	€3,000	€3,000	10m³/hr - 6 KVA
	Pipework from pump	€10,000	€10,000	50 to 110mm pipes
	Header tank	€6,000	€6,000	HDPE 10m³
Plant room	Switch panel	€1,500	€1,500	
	Ventilation	€2,000	€2,000	
	Heating control (not including temp controlled rooms)	€2,000	€2,000	
	Heating/cooling water systems for tank rooms	€10,000	€10,000	Chiller – 14.8 KW capacity, 4 bar water pressure. Power input 7KW
	Compressor/Blower	€4,000	€4,000	4 KW
	UV system	€6,000	€6,000	1100-watt multi-tube UV
	Sand filters	€2,500	€2,500	Suitable for 10m³/hr seawater
	100, 20, 10 & 1 µm filters	€1,000	€1,000	
	Temp sensor systems and alarms	€1,000	€2,000	Optional
Prep room	Growth chambers	€3,500 (2)	€7,000 (4)	€1750 each
	-20° under counter freezer	€400	€400	
	Gas blow torch	€50	€50	
	Fridge	€300	€300	
	Dishwasher	€400	€400	
	Epoxy labs sink with under sink cabinets	€3,750	€3,750	Sink dimensions – 400 x 500 x 250mm
	Regular sink	€300	€300	25L
	Distilled water system	€329	€329	Reverse osmosis – 5 bar
	3 taps and hose	€450	€450	Freshwater hot and cold and salt water ambient
	1L Glass reagent bottles	€150	€300	€30 each
	Benches and cabinets	€3,500	€4,600	

Room/Area	Equipment and Consumables	For 50km seeded string (Ex Vat)	For 250km seeded string (Ex Vat)	Notes
	Chairs and stools	€168	€168	
	Portable scales	€300	€300	
	Analytical balance	€835	€835	
	Microscopes with camera	€5,000	€5,000	Optical and dissecting
	Autoclave	€25,000	€25,000	135L (top loading)
	Storage racks	€1,480	€1,480	Steel shelving
	Shelving	€345	€345	Plastic
	Chemical store	€669	€669	Metal cabinet
	Consumables	€3,500	€9,000	Nutrients, Slides, PPE, Petri-dishes milli-q water
Culture room	Heavy duty shelves	€2,000	€3,000	€1000 each
	Lights (LED)	€2,500	€2,500	Adjustable with timer
	Glassware 5L flasks 10L flasks 1L Beakers	 €1905 (15) €6552 (24) €145 (5)	 €3810 (30) €19,110 (70) €290 (10)	 €127 each €273 each €29 each
	Air tubing and connectors	€100	€300	
Tank rooms				Minimum; 2 rooms (50km) 4 rooms (250km)
	Heavy duty shelves	€5,000	€13,000	€1000 each
	Lights	€5,000	€10,000	Adjustable with timer
	Tanks OR Boxes	€5,460 (13) €400	€13,440 (32) €1,000	€420 each €8 each
	Sump tanks for boxes	€80	€208	1 sump per 10 boxes - €16 each
	String and collectors	€7,500	€37,500	15c per meter
	IBC tanks for red seaweeds	€11,280 (20)	€11,280 (20)	€564 each (optional)
All	Electricity (running cost)	€15,000	€22,500	
Total with tanks		**€186,868**	**€272,406**	
Total with boxes		**€181,888**	**€260,174**	
Total without optional extras		**€169,608**	**€246,894**	

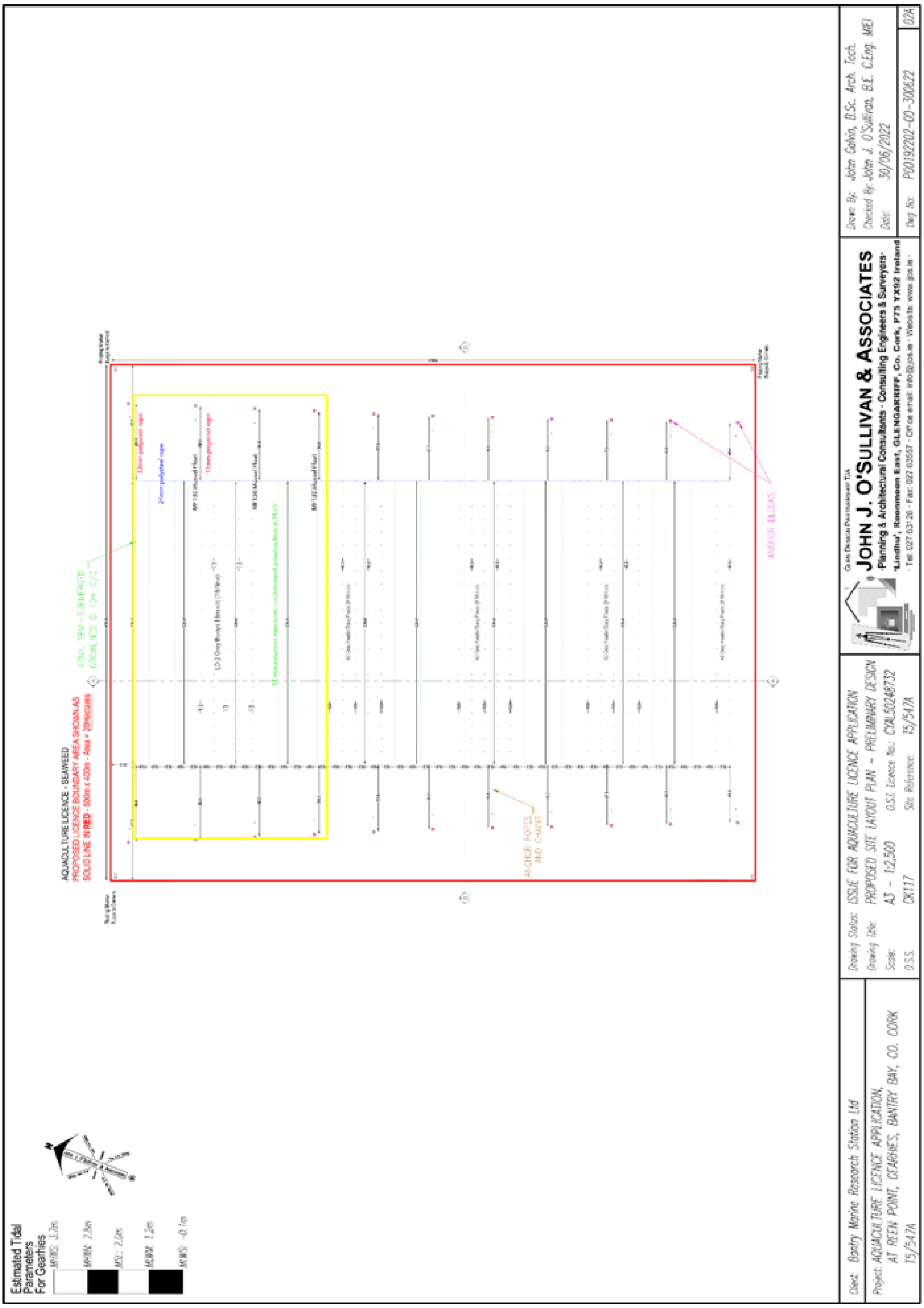
Appendix II.
Farm cost

Farm item	Equipment and Consumables	20 Ha farm sheltered & shallow site (MS1) 47 lines @ 220m (Ex-Vat)	20 Ha farm sheltered & shallow site (MS2) 50 lines @ 220m (Ex-Vat)	100 Ha site exposed & deep (MS2) 282 lines @220m (Ex-Vat)	Unit price (Ex-Vat)
Long lines	Mooring blocks (2.5T)	€6,600 (18)	€37,000 (100)	€208,680 (564)	€370
	Mooring blocks (4T)	€2,368 (4)			€592
	Growing line (220m)	€16,544 (47)	€17,600 (50)	€99,264 (282)	€1.6/m
	Extension line (25m)	€761 (10m x 94)	€2,025 (100)	€11,421 (564)	€0.81/m
	Header line (460m)	€1,472 (2)			€1.6/m
	Buoys LD2 grey	€29,600 (800)	€33,300 (900)	€187,812 (5,067)	€37
	Mussel Floats/barrels	€1,760 (22)	€8,000 (100)	€45,120 (564)	€80
	Rope from buoys and barrels to growing line/header line (2m)	€904 (822)	€1,100 (900)	€6,204 (5640)	€0.55/m
	Anchor line	€766 (22 x 24m)	€6,960 (100 x 24m)	€39,254 (564 x48m)	€1.45/m
	Shackles	€748 (22)	€3,400 (100)	€19,176 (564)	€34
	Chain	€2,244 (22 x 6m)	20,400 (100 x 6m)	€115,056 (564 x 12m)	€17/m
Total cost		€63,767	€116,105	€731,987	
Total cost per line		€1,357	€2,322	€2,982	
Navigation buoys	AtoN	€5,000 (4)	€5,000 (4)	€5,000 (4)	€1,250
	AtoN Mooring and chain	€4,000 (4)	€4,000 (4)	€4,000 (4)	€1,000
Total cost infrastructure		€72,767	€125,105	€740,987	

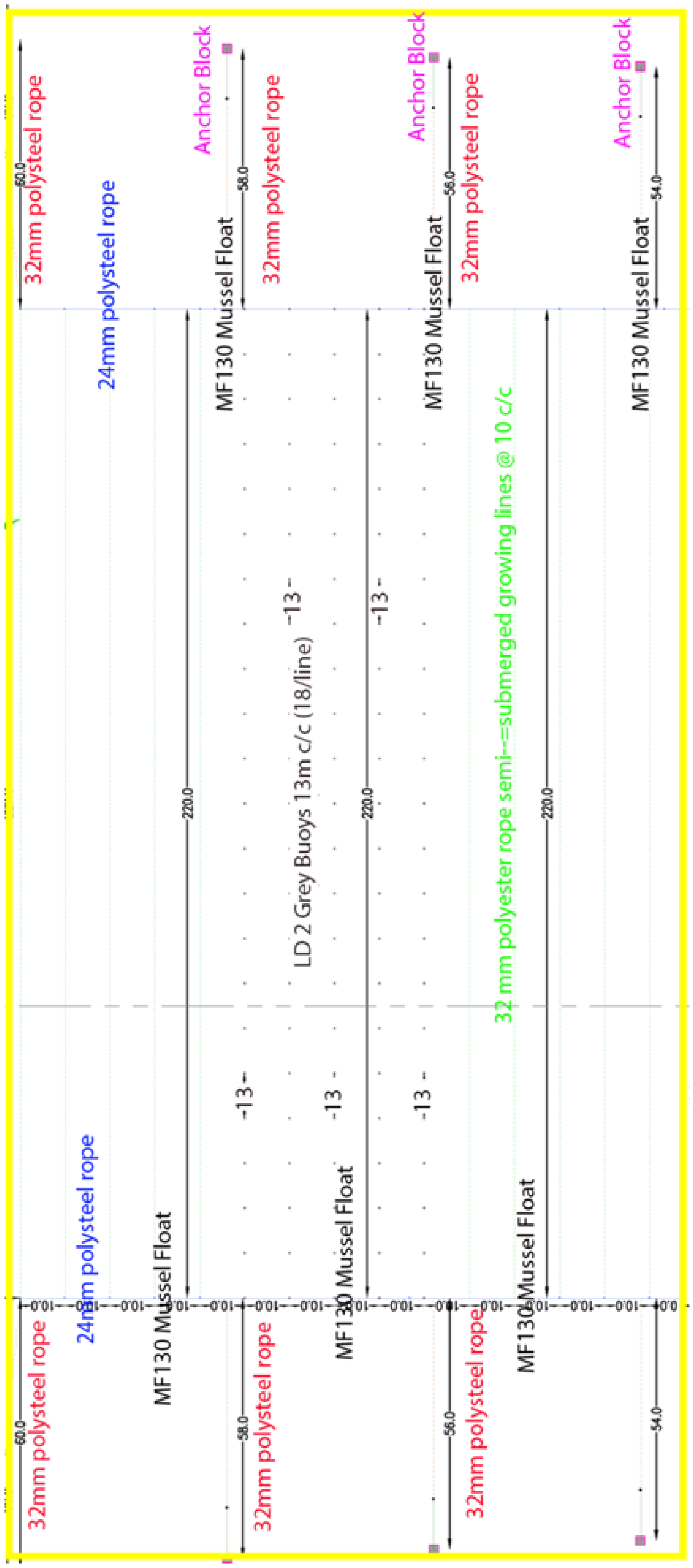
Farm item	Equipment and Consumables	20 Ha farm sheltered & shallow site (MS1) 47 lines @ 220m (Ex-Vat)	20 Ha farm sheltered & shallow site (MS2) 50 lines @ 220m (Ex-Vat)	100 Ha site exposed & deep (MS2) 282 lines @220m (Ex-Vat)	Unit price (Ex-Vat)
Deployment	Boat hire including skipper and 1 crew	€33,600 (1)	€33,600 (1)	€235,200 (3)	€2,800 per day 12 days (20Ha) 28 days (100Ha)
	Rib hire	€9,000 (1)	€9,000 (1)	€42,000 (2)	€750 per day 12 days (20Ha) 28 days (100Ha)
	Additional staff	€7,200 (3 people)	€7,200 (3 people)	€25,200 (6 people)	€200 per day 12 days (20Ha) 21 days (100Ha)
TOTAL		€49,800	€49,800	€302,400	
Harvesting	Boat hire including skipper and 1 crew	€22,400 (1)	€22,400 (1)	€103,600 (2)	€2,800 per day 8 days (20Ha) 18.5 days (100Ha)
	Rib hire	€6,000 (1)	€6,000 (1)	€27,750 (2)	€750 per day 8 days (20Ha) 18.5 days (100Ha)
	Additional staff	€4,800 (3 people)	€4,800 (3 people)	€22,200 (6 people)	€200 per day 8 days (20Ha) 18.5 days (100Ha)
TOTAL		€33,200	€33,200	€153,550	
OVERALL TOTAL COST OF FARM (Ex VAT)		€155,767	€208,105	€1,196,937	

* Excludes cost of seeded string

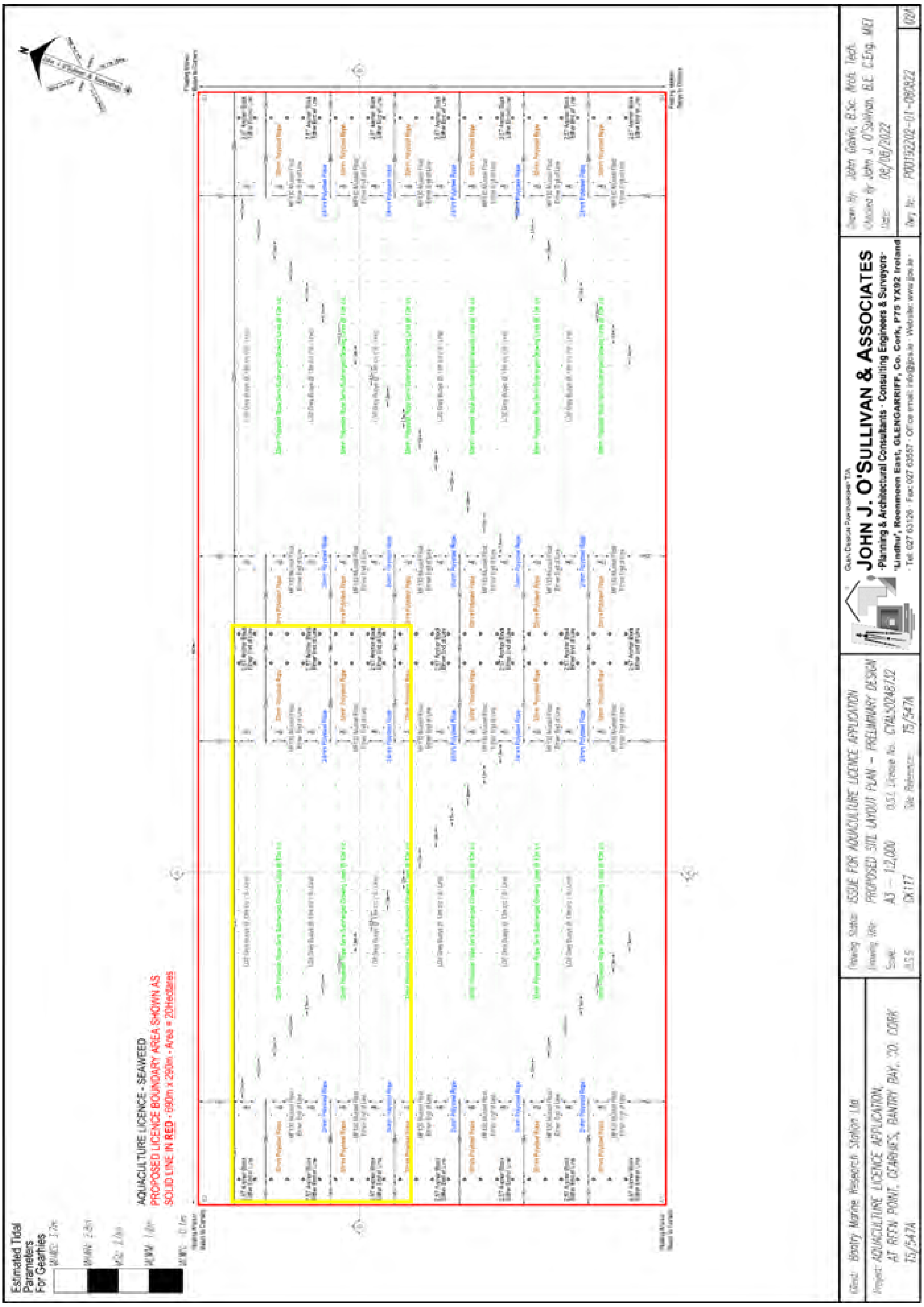
Appendix III.
Farm layout



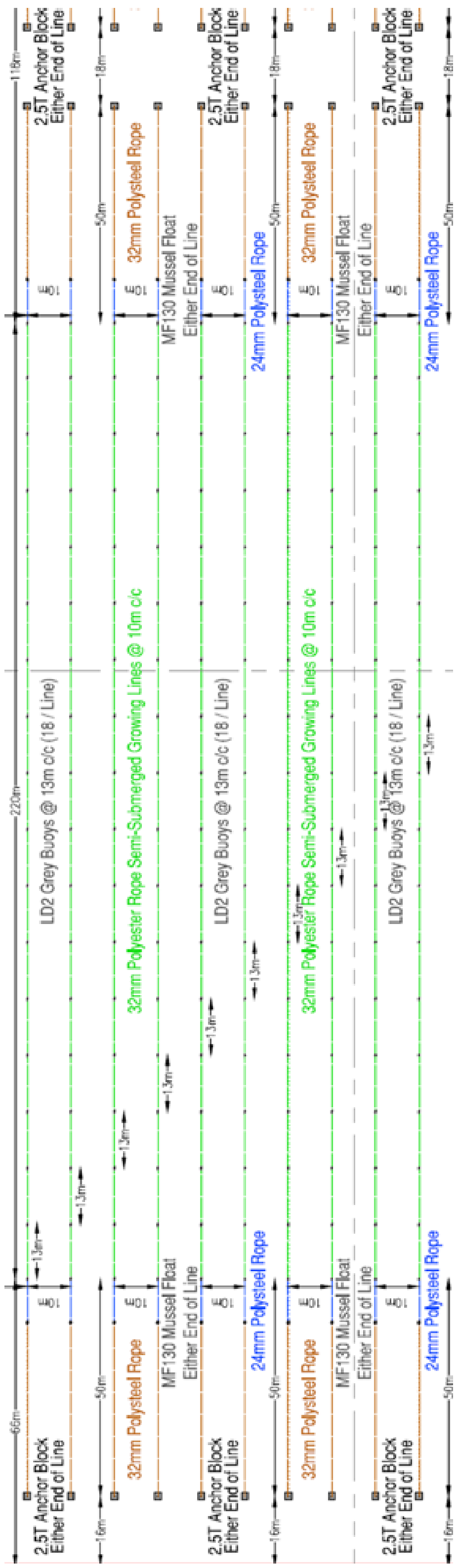
Proposed site layout for 20-hectare seaweed farm, mooring system 1 500 x 400m (yellow box extract below)



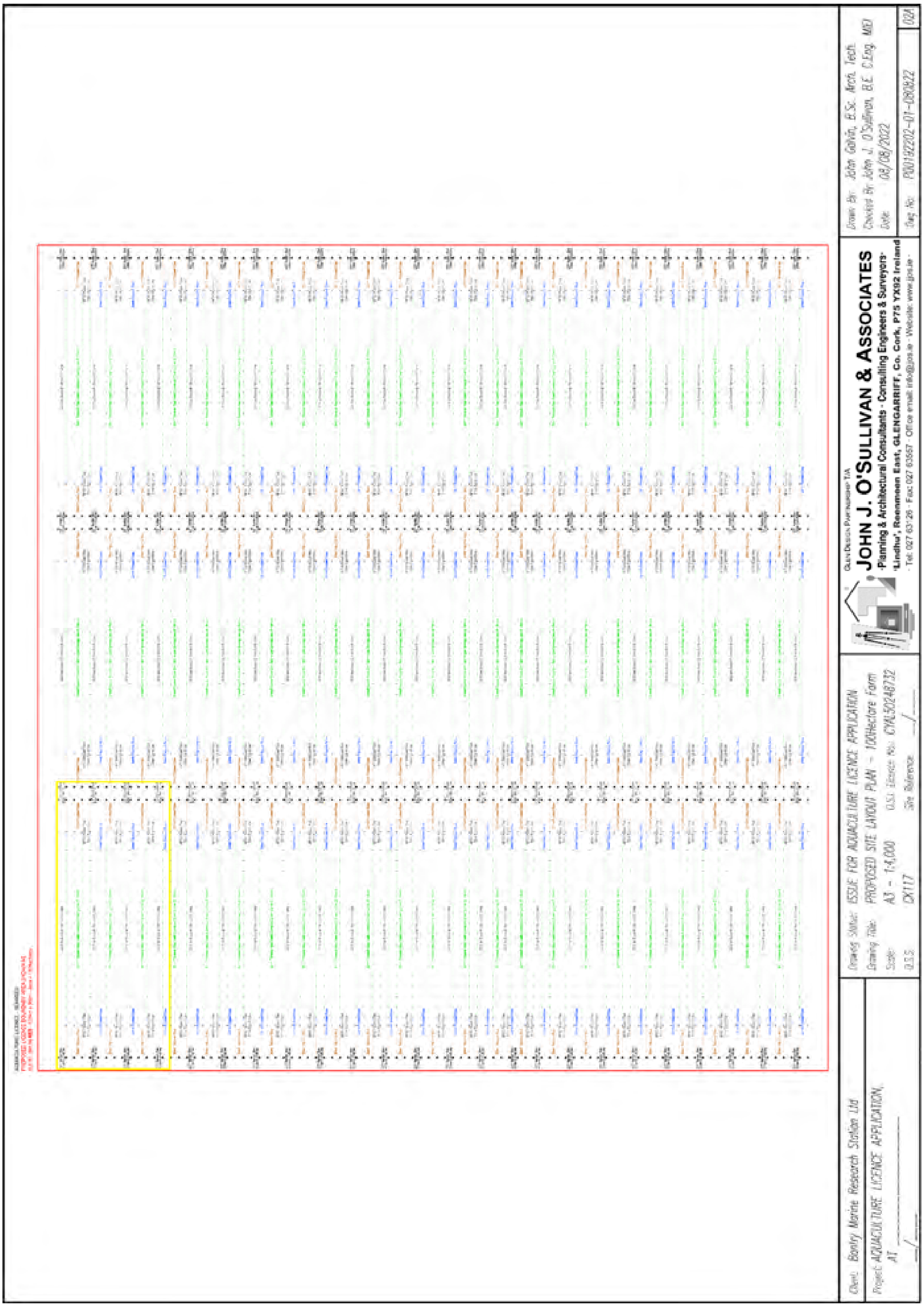
Extract of 20-hectare seaweed farm, mooring system 1 500 x 400m



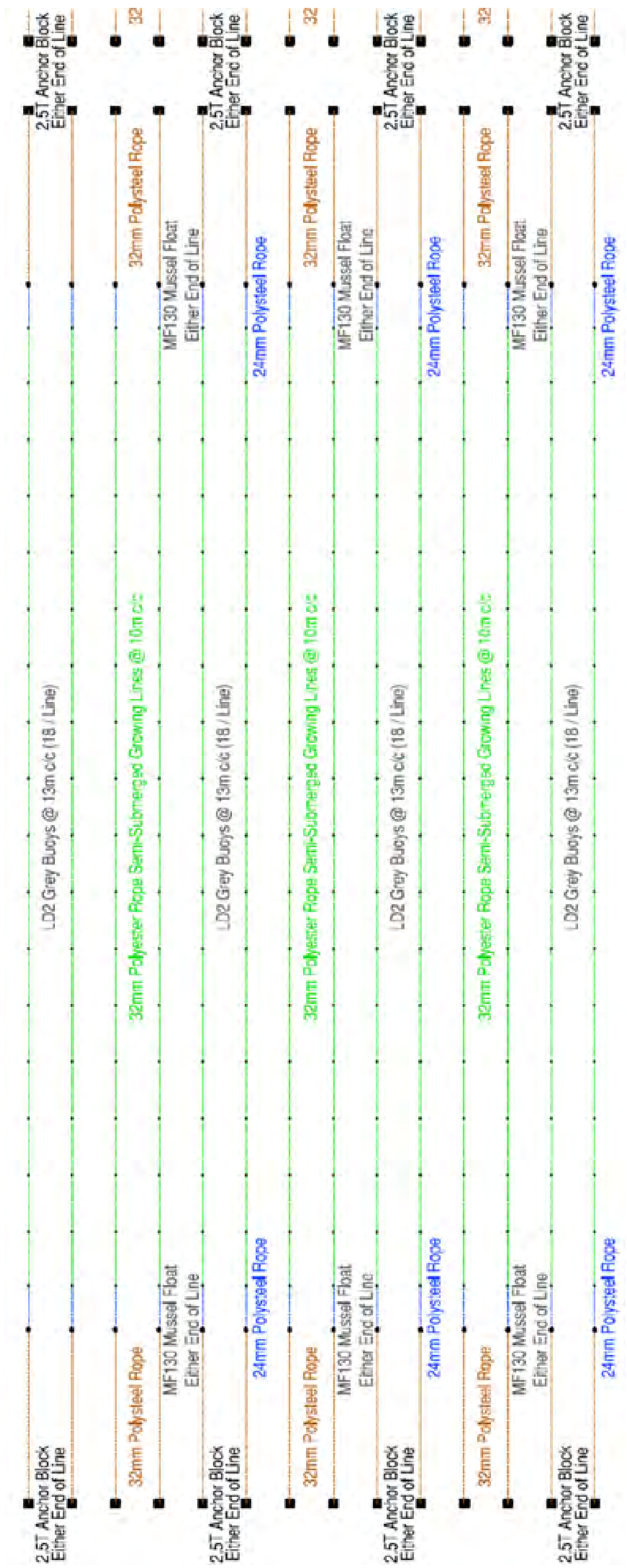
Proposed site layout for 20-hectare seaweed farm: mooring system 2 690m x 290m (yellow box extract below)



Extract of site layout for 20-hectare seaweed farm: mooring system 2 690m x 290m



Proposed site layout for 100-hectare seaweed farm using mooring system 2 (yellow box extract below)



Extract of site layout for 100-hectare seaweed farm using mooring system 2

Notes

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