Seaweed for Biofuels

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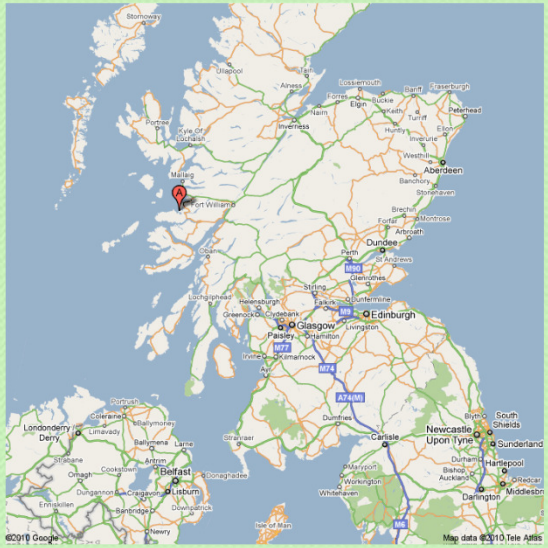
Seedling Production in Europe – From Laboratory to Industrial Scale

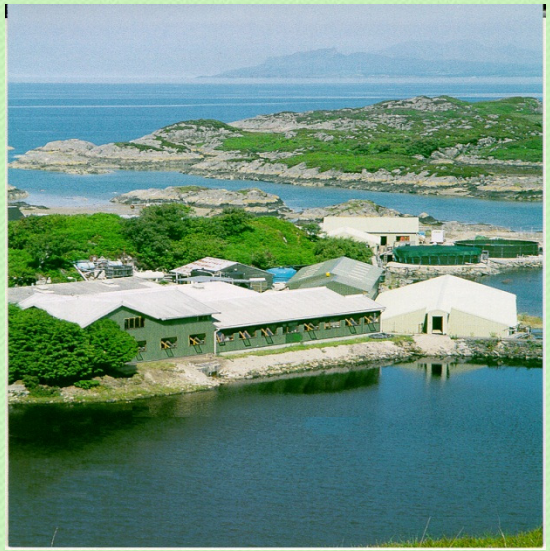
Dr Tim Atack and Dr Jon Dunningham

Viking Fish Farms Ltd
Ardtoe Marine Laboratory
Scotland

With thanks to the UK Crown Estate
Macroalgae Supply Chain Project Team :-
Alex Adrian (TCE), **Roger Dehaney** (Knox Nets
Walter Spiers (Muckairn Mussels), **Robin Turner** (Seaworks)

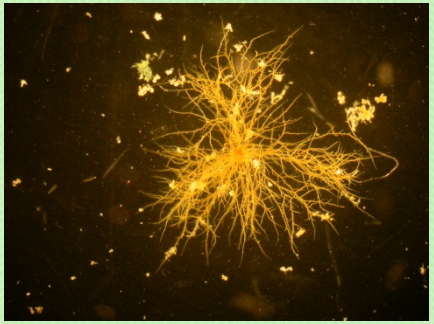
Brief Background

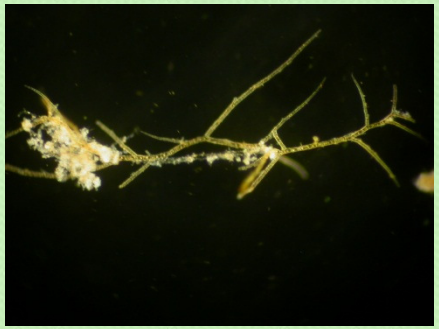


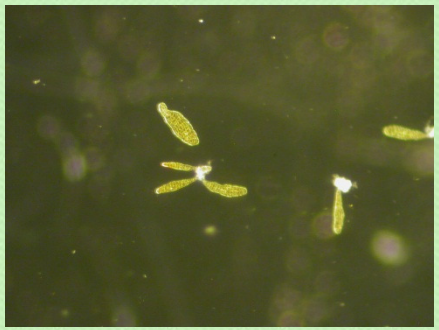


- Ardtoe was set up by the UK Seafish Industry Authority as an aquaculture research facility in 1964 and quickly gained an international reputation in the hatchery production of finfish and shellfish juveniles
- When we took over the lab in 2005, we scaled up the existing finfish hatchery (initially cod and turbot but also now wrasse) from the then laboratory scale to fully commercial levels
- We have since developed a shellfish hatchery operation, again taking it from an initial experimental level to it present commercial scale
- We are thus no strangers to kinds of problems that are inevitably involved in taking any technology from pilot to a fully commercial scale
- I will today therefore try to **outline the constraints to large scale commercial seaweed seedling** production, **as we see them**, and how we have been tackling those constraints

Ardtoe's Seaweed Hatchery

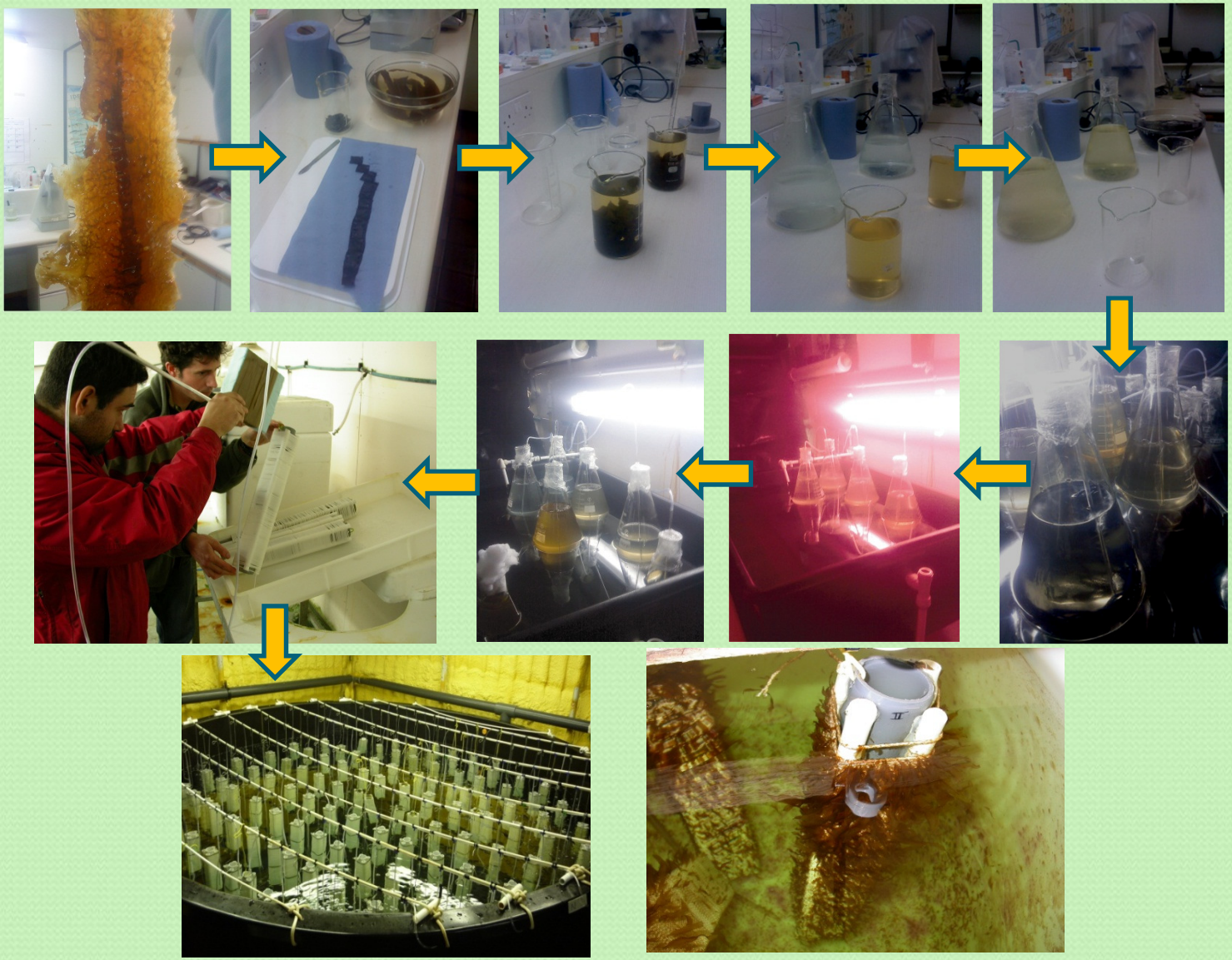






- Ardtoe started its seaweed hatchery in 2009 in response to a request from a salmon company for seeded strings for its integrated aquaculture (IMTA) operation
- The original technology we employed was freely given to us by the Scottish Association for Marine Science (SAMS), who had been producing and culturing seaweeds in their labs for several years as a part of various R&D programmes on sea urchins and IMTA systems.
- Our seaweed hatchery protocol has, until now, essentially been a more practical version of that basic lab methodology

Ardtoe's Present Hatchery Protocol



Grow-out Constraints to Hatchery Scale Up

- So, obviously, to scale the operation up, we just need to have **a lot more flasks, string, bobbins and nursery tanks**….or do we ?
- Such is a classic scale up mistake i.e. deciding that something works in 1 bucket, then to increase production 100 times, you simply need 100 buckets.
- This unfeasibility of the above "multi-bucket" route was clearly demonstrated when we were invited by the UK Crown Estate to help design the UK's first pilot scale demonstration seaweed farm, an outline of which was presented yesterday
- As a part of the process of deciding the **grow-out media** to trial, we noted that any seaweed-biomass-biofuel farm would probably have to be **tens/hundreds/or even thousands of hectares** in size, so we decided to test both traditional ropes and horizontal nets. Then had to consider how we would **seed those media**
- **For ropes**, one of the team noted from experience, that winding/cable tying **seeded strings** around ropes on an offshore site, in Scotland, in winter, is both labour intensive and an extremely slow process. Hence stocking a large grow-out farm in such a manner was **completely unfeasible, physically and economically**
- For nets, clearly attaching strings was not an option, so the **only feasible option for both nets and ropes** appeared to be :-

direct seeding

Technical Constraints to Hatchery Scale-up

10m diam tank

- So, problems solved, we would simply:-
  - **produce gametophytes** in the hatchery **as before**
  - **spray** the gametophytes **directly** onto **ropes and nets**,
  - **nursery rear** the sporophytes until they are **5mm+** long,
  - **transfer** the media **to the grow-out site**.

Easy !!.

- But then we considered the **practical problems** with the above plan

Problem 1. **How would we spray** :-
24 nets that are each 8m x 7m ?
2 ropes that are 12mm in diameter and 200m long ?
Problem 2. **How/where** would we **nursery rear** the seeded media ?
Problem 3. **How** would we **remove and transport the media** to the grow-out site without damaging the sporophytes ?

- We decided that we could :-
  - spray the nets with a **commercial paint sprayer** whilst pulling them off a **7m wide roller**,
  - **hang them from bars in a 10m** diameter x 2m deep outdoor tank
  - **Remove them with a fork lift** and then…

…THINK of a way of transporting them without damage !

Economic Constraints

So, we still had a few technical problems to tackle, but meanwhile I started to think about **the costs of producing seedlings**. As the audience might include some potential customers, I hesitate to give these figures but:-

- At a TCE Forum meeting it was suggested that to compete as biomass for biofuel seaweed would have to sell for < **$250/tonne dry weight** (cf maize €266/t and wheat €280/t). At c.85% water content the value of wet seaweed would thus be **€37.5/tonne**, or **€0.0375** per kilo

- If we estimate a farm productivity of **10 kgs wet weight per metre** of rope p.a., the **annual revenue** to the farmer might be **€0.375 Euro per metre** of rope (for nets we hope it will be more…)

So, what can the farmer afford to pay for his seedlings ?

- We can assume that he is **NOT** going to pay the hatchery more than his selling price !
- In finfish aquaculture my experience is that the farmers' costs of production dictate that the juvenile price cannot usually exceed **15% of the selling price** of the fish. Seaweed farmers do not of course have a feed costs (c50%+ of the production cost in fish culture) but they have drying and transport costs, so as an estimate at the present time I will take roughly the same figure i.e. **15% of the selling price** (though I hope it will be more !!)
- Hence the hatchery could sell seeded ropes (not including the rope) for €0.375 x 15% = **€0.056 (i.e. 5.6 Euro cents) per metre**. So, if the above calculation is anywhere near correct, one thing is clear:-

- **If hatcheries are to make a profit**, they will have to :-

  - **produce seeded media at extremely low cost** and, to make any real return on their capital investment,
  - **sell huge quantities of seeded media**

Trial Seeding and Nursery Protocols

We have tried to take all of the latter constraints into account in attempting to devise a hatchery production protocol that is:-

- Readily scalable
- Meets the growers needs
- Minimises hatchery capital investment
- Produces seedlings at the minimum cost
- Is energy efficient
- Allows simple, cheap and damage free transportation of the seedlings
- Might make money for the hatchery !

We are now carrying out a range of trials aimed at achieving the above goals:-

- **Seeding** **25m lengths of 12mm rope** and **1m square 25mm mesh nets** with either
  - **zoospores or**
  - **gametophytes**
- **Transferring** samples of each :-
  - **directly to the grow-out site** or
  - **to various on-site nursery tanks for rearing until sporophytes 5mm+**
- **Testing** various **transportation** methods
  - For media with zoospores
  - For media with young sporophytes

Seeding Trials

Gametophytes

Net spraying

Indoor Nursery

Outdoor nursery

Zoospores

Net +zoospores in header tank

Net +zoospores in outlet tank

Net +zoospores in header + 6 weeks

Transport of nets to grow-out site

In spore solution

In cool bags

Seeding Trials (cont)

Loose rope in zoospore solution

25m 12mm rope on bobbin

Bobbin seeding tank

Nets and ropes at trial grow-out site (Muckairn Mussels Loch Etive, Scotland)

And the Final Large Scale Seeding Protocol ???

Trials are still ongoing but the results to date indicate the following seeding protocol should be feasible :-

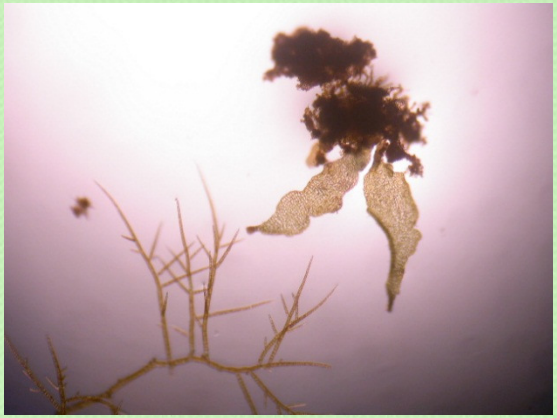
Adult Sporulation

- Preparation of wild-collected adult sporophytes as now
- **Hydration** of the chilled/dried blades in **large scale polythene bins** filled with **filtered and UV treated water**, **NOT** flasks and autoclaved water as now
- Further development of **out-of-season sorus induction** in adult sporophytes using temperature and photoperiod control in order to **maximise use of hatchery facilities** and **extend grow-out season**

Seeding

- **Media to be immersed** in 150 litre+ tanks containing in **1 micron filtered and UV-treated, water**
- **Spore** solution **added**
- Left with **aeration for 10-12 days** under natural light
- **Media removed**, checked for development, **packed in damp plastic bags**
- **Shipped** to farmer

Remaining Questions



Directly seeded S. latissima sporophyte
24 days post-sporulation

- Will direct seeding work for all species of interest ?
- Will the seedling density be high enough, and consistent enough ?
- Can the media be cleaned and re-seeded after each production cycle ?
- Are there synthetic materials that might be better than the nylon currently being trialled ?
- For how long can direct seeded media be shipped ?

And undoubtedly there are more, yet unknown, questions to be answered…….

THANKS FOR YOUR ATTENTION