Sustainable Pathways for Algal Bioenergy
Design and trial of a new structure for seaweed production at sea

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Situation

CEVA is a demonstration pilot for seaweed production

Focus of our research = how to improve the cost-effectiveness of the cultivation of kelp at sea
- Increase the productivity of the biomass (kg/m of rope)
- Optimize the occupation of the area at sea to increase the yield (kg/ha)

Facility
- Inland hatchery
- 6 ha at sea
  - Depth 12-25 m
  - Sheltered area with low wave action (1-1.5m)
  - Current 3-4 knots at high tides period
Since the 90’s, seaweed production was done on longlines

Space between lines = 50 m because of **strong water currents**

Even if a good productivity is achieved, the yield per ha would be low
Design of a new structure

- Design of « production units »
  - 20 m width
  - 50/100 m long

- Idea = semi-rigid framework to strengthen the structure so it’s possible to reduce the space between the lines

11 ropes/unit
**Design of a new structure**

**General concept**

**Space between lines = 2 m**

- **5L buoy**
- **1000L buoy**
- **Mooring**
- **Tube PEHD Ø 315 mm = main tubes**
- **Tube PEHD Ø 90 mm = spacer**
- **50 or 100 m long**
- **Header rope Ø 32 mm**
Design of a new structure

General concept: cross-section view
Design of a new structure

At scale view
Sustainable Pathways for Algal Bioenergy

Mooring study

Design of a new structure

Mooring line design
Design of a new structure

Total cost = 40 000 €
- For the 4 production units (2 of 50 m long + 2 of 100 m long)
- Including feasibility study + PEHD tubes + anchoring equipment

Pros & Cons

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher yield per ha</td>
<td>Strong tension</td>
</tr>
<tr>
<td>Less moorings to survey</td>
<td>Boat should be well-adapted: not too large</td>
</tr>
</tbody>
</table>

Fall 2013: set-up of the units at sea
Two species are grown
- *Alaria esculenta* (AE)
- *Saccharina latissima* (SL)

Dec 2013-Jun 2014: First trial at the new structure

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Density 1 (spores/m)</th>
<th>Density 2 (spores/m)</th>
<th>Date of seeding</th>
<th>Date of transfer at sea</th>
<th>Time at hatchery (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE</td>
<td>Ile Grande</td>
<td>368 000</td>
<td>61 333</td>
<td>04/12/2013</td>
<td>14/01/2014</td>
<td>41</td>
</tr>
<tr>
<td>SL</td>
<td>Pors Rand</td>
<td>8 460 000</td>
<td>1 410 000</td>
<td>05/11/2013</td>
<td>11/12/2013</td>
<td>36</td>
</tr>
</tbody>
</table>

Direct seeding of spores onto strings
Monitoring of biological & biochemical data

Monthly monitoring from March to June

Measurement of:
- Productivity (g FW per m of rope)
- Density of plants (number per m of rope)
- Morphological characteristics of the 12 largest plants (total length, length of stipe, width, weight, weight of stipe)
- Dry matter
- Sampling for biochemical analysis of the biomass

Peteiro et Freire, 2012
Monitoring of environmental data

Underwater Light Intensity

Underwater Temperature

Nutrients

NO3 + NH4 + NO2

PO4
Results: density of plants

SL: no difference between seeding densities

AE: difference between seeding densities decreases over time. At the end, there is no difference anymore between the two densities
Results: productivity

For both species: no difference between seeding densities

Higher productivity achieved with SL

Density used to seed AE might have been too low

SL density 1 (8.5 M spores/m)
SL density 2 (1.4 M spores/m)
AE density 1 (0.6 M spores/m)
AE density 2 (0.4 M spores/m)
Results: morphological characteristics of plants

With this low seeding density, AE had higher width than usual → possible interest for downstream processing.
Results: morphological characteristics of plants

In the last months, seaweeds get epiphyted. It’s especially the case for AE in 2014.

It’s recommended to harvest before that time to prevent the loss of biomass and quality. A good time to harvest at our site is April-May.
Results: biochemical composition

Seasonal variation of biochemical composition of Saccharina

Time of harvest can be decided depending on biochemical composition
Crop management: comparison of two techniques

A) One harvest per year, in Spring

B) Two harvests per year (1<sup>st</sup> in Spring, 2<sup>nd</sup> in Autumn after regrowth of the blade)

One harvest, full plant

1<sup>st</sup> harvest, above the meristem

2<sup>nd</sup> harvest, full plant
Crop management: comparison of two techniques

<table>
<thead>
<tr>
<th>Crop management</th>
<th>Species</th>
<th>Yield at 1st harvest</th>
<th>Yield at 2nd harvest</th>
<th>Total yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Saccharina</td>
<td>140 kg</td>
<td>To come</td>
<td>140 kg</td>
</tr>
<tr>
<td>B</td>
<td>Saccharina</td>
<td>150 kg</td>
<td>To come</td>
<td>To come</td>
</tr>
</tbody>
</table>
Perspectives within the EnAlgae project

- New trial is planned in 2014-2015
  - At 50 m-unit, keeping a distance of 2 m between the lines
  - At 100 m-unit, increasing the space between the line to 4 m

- 4 species
  - *Alaria esculenta*
  - *Saccharina latissima*
  - *Laminaria digitata*
  - *Laminaria ochroleuca*

- Seeding technique: comparison of two techniques
  - Direct seeding of spores on strings (which are then coiled around the rope)
  - Direct seeding of spores on ropes (which are transferred at sea right after seeding) - No maintenance of plantlets at sea so it’s a cheapest option

Growing demand on the French market
Further perspectives

- IMTA: seaweeds + salmon + mussels

- Production model that is
  - More profitable than only seaweeds. Combination of low (seaweeds) and high-value (salmon) products
  - More sustainable than only fish. Bioremediation of animal wastes by seaweeds

- Future research to be studied at CEVA
  - N balance within an IMTA site
  - Other environmental concerns
  - Potential increase in yield of seaweeds

Objectives:
- Cage à poisson: 10 tons
- Tube PEHD élevage de moules: 20 tons
- Radeau d’algues: 50 to 100 tons
Thank you

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