Seaweed culture makes abalone farming more sustainable: wishful thinking or true economic potential?

Sylvain HUCHETTE

Photo: David Geoffrion & Simon Cohen
18 years of production and R&D

- Farming the only European abalone species *Haliotis tuberculata*
  - Rather small commercial species (max length <13cm)
  - Limited knowledge for its potential in aquaculture
- Traditionnally fished and consumed locally
  - Gathered at low tide & becoming rarer
  - Cooked in butter
  - French professional fishermen land about 40T/year
France Haliotis is based in Northwest Brittany
R&D collaborations

- French network:
  - UBO – IUEM - IFREMER
  - Station Biologique de Roscoff CNRS
  - Museum National d'Histoire Naturelle
  - SYSAAF

- International collaborations:
  - Aquavitae project (NOFIMA, ULPGC, Rhodes University...)
  - University of Melbourne (Rob Day)
Main R&D topics

- Ranching/reseeding
- Pathology (*Vibrio harveyi*)
- Shell formation & microstructure
- Nutrition & behaviour
- Genetic selection
- Global warming & Ocean acidification
- IMTA - seaweed culture
Hatchery & nursery

- Tank culture of *Ulvella* spp. for feeding of post-larvae and smaller juveniles

Photo: Antoine Devouard/Matéis Look at Sciences & Alexandre Lamoureux
Sea-based grow-out in benthic cages

Photo: Chris Miller
• The cages are made of 4 food-grade plastic boxes of 500L each
• The black oyster settlement cups are used to provide shelter in the cage. They allow safer animal handling for transfer or harvest.
Abalone cages make great artificial reefs

- Home for algae, invertebrates, fish...
- Over 60 animal species are found living and sheltering in and around the cages
Feeding abalone

Is it a good strategy to use fresh seaweed?

Photo: Chris Miller
Which seaweed & what quantity do we need to produce commercial size abalone?

2007-2022: 15 years of research to optimise one equation

Photo: France Haliotis & Chris Miller Sarah Chajari

This project has received funding from the European Union’s Horizon 2020 Science with and for Society programme under grant agreement no. 818173
Seaweed are harvested from local shores
Video: Titouan Larose, France Haliotis
**Haliotis tuberculata feeding preferences**  
*(Roussel et al., 2019)*

- Preferred seaweed: *Enteromorpha intestinalis (Ulva sp.)*
- Least preferred seaweed: *Laminaria hyperborea*
- Significant effect of seaweed texture on feeding preference

<table>
<thead>
<tr>
<th>Ingested seaweed</th>
<th></th>
</tr>
</thead>
</table>
| *Enteromorpha intestinalis* | I  
| *Asparagopsis armata* | II 
| *Ulva spp* | III |
| *Saccharina latissima* | IV |
| *Saccorhiza polyschides* | V  
| *Palmaria palmata* | VI |
| *Laminaria digitata* | VII |
| *Laminaria hyperborea* | VIII |
Average weight of 30 months abalone fed fresh monospecific diets for one year (Roussel et al. 2019)

- D: Laminaria digitata
- H: Laminaria hyperborea
- S: Saccharina latissima
- U: Ulva spp.
- G: Gracilaria and mix of other filamentous reds
- P: Palmaria palmata
- M: Mix
Experience shows great annual & seasonal variability in seaweed field productivity

Example of the main biotic and abiotic factors of variability:

- Tides
- Weather
- Other Fishermen
- Grazers

Biodiversity
Improve seaweed stock management

Harvest are recorded in details:
• harvester,
• harvested area location & surface,
• Harvest duration,
• yield,
• CPUE...

Objective: learn about the limits of our system

Harvest areas of L. digitata, positioned on the Ortholittoral V2 map with to the ArcGIS Explorer software
Productivity of natural reefs in 2017
Total yield and harvested surface area of reef for each species

- **P. palmata 73.1 Ha**
  - Total 44T
  - 0.06 kg/m²

- **S. latissima 46 Ha**
  - Total 27T
  - 0.06 kg/m²

- **L. digitata 5.5 Ha**
  - Total 38T
  - 0.69 kg/m²
Seasonal growth of abalone fed fresh seaweed

Conversion of seaweed to produce 1 kg of abalone between 18 and 30 months (Roussel et al 2019)

• D: Laminaria digitata
• U: Ulva spp.
• S: Saccharina latissima
• P: Palmaria palmata
Conversion ratio of fresh seaweed in abalone

Conversion of seaweed to produce 1 kg of abalone between 18 and 30 months (Roussel et al 2019)

- D: Laminaria digitata
- U: Ulva spp.
- S: Saccharina latissima
- P: Palmaria palmata
And the resulting feeding costs...

**Production cost of 1 kg of abalone using seaweed**

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>P. palmata</strong></td>
<td>Fishery Closure</td>
<td>2.51 € But small quantities</td>
<td>1.07 €</td>
<td>0.71 €</td>
</tr>
<tr>
<td><strong>L. digitata</strong></td>
<td>10.63 €</td>
<td>5.94 €</td>
<td>1.68 €</td>
<td>Not tested</td>
</tr>
<tr>
<td><strong>S. latissima</strong></td>
<td>Too small</td>
<td>3.97 €</td>
<td>2.00 €</td>
<td>Not tested</td>
</tr>
</tbody>
</table>
P. palmata and S. latissima fields are limited...

- We needed to explore other options...
Seaweed culture
Exploring seaweed farming potential

Sea-based IMTA

Evaluation of the nutrition potential of each species for abalone

Land-based seaweed farming
Imagining a sea-based IMTA using abalone

Light and nutrients

1.5 km longlines
20T Saccharina latissima

200 cages
12T abalone

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Seaweed culture on longlines

*Saccharina latissima*  *Alaria esculente*

Photo: Hugo Morel

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Land-based seaweed farming
Juvenile age at transfer (days)

Nursery performances

Beginning of Seaweed culture & feeding with cultured Ulva

1st generation of genetic selection

2nd generation of genetic selection
### Three months nutrition trial with 6 seaweed species

<table>
<thead>
<tr>
<th>Monospecific diet</th>
<th>FCR (kg seaweed/kg abalone)</th>
<th>Monthly growth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alaria sea-based IMTA</strong></td>
<td>11.4</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>Calliblepharis wild</strong></td>
<td>6.2</td>
<td>2.4</td>
</tr>
<tr>
<td><strong>Chondrus wild</strong></td>
<td>3.5</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Saccharina sea-based IMTA</strong></td>
<td>5.7</td>
<td>3.2</td>
</tr>
<tr>
<td><strong>Palmaria palmata wild</strong></td>
<td>2.3</td>
<td>3.3</td>
</tr>
<tr>
<td><strong>Ulva spp. culture</strong></td>
<td>5.1</td>
<td>4.1</td>
</tr>
</tbody>
</table>

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Impact of seaweed farming
Economic model by Øystein Hermansen, Nofima

200 cages farm (9,4T)

- Stocking: 236,478 €
- Wild macroalgae: 76,767 €
- IMTA macroalgae: 64,882 €

200 cages farm with 30% IMTA macroalgae (9,9T)

- Stocking: 247,673 €
- Wild macroalgae: 66,312 €
- IMTA macroalgae: 44,425 €
- Margin: 38,078 €

IMTA sugarkelp: better quality, better growth, better FCR, more production, more sustainable farm but higher feeding cost.

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French ecosystem
French ecosystem: Production under threats

There is a strong demographic pressure on French coastal areas:

• Conflict for Space & resources:
  • tourism & real estate
  • Industrial fishing industry for macroalgae
  • Wind farming development

• Pollution
  • Microbiological contaminations
  • Oil spills

• Ocean warming & acidification
• Change in policy/regulations
French ecosystem: a wealth of opportunities

- Gastronomy, culture & sustainable farming
  - Organic Certification for seaweed

- CCF: "No quality cooking without quality products"

- Ethic Ocean-Aquavitae Master class

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Getting abalone known to French gastronomes

In France, abalone are sold locally to gastronomy restaurants for unique culinary experiences

- Younger, smaller and tenderer...
- Regularly calibrated, and always available,
- No impacts on wild populations,
- Easy to prepare & great taste.
Diversification opportunities

- Fresh and dry seaweeds to our abalone customers...
- Growing interest for seaweed in Europe for a more vegetal regime
Thank you for your attention...

Any question?

Photo: Chris Miller