Large scale cultivation of *Ulva* - about Scandinavian biodiversity and off-shore biomass production



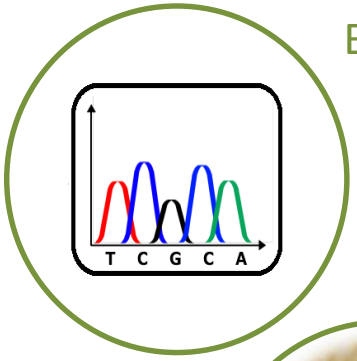

Sophie Steinhagen

ALGET 2, 3rd February

Content

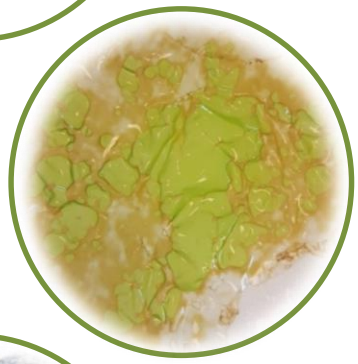
Industrial application

Biodiversity assessments

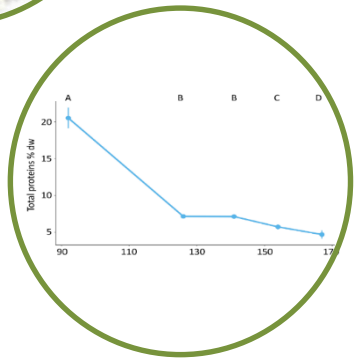


Protein enrichment and extraction

Life cycle control



Biochemical biomass profiling



Large-scale cultivation (on- & off-shore)

Characteristics of *Ulva*

- One of the first described algal taxa (Linnaeus 1753)
- Globally distributed
- Adapted to high disturbed areas
- Opportunistic
- Capable of forming mass accumulations of biomass
- Among most prominent fouling organisms
- Promisig renewable resource (e.g. food, biomaterials)

Not all *Ulva* species share the same traits
→ Correct species identification

Source: Catxalot

Biodiversity of *Ulva*

Ulva species in Sweden were formerly seperated into two (main) entities:

Ulva lactuca

Ulva intestinalis

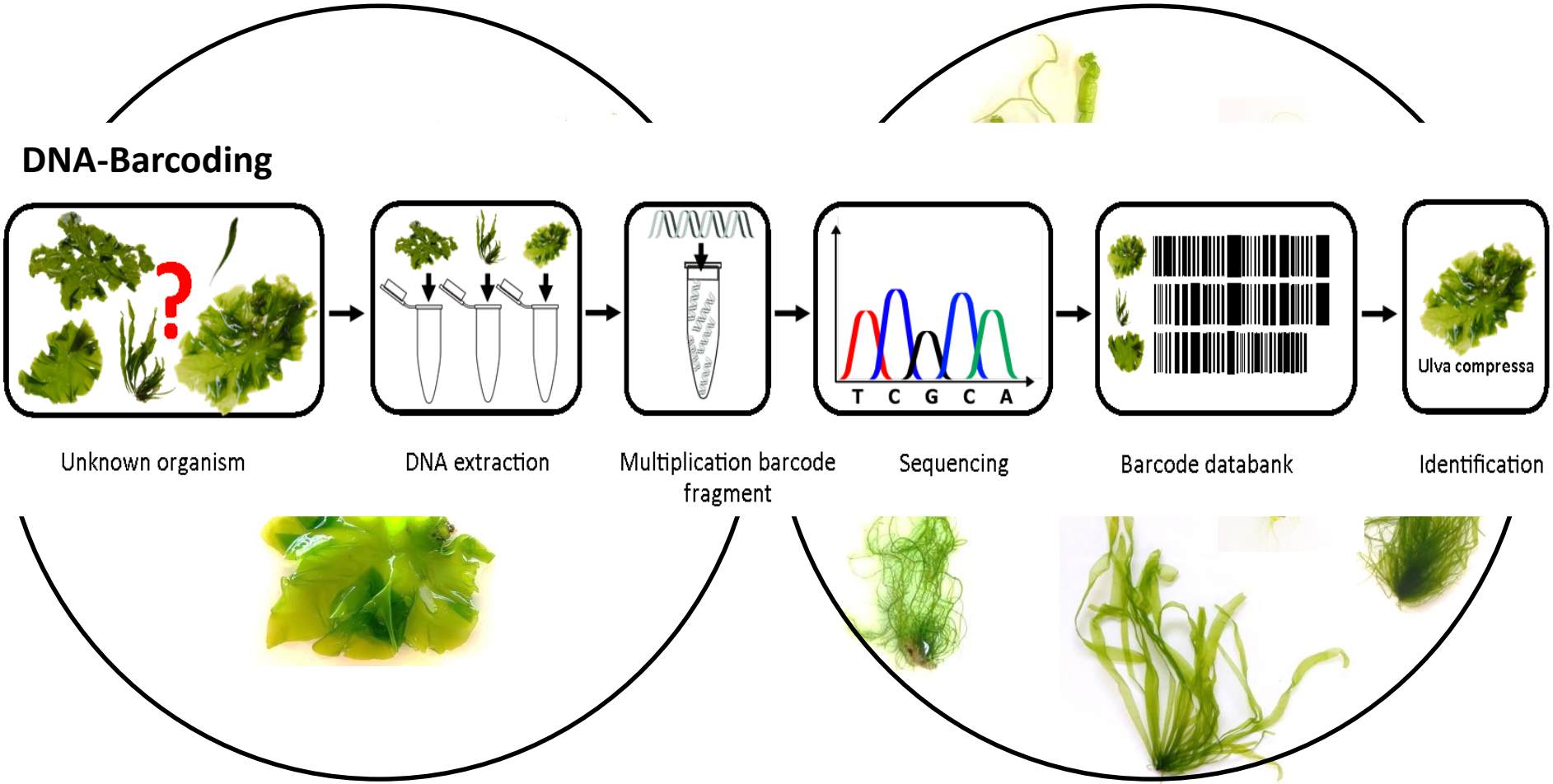
„Sea lettuce“
Havssallat

„Gut weed“
Tarmtång

Biodiversity of *Ulva*

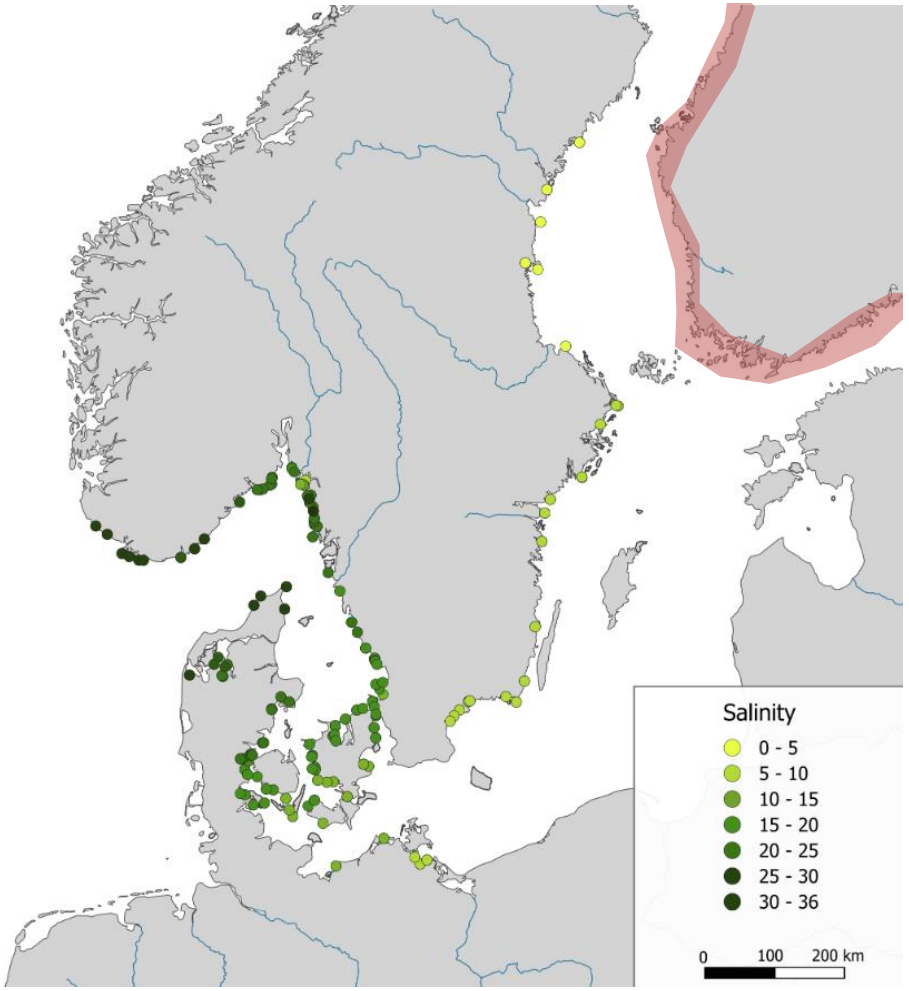
leaf-like

tubular



Mapping the biodiversity of green seaweeds

- Mapping the biodiversity of *Ulva sensu lato* in the Baltic Sea to,
  - A.) gather knowledge on the distribution of species (ecotypes; invasive species, mass accumulations)
  - B.) assess the species ecological differences along a salinity gradient (relevant for cultivation success)
  - C.) Determine biochemical profiles among species and within species



Samples: DNA barcoding, genotyping, biomass for biochem. profiling, microbiome)

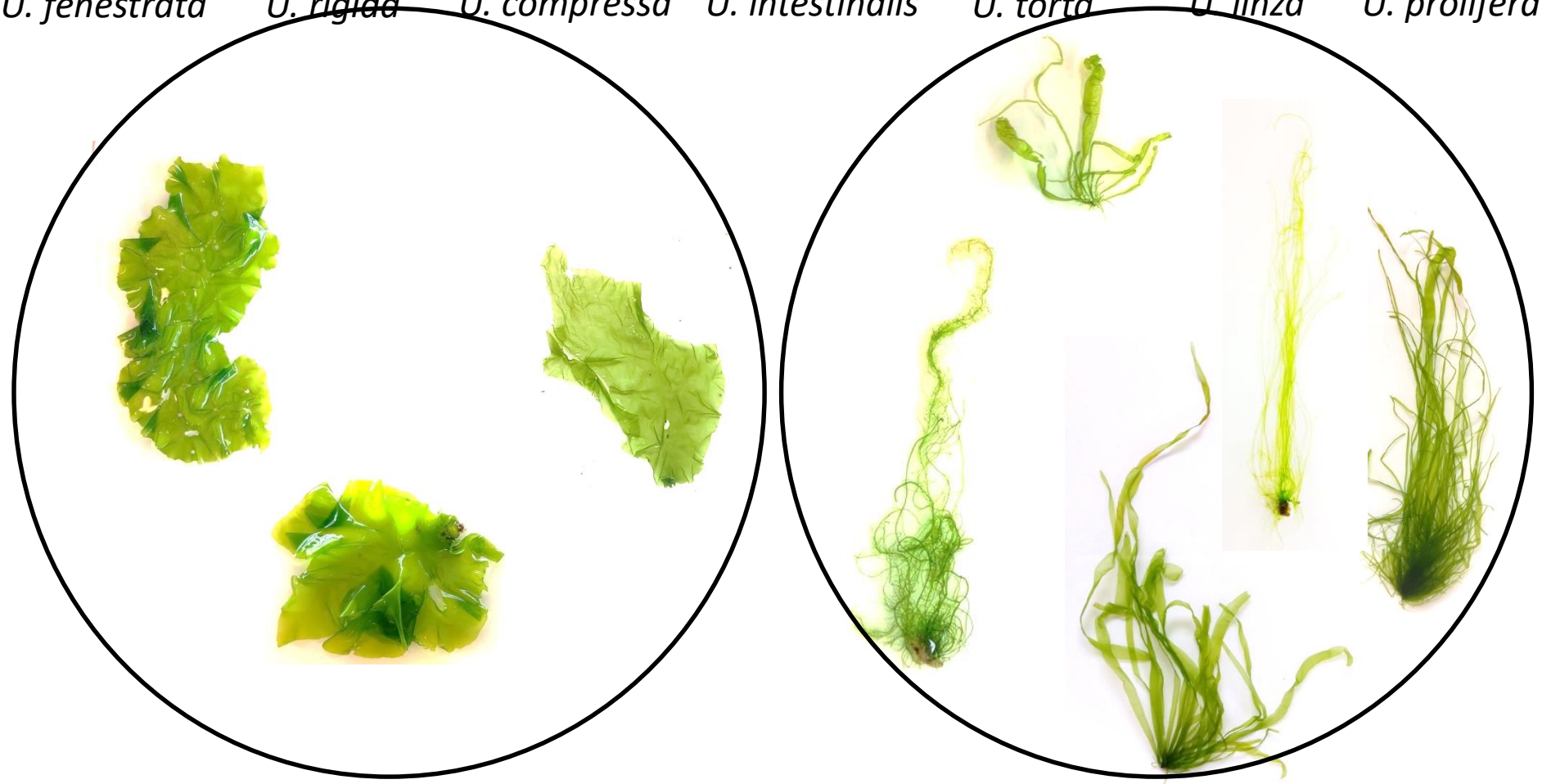
Biodiversity of *Ulva*

leaf-like

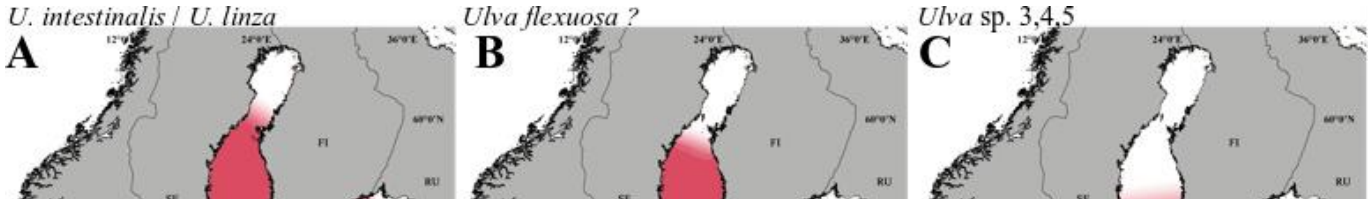
U. fenestrata *U. rigida* *U. compressa* *U. intestinalis*

tubular

U. torta *U. linza* *U. prolifera*

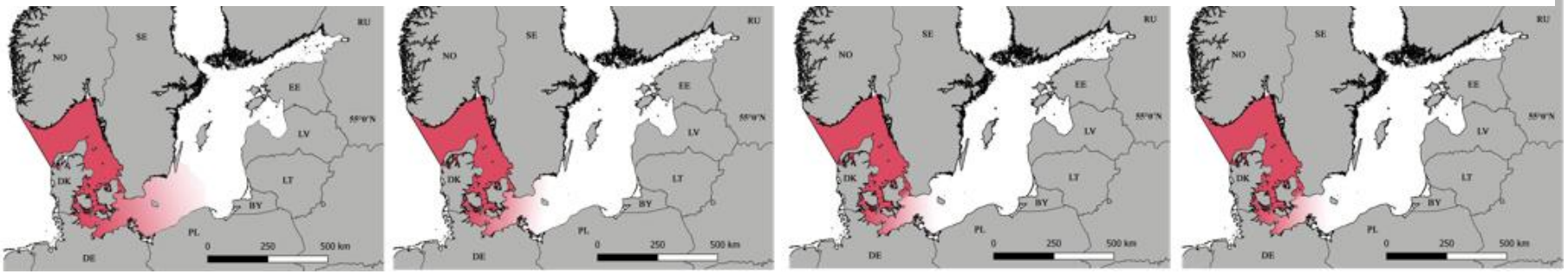


Mapping the biodiversity of green seaweeds



→ **Higher biodiversity and distinct species distributions**

→ **Several historic mis-identifications**



Mapping the biodiversity of green seaweeds

→ **Which species to cultivate?**

- **Differences Skagerrak, Kattegat, Baltic Sea**

APPLIED PHYCOLOGY
2020, VOL. 1, NO. 1, 80-92
https://doi.org/10.1080/26388081.2020.1827454

Open access

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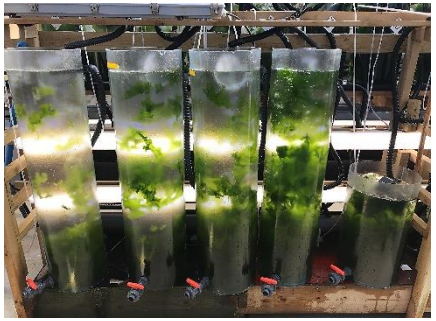
Effects of geographical location on potentially valuable components in *Ulva intestinalis* sampled along the Swedish coast

Joakim Olsson [a], Sofia Raikova [b], Joshua J. Mayers [a], Sophie Steinhagen [c], Christopher J. Chuck [b], Göran M. Nylund [c], and Eva Albers [a]

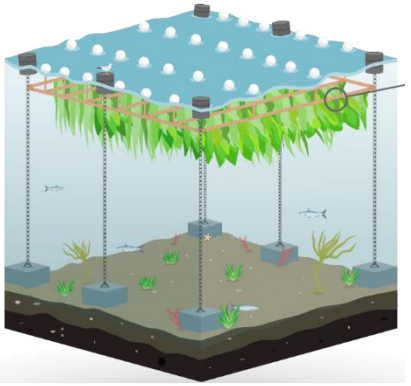
Aquaculture of *Ulva*

Green house


- Permanent access to biomass
- Total control about cultivation parameters
- Year round biomass production

Open water seafarm

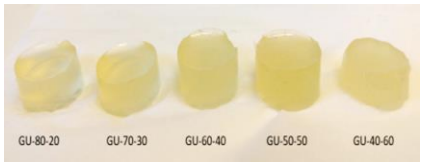
- Sustainable cultivation
- Large scale biomass production
- Less maintenance


Why *Ulva* ?

Ulvan dialdehyde-gelatin hydrogels for removal of heavy metals and methylene blue from aqueous solution

Niklas Wahlström[a], Sophie Steinhagen[b], Gunilla Toth[b], Henrik Pavia[b], Ulrica Edlund[a,*]

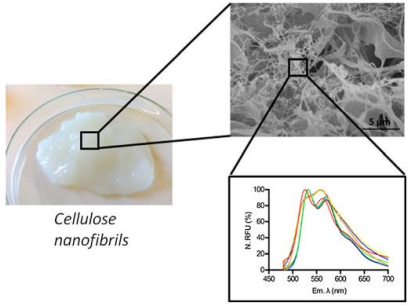
[a] Fiber and Polymer Technology, KTH Royal Institute of Technology, Teknikringen 56, SE-100 44, Stockholm, Sweden
[b] Department of Marine Sciences, Lovén Centre for Marine Sciences – Tjärnö, University of Gothenburg, SE-452 96, Strömstad, Sweden



ORIGINAL RESEARCH

Cellulose from the green macroalgae *Ulva lactuca*: isolation, characterization, optotracing, and production of cellulose nanofibrils

Niklas Wahlström · Ulrica Edlund · Henrik Pavia · Gunilla Toth · Aleksander Jaworski · Andrew J. Pell · Ferdinand X. Choong · Hamid Shirani · K. Peter R. Nilsson · Agneta Richter-Dahlfors



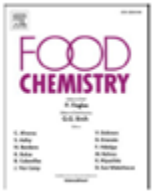
Cellulose nanofibrils

Ulva fenestrata protein – Comparison of three extraction methods with respect to protein yield and protein quality

L. Juul[a,b], M. Danielsen[a,b], C. Nebel[a], S. Steinhagen[f], A. Bruhn[b,d], S.K. Jensen[b,e], I. Undeland[g], T.K. Dalsgaard[a,b,c,*]

In vitro digestibility and Caco-2 cell bioavailability of sea lettuce (*Ulva fenestrata*) proteins extracted using pH-shift processing

João P. Trigo[a,*], Niklas Engström[a], Sophie Steinhagen[b], Louise Juul[c], Hanna Harrysson[a], Gunilla B. Toth[b], Henrik Pavia[b], Nathalie Scheers[a], Ingrid Undeland[a,*]

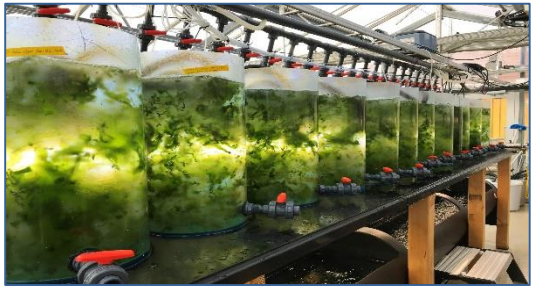
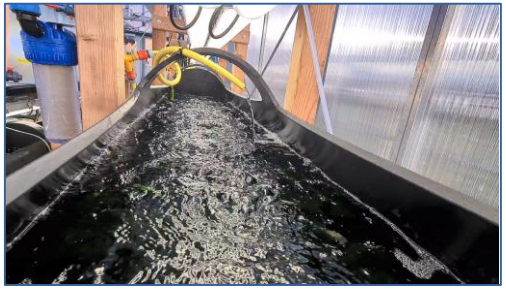


Why *Ulva* ?

Ulvan dialdehyde-gelatin hydrogels for removal of heavy metals and methylene blue from aqueous solution

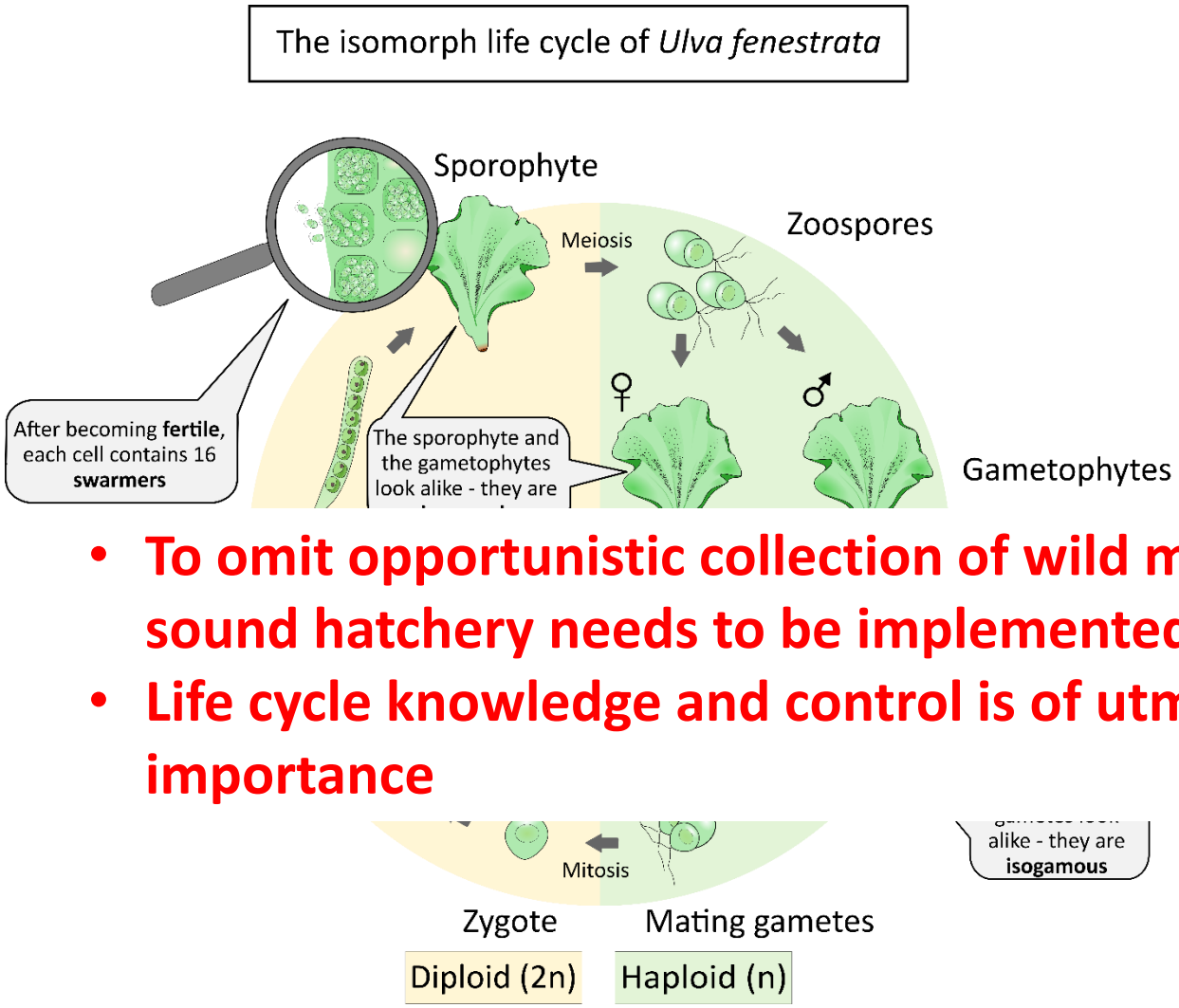



Prerequisite: cultivation on industrial scale beyond lab- or pilot level!

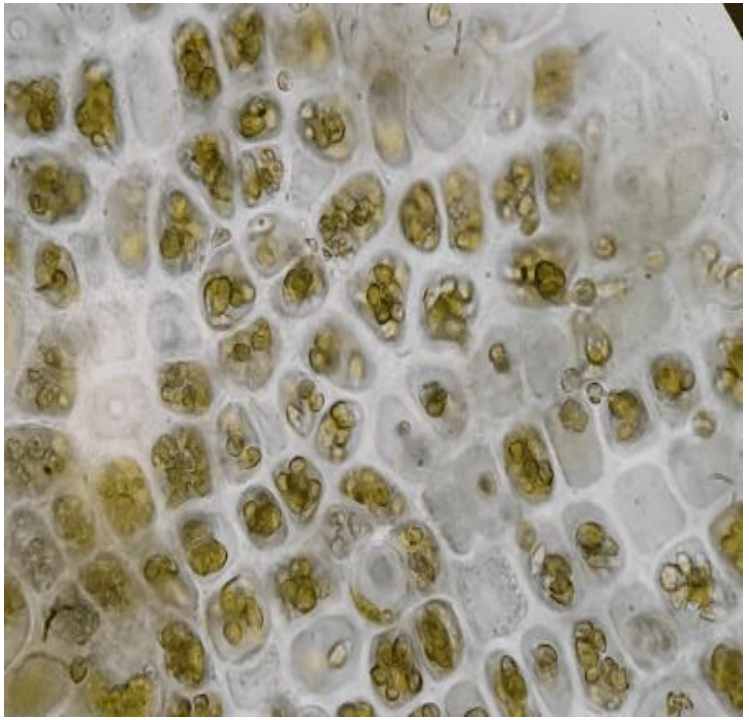

Gunilla B. Toth [b], Henrik Pavia [b], Nathalie Scheers [a], Ingrid Undeland [a,*]

The life cycle of *Ulva*

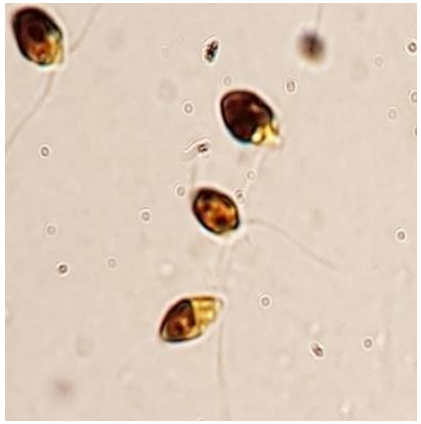


- **To omit opportunistic collection of wild material a sound hatchery needs to be implemented!**
- **Life cycle knowledge and control is of utmost importance**

The life cycle of *Ulva*



Zoids (quadriflagellate)



Gametes (biflagellate)

Experimental set-up

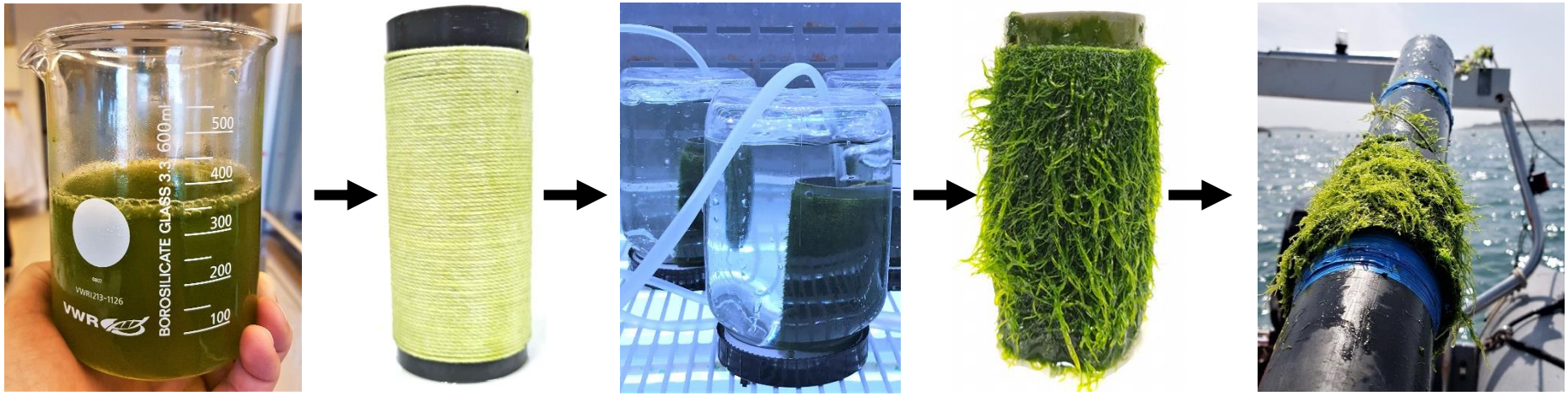
Part I: Hatchery

- Induction of fertility (*U. fenestrata*) application of gametes to coiled twine
  - Swarmer density (10 000, 500 swarmers/ml)
  - Temperature (10°C, 15°C)
  - Nutrients (PES, PES x3)

} Fully crossed design; n = 5; twine length = 7-10 m

Part II: Seafarm cultivation

- After 7 weeks hatchery transfer to seafarm
- Growth at Swedish winter conditions



Experimen Seafarm cultivation

- Successful large-scale ocean-based cultivation
- *U. fenestrata* is a suitable crop northern European hemisphere
- Copes very well with the harsh conditions.
- The off-shore cultivated biomass was found to be enriched by several high-value macro-and micronutrients
- We were able to show that pre-treatments during the hatchery phase affect the biomass yield and biochemical composition

→ Seasonal variation in growth/ biochemicals?

Journal of *Marine Science and Engineering*

MDPI

Article

Sustainable Large-Scale Aquaculture of the Northern Hemisphere Sea Lettuce, *Ulva fenestrata*, in an Off-Shore Seafarm

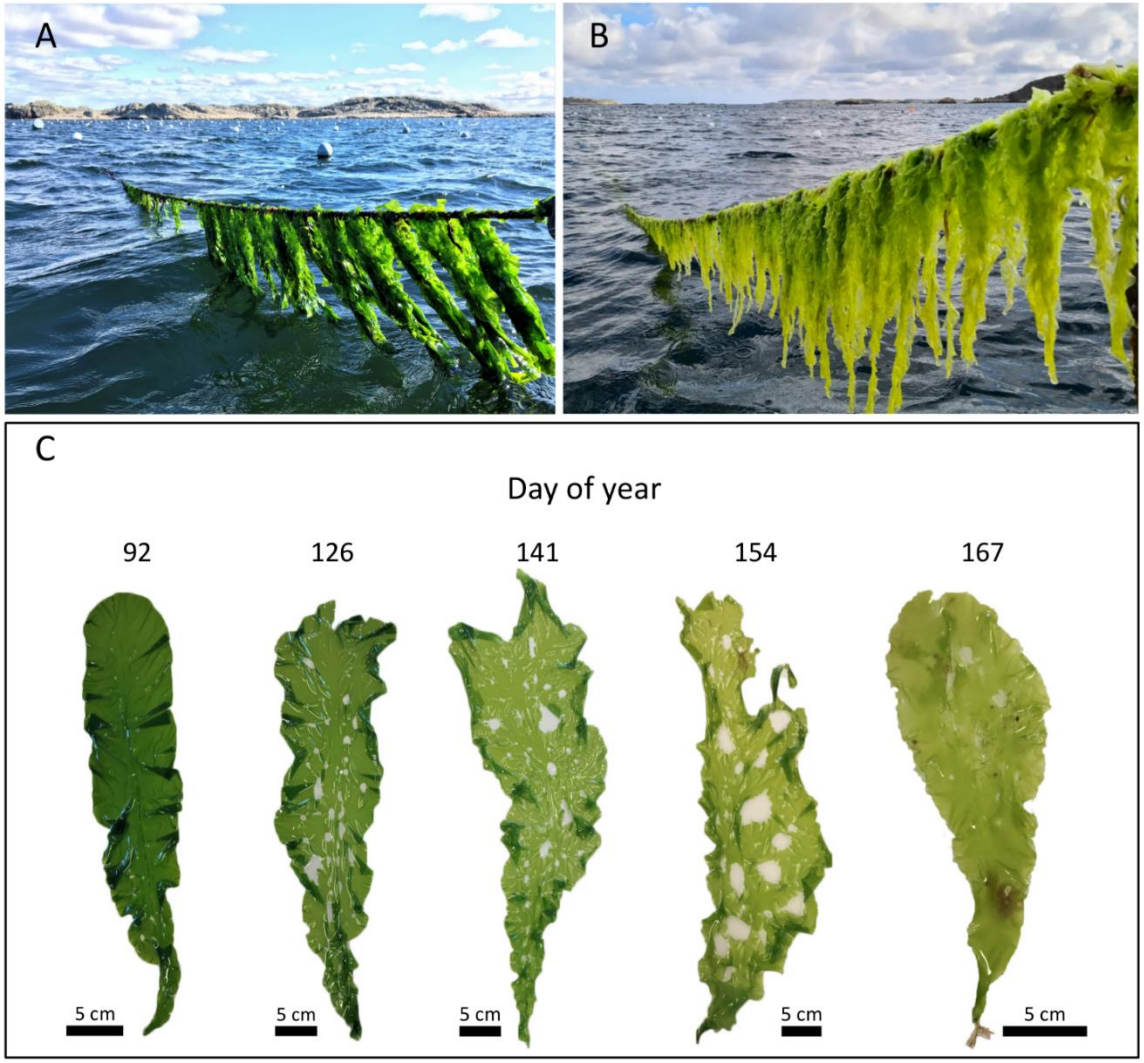
Sophie Steinhagen [1,*], Swantje Enge [1], Karin Larsson [2], Joakim Olsson [3], Göran M. Nylund [1], Eva Albers [3], Henrik Pavia [1], Ingrid Undeland [2] and Gunilla B. Toth [1]

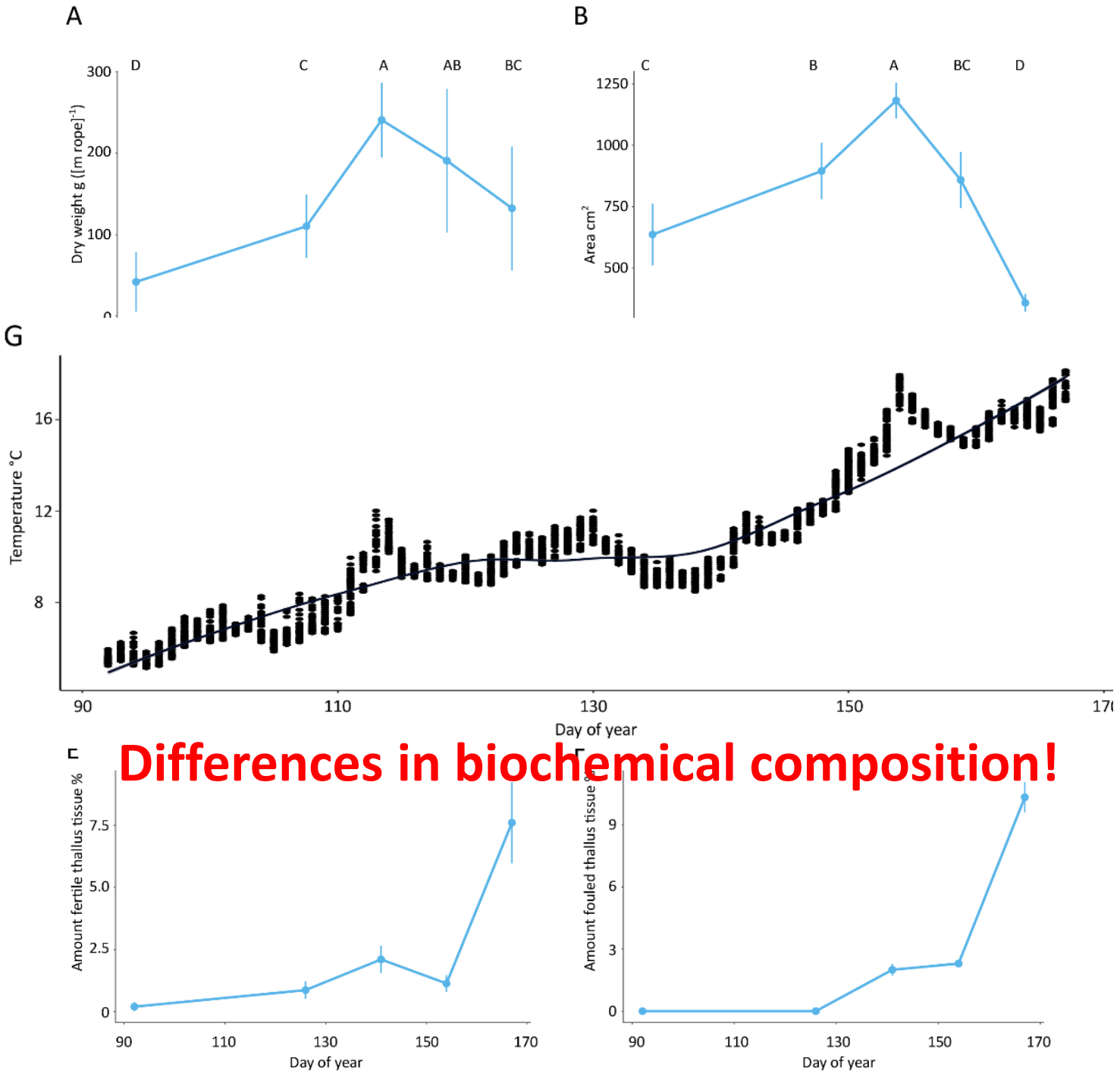
Results: Seafarm cultivation

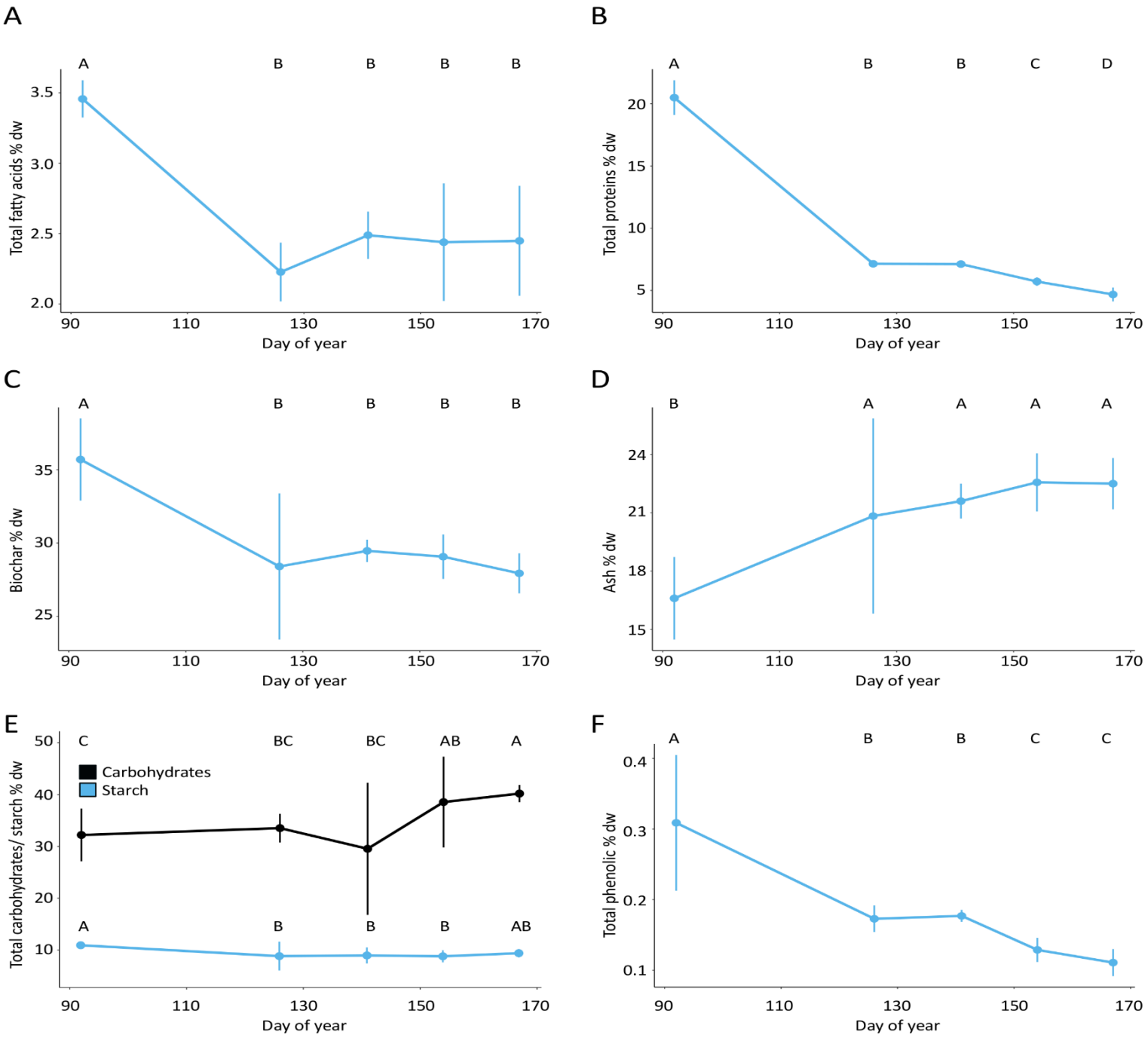
Extended growth periods (seasonality):

- **I:** 01.04.2020
- **II:** 05.05.2020
- **III:** 20.05.2020
- **IV:** 02.06.2020
- **V:** 15.06.2020

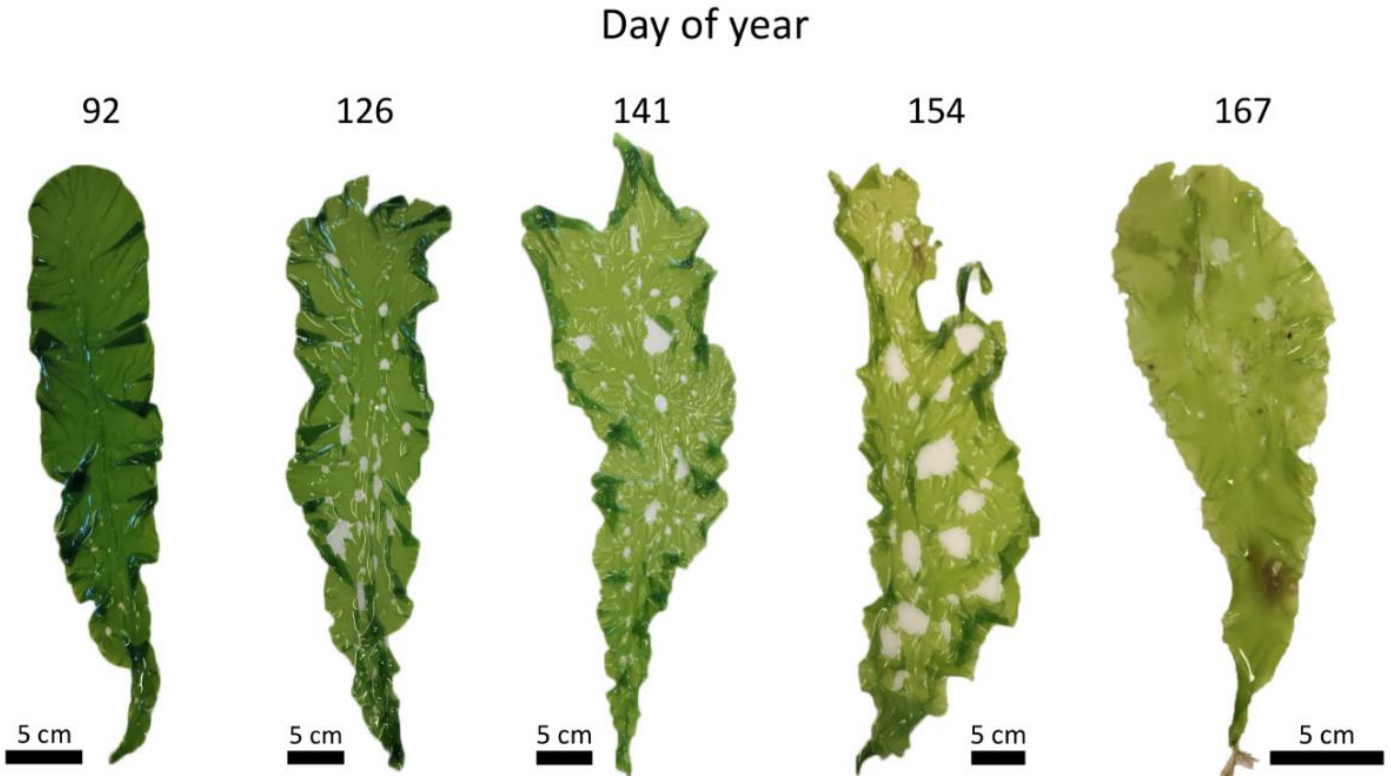
- Changes in biochemical profile?
- Increase of biomass yield?

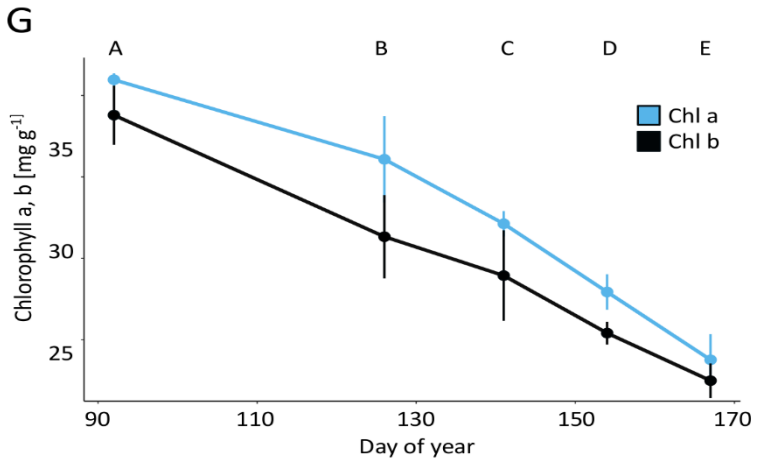


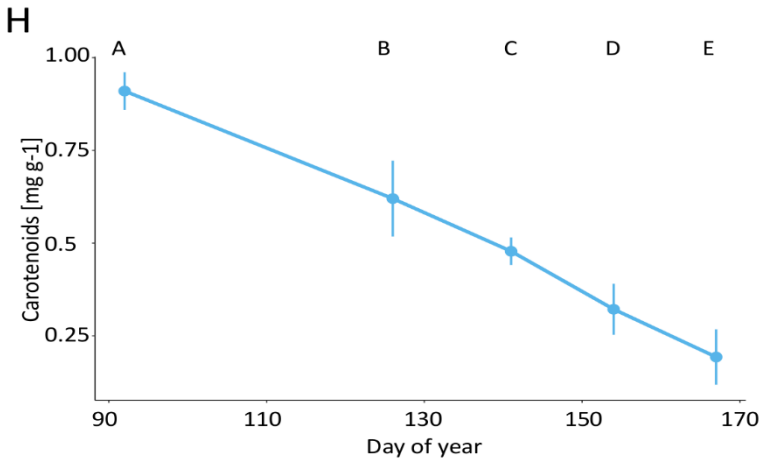

A
D
C
A
AB
BC
300
200
100
0
Dry weight g ([m rope]$^{-1}$)
B
C
B
A
BC
D
1250
1000
750
500
Area cm^2
G
16
12
8
Temperature °C
90
110
130
150
Day of year
Differences in biochemical composition!
Amount fertile thallus tissue %
7.5
5.0
2.5
0
90
110
130
150
170
Day of year
Amount fouled thallus tissue %
9
6
3
0
90
110
130
150
170
Day of year


A
A
B
B
B
B
Total fatty acids % dw
3.5
3.0
2.5
2.0
90
110
130
150
170
Day of year
B
A
B
B
C
D
Total proteins % dw
20
15
10
5
90
110
130
150
170
Day of year
C
A
B
B
B
B
Biochar % dw
35
30
25
90
110
130
150
170
Day of year
D
B
A
A
A
A
Ash % dw
24
21
18
15
90
110
130
150
170
Day of year
E
C
BC
BC
AB
A
Carbohydrates
Starch
Total carbohydrates/ starch % dw
50
40
30
20
10
A
B
B
B
AB
90
110
130
150
170
Day of year
F
A
B
B
C
C
Total phenolic % dw
0.4
0.3
0.2
0.1
90
110
130
150
170
Day of year

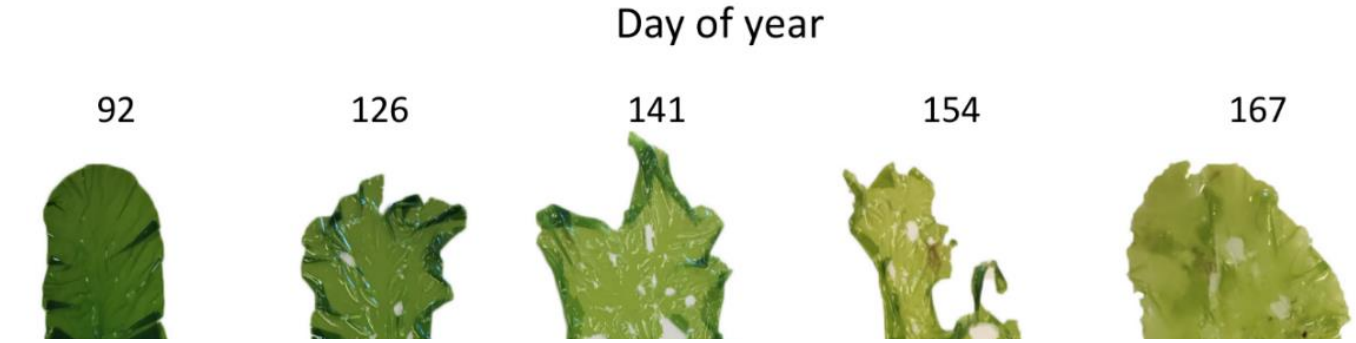
Results: Seafarm cultivation







Results: Seafarm cultivation



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ORIGINAL RESEARCH article

Harvest time can affect the optimal yield and quality of sea lettuce (Ulva fenestrata) in a sustainable sea-based cultivation

Sophie Steinhagen[1*], Swantje Enge[1], Gunnar Cervin[1], Karin Larsson[2], Ulrica Edlund[3], Alina E. Schmidt[3], Niklas Wahlström[3], Barbro Kollander[4], Henrik Pavia[1], Ingrid Undeland[2] and Gunilla B. Toth[1]

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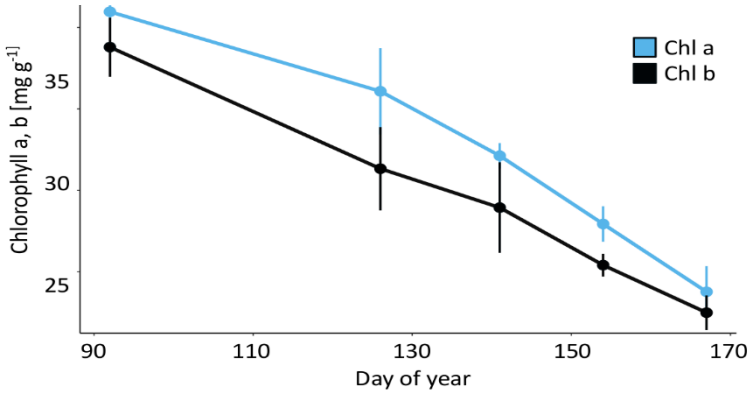

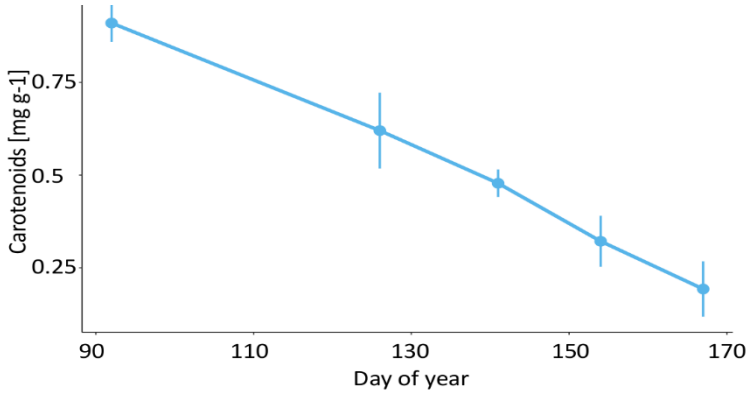


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