Intensiivse vesiviljeluse uued võimalused- edusammud *Ulva* kultiveerimistehnoloogiate väljatöötamisel meil ja mujal –

Georg Martin,

TÜ Eesti mereinstituut

Vetika- ja karbikasvatuse seminar
15.11.2021 algusega kell 12.00
Hestia Hotel Europa Põhja-Euroopa konverentsisaalis (Paadi 5, Tallinn)

Kalanduse teabekeskus www.kalateave.ee
EMKF RAKENDUSKAVA 2014-2020
Euroopa Liit Euroopa Merendus- ja Kalandusfond
Interreg Baltic Sea Region
EUROPEAN REGIONAL DEVELOPMENT FUND
EUROPEAN UNION
Blue Platform

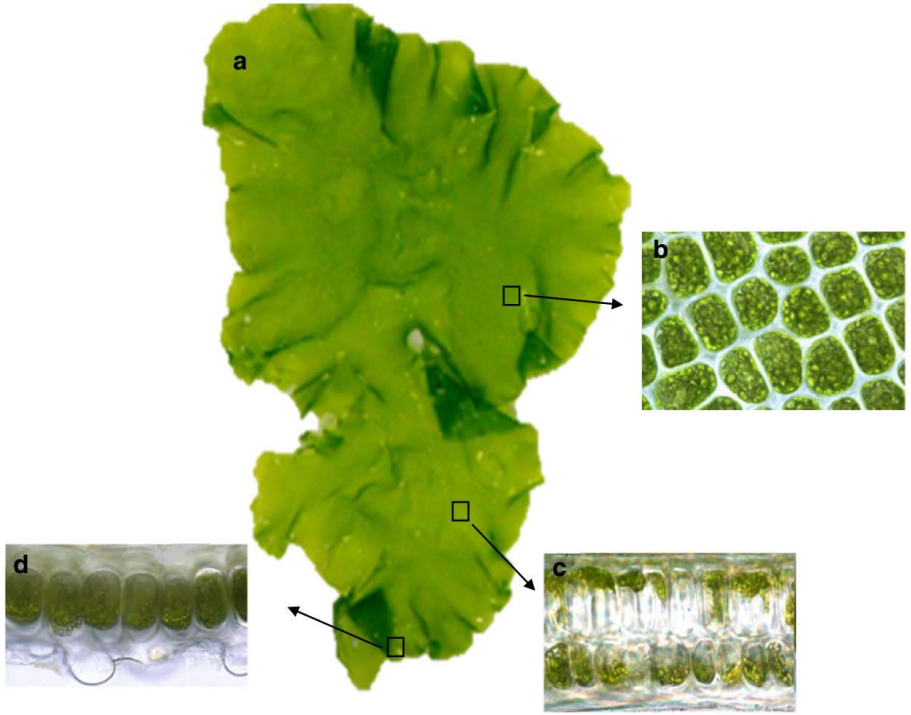


Fig. 1 Thallus organization in *Ulva* (**a**: Ulva thallus, **b**: Cell organization in surface view, **c**: Transverse section of thallus, **d**: Transverse section of rhizoidal cell). Adopted from Lawton et al. (2013)

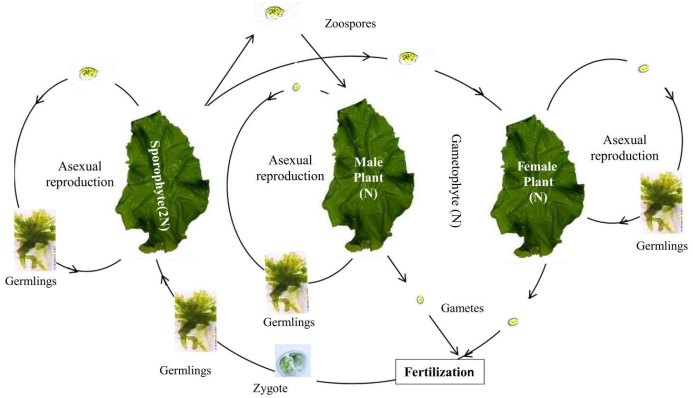


Fig. 3 Typical life cycle in *Ulva*

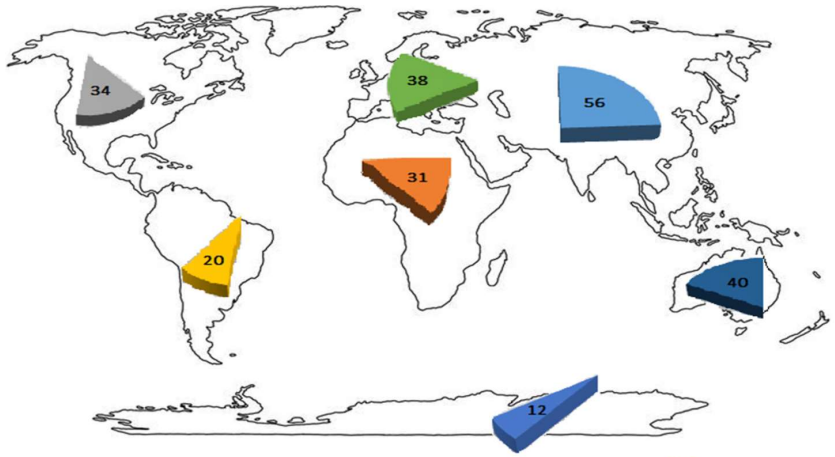


Fig. 2 World map showing continent-wise distribution of number of distinct species of *Ulva*. Source: Guiry and Guiry (2020)

Journal of Applied Phycology (2020) 32:2725–2741
https://doi.org/10.1007/s10811-020-02148-7

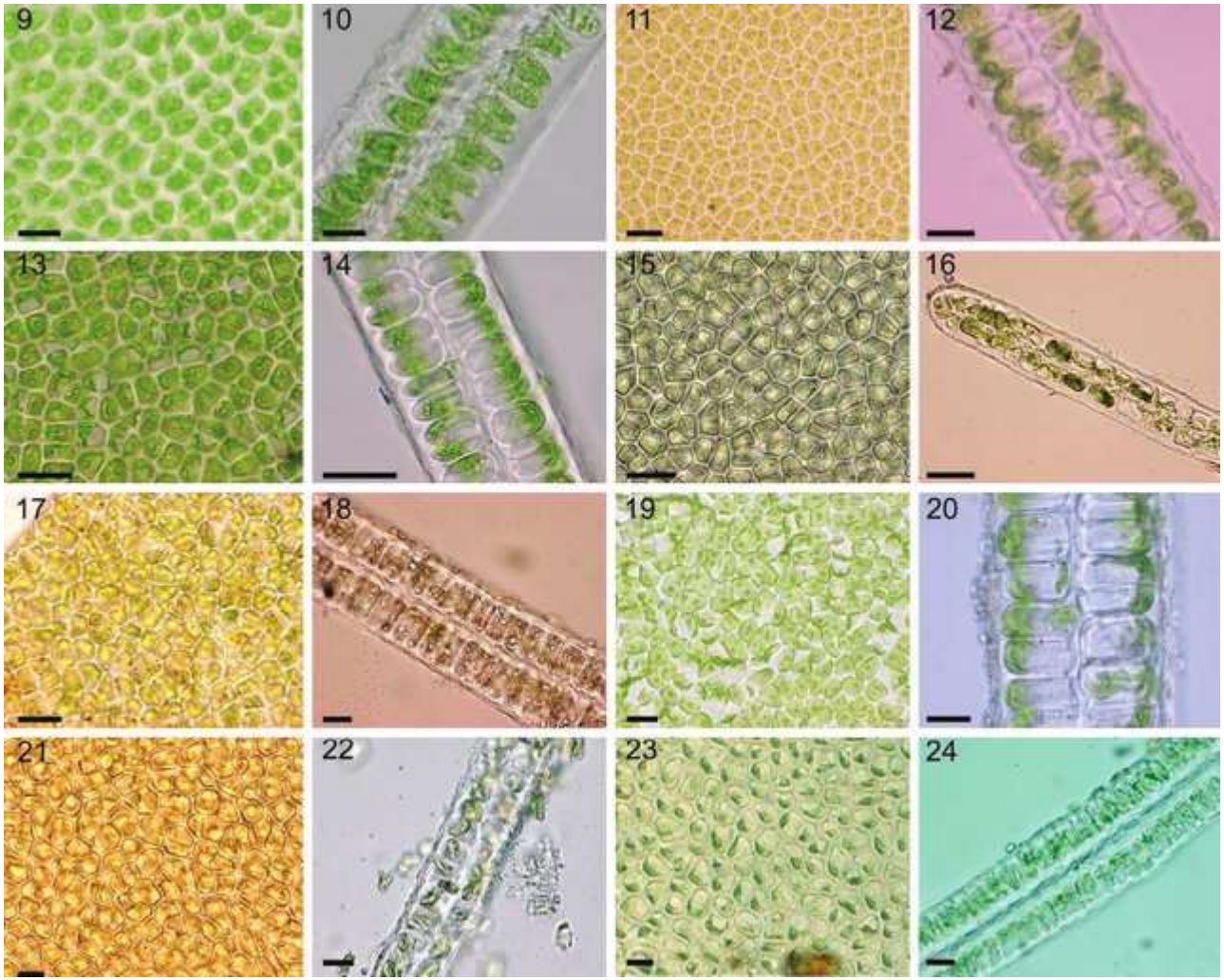
Concise review of green algal genus *Ulva* Linnaeus

Vaibhav A. Mantri[1,2] · Mudassar Anisoddin Kazi[1] · Nikunj B. Balar[1,2] · Vishal Gupta[3] · Tejal Gajaria[1,2]

Received: 17 January 2020 / Revised and accepted: 4 May 2020 / Published online: 26 June 2020

Abstract
The green algal genus *Ulva* is widely distributed around all continents. Plants with both distromatic or monostromatic thalli now form a single taxon based on ITS rDNA and *rbc*L gene sequencing. *Ulva* is known to occupy several ecological niches including freshwater and marine (intertidal and subtidal) habitats, attributed to its tolerance to key determinants such as light, temperature, and salinity. The genus is perceived as model system to study life cycle, morphogenesis and development from simple to complex multicellularity. The life cycle is isomorphic and biphasic type, knowledge of which is important in developing viable cultivation techniques. The culture of *Ulva* is by photo-bioreactor, land-based, and open-sea farming producing about 1500 t dry annum^{-1} biomass. The understanding of scientific basis for eutrophication-driven green tide events is of paramount importance for coastal ecosystem management. Studies related to cross-kingdom cross-talk between *Ulva* and surrounding microbes have been recently undertaken through high-throughput techniques to understand their role in growth, development, and morphogenesis. Several regional species are rich in vital nutrients and thus qualify in the functional food sector, and recent research is poised to develop a bio-refinery model for complete utilization of feedstock. *Ulva* spp. are also used as a feed source in aquaculture and for environmental bioremediation.

Keywords Chlorophyta · Bio-refinery · Green tide · Life cycle · Microbiome · Photo-bioreactor · *Ulva*



Ciaran et al 2006

Fig. 9. *U. rigida*, Fig. 10. *U. rigida*, Fig. 11. *U. scandinavica*, Fig. 12. *U. scandinavica*, Fig. 13. *U. lactuca*, Fig. 14. *U. lactuca*, Fig. 15. *U. gigantea*, Fig. 16. *U. gigantea*, Fig. 17. *U. rotundata*, Fig. 18. *U. rotundata*, Fig. 19. *Umbraulva olivascens*, Fig. 20. *Umbraulva olivascens*, Fig. 21. *U. californica*, Fig. 22. *U. californica*, Fig. 23. *U. compressa*, Fig. 24. *U. compressa*.

Tubular thalli, partly inflated, unbranched, except occasionally near the base

Typical large expanse on coastal rocks

Cells in random order with hood-shaped chloroplasts and one pyrenoid per cell.
Diameter of cells: 12.4–15.7 µm (can be up to 25 µm)

Ulva intestinalis

http://www.outerhebridesalgae.uk/

Miks just *Ulva*?

● Globaalne levik, madal rannikumeri, lihtne ligipääs kultiveerimismaterjalile (www.algaebase.com/Guiry 2020).

● Ülikiire kasvukiirus, võib kahekordistada oma biomassi päevaga ja on võimalik kasvatada suurtel pindadel ja kogustes aasta läbi, nii kinnitunult kui kinnitumata vormis (Broch et al., 2012, Bruhn et al. 2011; Shpigel et al., 2015; Praeger et al., 2019). Lihtne paljundada nii vegetatiivselt kui spooridena (Praeger et al, 2019).

● Lihtne kasvatada nii avameres kui maapealsetes tingimustes (Bolton et al., 2016)

● Mujal maailmas olemas kogemus biomassi tootmiseks ja kasutamiseks (värskelt või kuivatatult) inimtoiduks, loomasöödaks ja väärtuslike lisatoodete (kosmeetikatööstus, toidulisandid jne) tootmiseks (Bikker et al., 2016. Kidgell et al., 2019).

● Plastilisus biokeemilise koostise poolest, suur arv dokumenteeritud bioaktiivseid koostisaineid mis omavad antimikroobseid, antiviraalseid, antioksüdantsed ja vähivastaseid omadusi (Mantry et al., 2020).

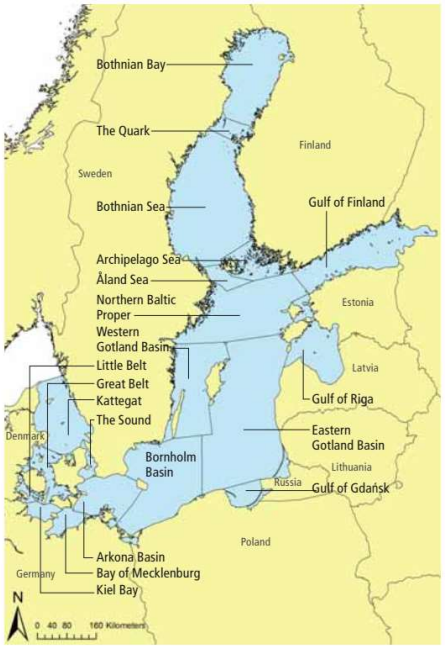
● Suurepärased omadused biofiltreerimiseks, toetades erinevaid ökosüsteemi teenusid ja kasutatav nii avavee kui maapealsete vesiviljeluse projektide kestlikumaks muutmisel (Msuya & Neori 2008, Neveux et al., 2017: Gao et al., 2018).

● Võime kiirelt salvestada süsinikku (Gao et al., 2018).

● Potentsiaalne tooraine biolaguneva materjali (bioplastiku) tootmiseks (Helmes, 2018; Zhang et al., 2019).

● Ulva on egeneetiliselt hästi uuritud ja hetkel ainuke suurvetikas mida saab geneetiliselt muundada (Oertel et al. 2015; de Clerck et al. 2018, Blomme et al. 2021)

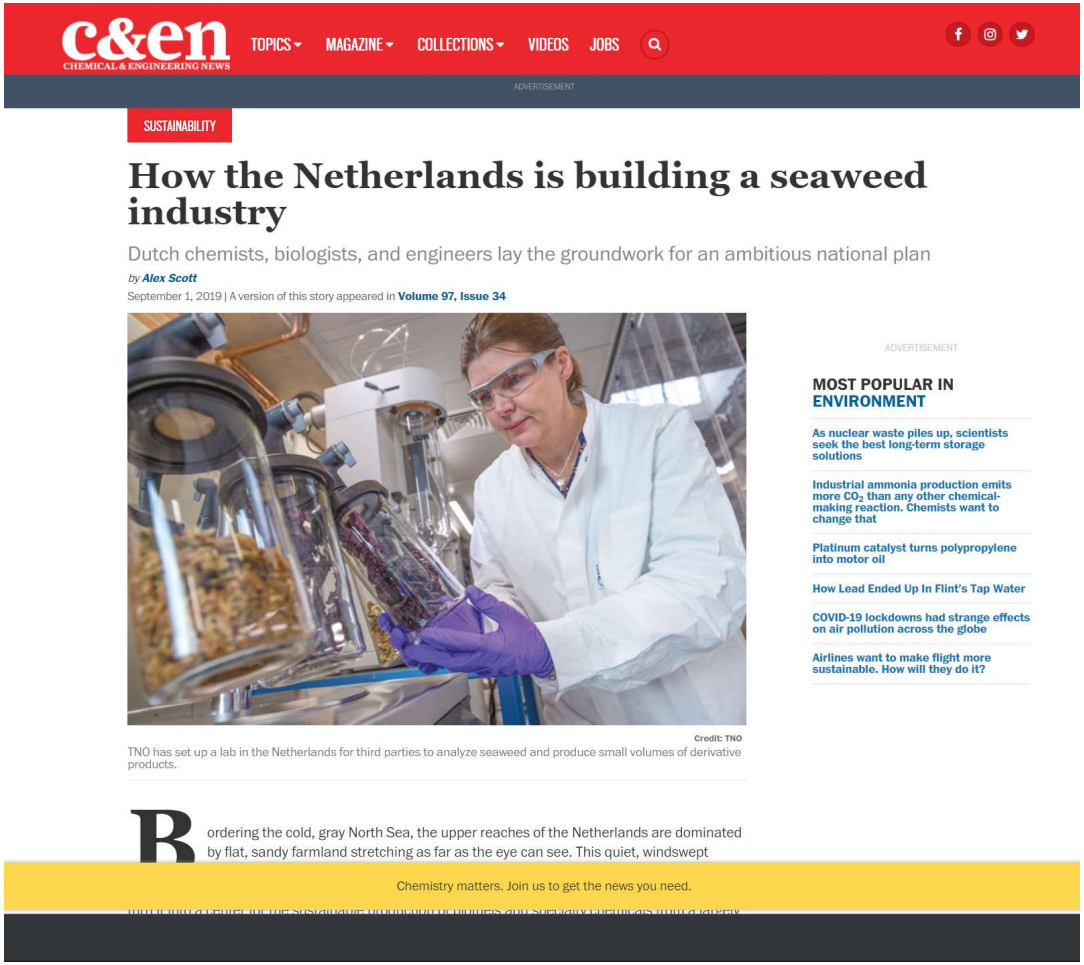
Ulva läänemeres



HELCOM Checklist for Baltic Sea Macrophyte Species

No	Valid scientifc name (2019)	Distribution (2018 subbasins)																	Family	Genus	Vernacular names
		A	B	C	D	E	F	H	I	J	K	L	M	N	O	Q		R			
		Kattegat	Great Belt	Kiel Bay	Bay of Mecklenburg	The Sound	Arkona Basin	Bornholm Basin	Western Gotland Basin	Eastern Gotland Basin	Gdansk Basin	Gulf of Riga	Nothern Baltic Proper	Gulf of Finland	Åland Sea	Bothnian Sea	The Quark	Bothnian Bay			
494	***Ulva clathrata***	X	X	X	X	X	X	X	X	X	X		X	X	X		P		Ulvaceae	*Ulva*	
495	***Ulva compressa***	X	X	X	X	X	X	X	X		X		X	X	X		P		Ulvaceae	*Ulva*	
496	***Ulva curvata***	X				X	X												Ulvaceae	*Ulva*	
497	***Ulva flexuosa***	X	X	X		X	X	X	X		X	X	X	X	X		P	X	Ulvaceae	*Ulva*	
498	***Ulva flexuosa subsp. paradoxa***	X	X	X		X										X	X		Ulvaceae	*Ulva*	
499	***Ulva intestinalis***	X	X	X	X	X	X	X	X	X	X	X	X	X	X	P	P	X	Ulvaceae	*Ulva*	Gut weed; gutweed
500	***Ulva lactuca***	X	X	X	X	X	X	X		X						P			Ulvaceae	*Ulva*	Sea lettuce
501	***Ulva linza***	X	X	X	X	X	X	X	X	X	X	X	X	X	X	P	P	X	Ulvaceae	*Ulva*	
502	***Ulva prolifera***	X	X	X	X	X	X	X	X	X	X	X	X	X	X	P	P		Ulvaceae	*Ulva*	
503	***Ulva prolifera***	X																	Ulvaceae	*Ulva*	
504	***Ulva torta***	X	X	X	X		X			X	X								Ulvaceae	*Ulva*	

Reinier Nauta checks Ulva growth in a 25,000 L saltwater tank at the NIOZ Seaweed Research Centre.



c&en CHEMICAL & ENGINEERING NEWS

TOPICS MAGAZINE COLLECTIONS VIDEOS JOBS

ADVERTISEMENT

SUSTAINABILITY

How the Netherlands is building a seaweed industry

Dutch chemists, biologists, and engineers lay the groundwork for an ambitious national plan

by Alex Scott

September 1, 2019 | A version of this story appeared in Volume 97, Issue 34

Credit: TNO

TNO has set up a lab in the Netherlands for third parties to analyze seaweed and produce small volumes of derivative products.

Bordering the cold, gray North Sea, the upper reaches of the Netherlands are dominated by flat, sandy farmland stretching as far as the eye can see. This quiet, windswept

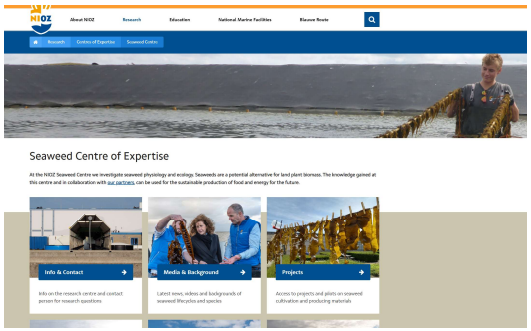
ADVERTISEMENT

MOST POPULAR IN ENVIRONMENT

- As nuclear waste piles up, scientists seek the best long-term storage solutions
- Industrial ammonia production emits more CO_2 than any other chemical-making reaction. Chemists want to change that
- Platinum catalyst turns polypropylene into motor oil
- How Lead Ended Up In Flint's Tap Water
- COVID-19 lockdowns had strange effects on air pollution across the globe
- Airlines want to make flight more sustainable. How will they do it?

Chemistry matters. Join us to get the news you need.

https://cen.acs.org/environment/sustainability/Netherlands-building-seaweed-industry/97/i34



The Dutch Weed Burger, a food company, is finding success selling burgers in Amsterdam infused with Ulva and sugar kelp.

Ulva kultiveerimise projektid mujal

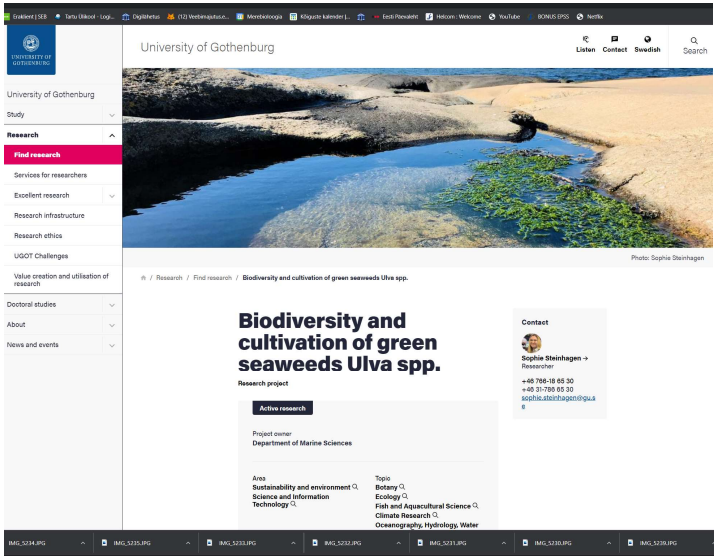
USA

Ulva sp cultivated in ponds at the University of Baja California in collaboration with PROMAC and Blue Evolution

Goal: Generating knowledge about physiological responses of seaweeds (including Ulva sp) to changing experimental conditions during cultivation. Applying this knowledge to optimize cultivation conditions.

https://www.researchgate.net/project/Ulva-Project-Physiological-responses-and-growth-of-Ulva-sp-under-experimental-cultivation-in-land-based-ponds

ROOTSI



https://www.gu.se/en/research/biodiversity-and-cultivation-of-green-seaweeds-ulva-spp

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

Malmö 29.11.2010

Cultivation of *Ulva lactuca* for bioenergy

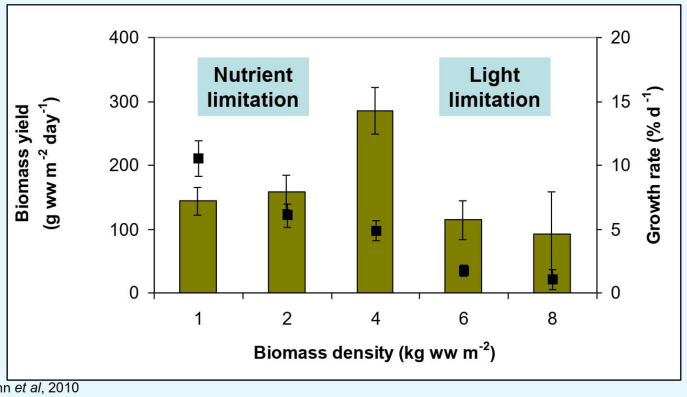
Bruhn A, Rasmussen MB, Dahl J, Nikolaisen LS, Nielsen HB, Thomsen AB, Sander B and Ravn E



AlgeCenter Danmark

Production potential

Optimal stocking density = 4 kg m^{-2} (N=3)



6: Bruhn *et al*, 2010

Production potential

Cultivation facility [5]

- 56º 47' 16'' North (Mors)
- 1 m^2 tanks
- continuous aeration
- addition of N and P
- water exchange 6 times per day
- salinity 25-28.5 psu
- weekly adjustment of stocking density

5: Bidwell 1985

Conditioning and storage

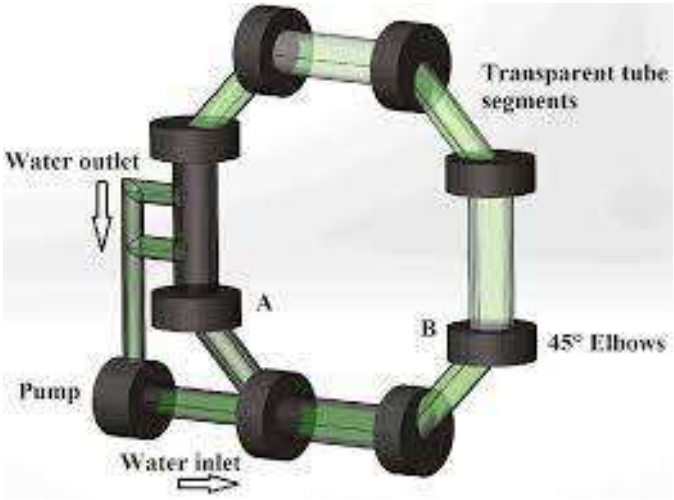
- **For futher processes**
  - **Avoid sand at harvest**
  - **Avoid salt – or rinse**
- **Screwpress**
  - **reduction to 30 % water content**
- **Pelletisation**
  - **Unproblematic**
  - **Water content of 17.5 % and a density of 800 kg m^{-3}**
  - **Compression of biomass by a factor 12**


https://fileadmin.cs.lth.se/luarchive/www.oresund.org/logistics/content/download/76177/443542/file/Cultivation%20of%20Ulva%20lactuca%20for%20biofuels.%20Anette%20Bruhn,%202010..pdf

Patenteeritud ja toimivad *Ulva* kultiveerimise tehnoloogiad

Patented “Ulva Bioreactor” model which gave annual Ulva lactuca biomass production data of around 50 Mt (metric tonnes) dry weight/ha/year (≈365 days). Towards A Seaweed Based Economy " : The Global Ten Billion People Issue At The Midst Of The 21St Century. Available from:

https://www.researchgate.net/publication/293647996_Towards_A_Seaweed_Based_Economy_The_Global_Ten_Billion_People_Issue_At_The_Midst_Of_The_21St_Century [accessed Nov 11 2021].



Sebök, Stefan, Herppich, Werner B. and Hanelt, Dieter. "Outdoor cultivation of *Ulva lactuca* in a recently developed ring-shaped photobioreactor: effects of elevated CO_2 concentration on growth and photosynthetic performance" *Botanica Marina*, vol. 62, no. 2, 2019, pp. 179-190. https://doi.org/10.1515/bot-2018-0016

Projekt: Mereveel põhineva kalakasvatuse heitvee puhastamine suurvetikate kultiveerimise kaudu.

EMKF RAKENDUSKAVA 2014-2020

Euroopa Liit
Euroopa Merendus- ja Kalandusfond

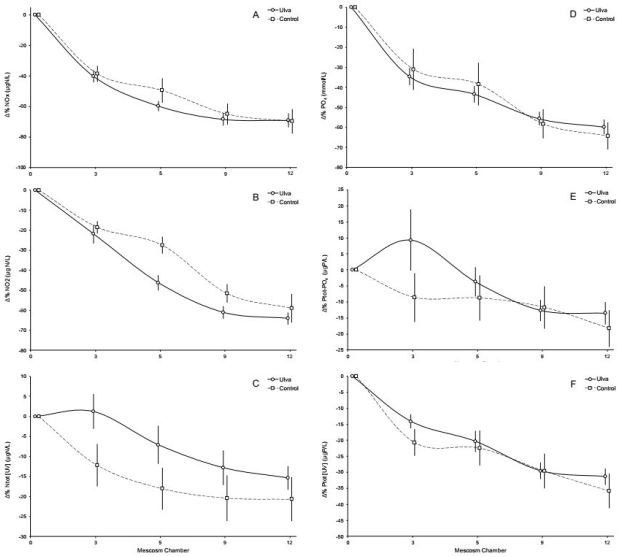


Figure 1: Change in the mean concentration of the nutrients (A = nitrite; B = nitrate; C = total nitrogen; D = phosphate; E = phosphorus; and F = total phosphorus) as a percentage relative to the initial trout stocked mesocosm across the mesocosm series. The mesocosms ranked four, five and six in the Ulva series were stocked with macroalgae. The control series contained no macroalgae. Error constructed as ±1 standard error.

TARTU ÜLIKOOL

EMKF RAKENDUSKAVA 2014-2020

MEREVEEL PÕHINEVA KALAKASVATUSE HEITVEE PUHASTAMINE SUURVETIKATE KULTIVEERIMISE KAUDU

Euroopa Merendus ja Kalandusfondi rakenduskava 2014-2020 meetme 2.1
"Vesiviljeluse innovatsioonitoetus" projekti lõpparuanne
(projekti viitenumber 821017780003)

Toetuse saaja: Tartu Ülikool
Aruande koostaja: Georg Martin (TÜ Eesti mereinstituut)

2021

FILTRATION OF DISSOLVED ORGANIC NUTRIENTS FROM FISH FARM WASTEWATER USING A MACROALGAE BIOFILTER

JACK R. HALL* & GEORG MARTIN
Estonian Marine Institute, University of Tartu, Estonia

ABSTRACT

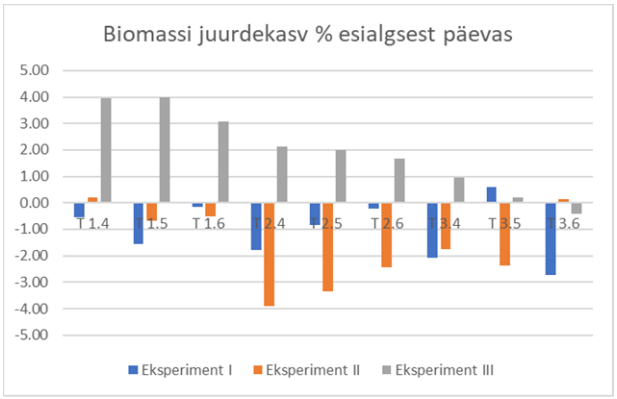
Intensive animal aquaculture damages the environment by releasing large quantities of nutrients which drives eutrophication in aquatic ecosystems. Macroalgae are efficient in uptaking nutrients as they grow with past studies suggesting their integration into aquaculture systems as a means to improve wastewater quality. This study was designed to assess the feasibility of using macroalgae as a biological filtration system for the removal of dissolved nutrients found in finfish farm wastewater. To test this, an experimental fish farm and mesocosm system was established on the northern coast of Saaremaa island, West Estonian archipelago. The green algae *Ulva intestinalis* was selected as a good candidate to assess the efficacy of a macroalgae biofiltration system to uptake nutrients. The results obtained show at best a 18–25% reduction in waste water nutrient concentrations for the nitrogenous compounds nitrite and nitrate for mesocosms stocked with macroalgae compared with the control. The system experienced an average 60% reduction in nitrogen and phosphorus concentrations in wastewater outflow compared to concentrations present within the finfish mesocosm. Additionally, the subsequent biomass gain of the incubated macroalgae species *Ulva intestinalis* is reported to be 4% per day at its maximum rate. The results obtained in this study indicate that *Ulva intestinalis* can be integrated into aquaculture systems as a nitrogen biofilter. In addition, the macroalgae biomass produced may offer aquaculture operations an additional income stream improving farm economics.
Keywords: aquaculture, biofilter, macroalgae, nutrients, bioremediation, ulva, nitrogen, IMTA.

1 INTRODUCTION

The decline of wild fish stocks has necessitated the need for aquaculture to offset the increasing global demand for fish protein [1]. However, as demand for fish protein grows the increasing intensification of finfish aquaculture requires ever greater inputs, in particular, that of fish feed [2], [3]. However, as no operation is 100% efficient, wastes in such systems are formed as either by-products or as unused inputs. As a consequence, Intensive finfish aquaculture is known to cause several adverse environmental impacts through the excessive output of nutrients, particularly nitrogen and phosphorous, into aquatic ecosystems [4]–[6]. For instance, the production of finfish in Japan has been found to generate on average approximately 0.8 kg of N and 0.1 kg of phosphorus irrespective of fish species cultivated [7]. Furthermore, the waste discharged by 63,000 tons of finfish or the total amount of cultivated fish in Japan for the year of 1999 is equivalent to that of 5 million people [7]. Consequently, coastal eutrophication has been identified as on major ecological impact and one that disproportionally effects enclosed and coastal systems associated with finfish aquaculture. This highlights the need for the development of strategies that limit the output of nutrients as a means to protect the environment and to ensure the future expansion and intensification of finfish aquaculture is conducted in a sustainable manner. Therefore, the challenge that is presented is to develop methods and technologies that minimize the negative environmental impacts of finfish aquaculture wastes.

* *ORCID: https://orcid.org/0000-0002-7446-855X*

WIT Transactions on Ecology and the Environment, Vol 250, © 2021 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/WRM210071



Projekt: Rohevetika *Ulva intestinalis* kasvatamise tehnoloogia mahutites mere- ja magevees.

Eesmärk: selgitada välja rohevetika Ulva intestinalis kasvatamiseks optimaalsed tingimused ja selle baasil kirjeldada vetika kasvatamiseks optimaalne tehnoloogia.

Asukoht: Kesknõmme kalakasvatuse ja Pihtla kalakasvatus

Tingimused: Kesknõmme – looduslik merevesi
Pihtla – magevesi (kunst merevesi)

Jälgitavad parameetrid: vetika biomass (kord nädalas), soolsus, toitained, valgus, temperatuur

Projekt: Rohevetika *Ulva intestinalis* kasvatamise tehnoloogia mahutites mere- ja magevees.

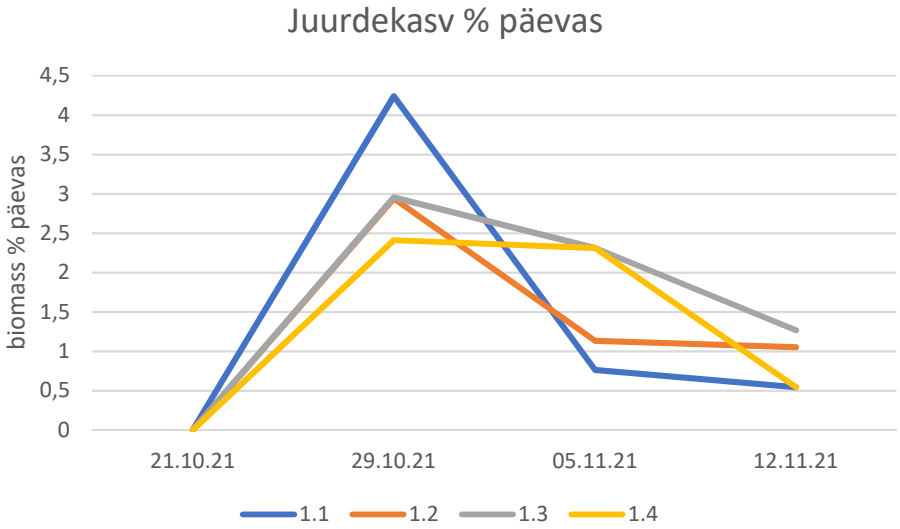




Pihtla eksperiment 2/2021
Algus 21.10.2021
Soolsus 6 PSU
Toitained +N; +P

EMKF RAKENDUSKAVA 2014-2020

Euroopa Liit
Euroopa Merendus- ja Kalandusfond



Juurdekasv perioodil kokku g	520	440	620	500
juurdekasv päevas g	23.64	20.00	28.18	22.73
juurdekasv kokku %	46.43	43.14	56.36	43.86
juurdekasv % päevas	2.11	1.96	2.56	1.99

Rahvusvaheline koostöövõrgustik: COST CA20106.

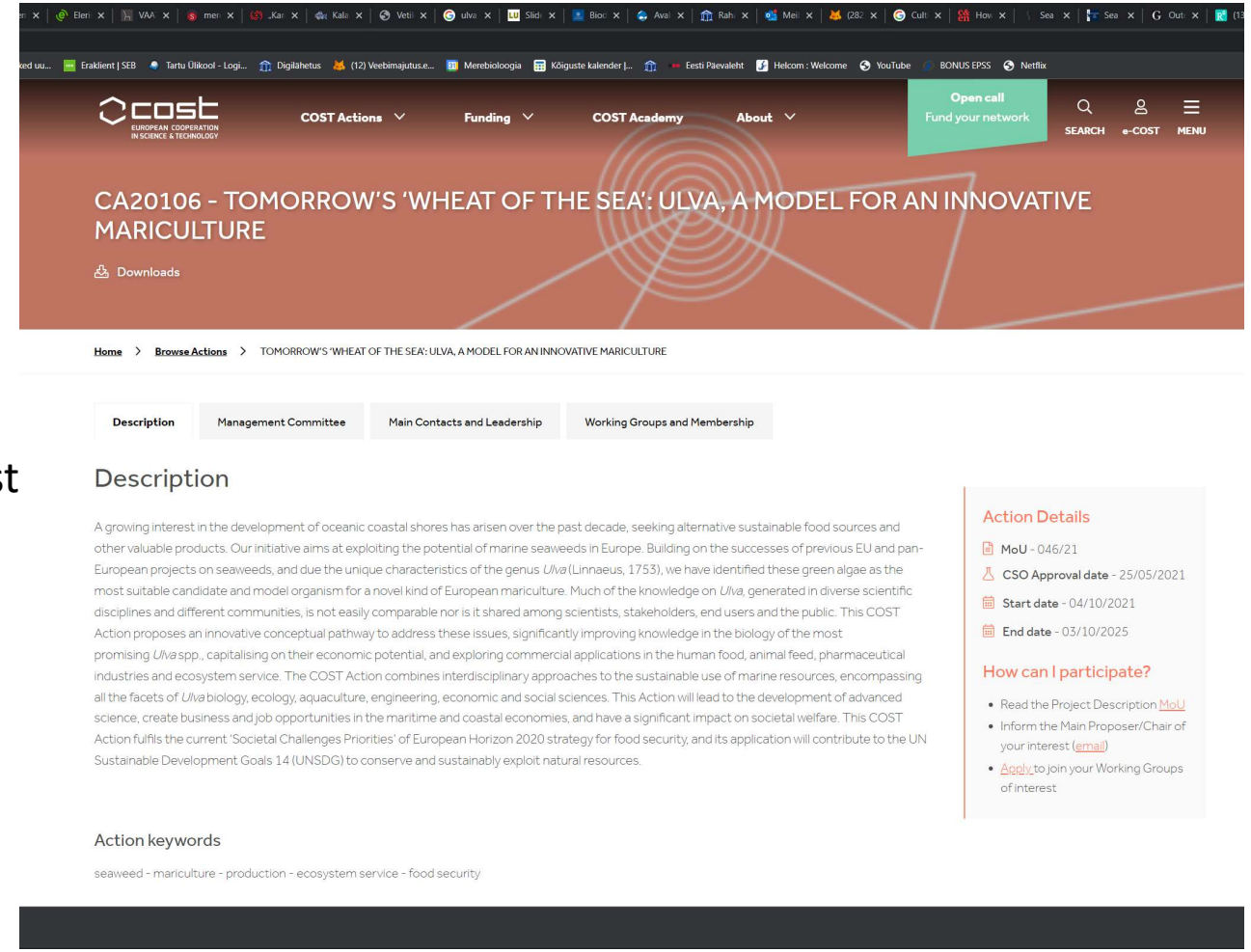
Eestipoolsed
juhtkomitee liikmed:

Georg Martin, TÜ EMI
Tiina Paalme, TÜ EMI

76 eksperti 22 Euroopa riigist
6 eksperti väljaspoolt

- Konverentsid
- Seminarid
- Töötoad
- Ühispublikatsioonid

- ➢ Kasvatamine
- ➢ Kasutamine
- ➢ Uued rakendused



Rohkem infot: https://www.cost.eu/actions/CA20106/