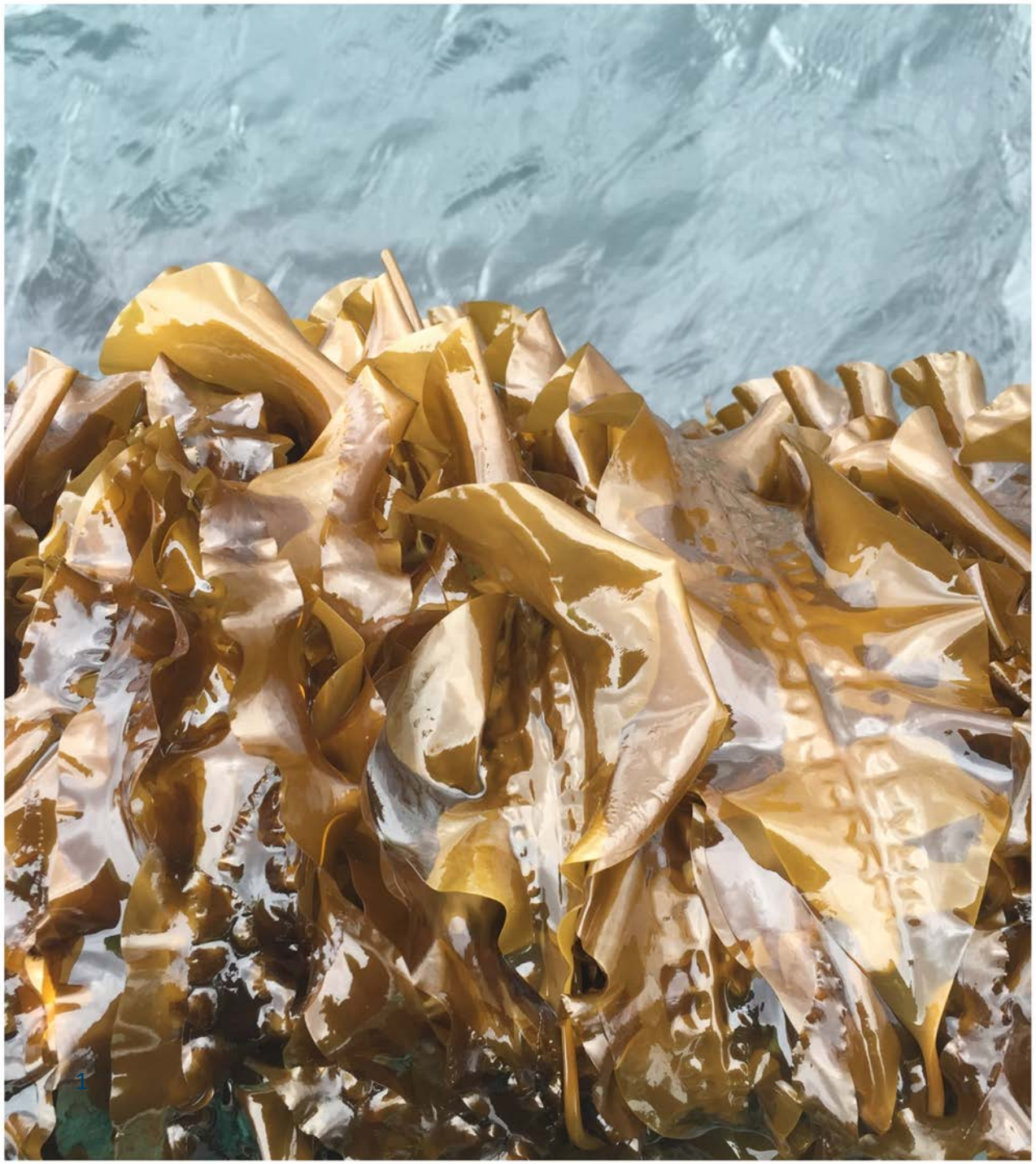

Cultivation of sugar kelp (*Saccharina latissima)* along the Norwegian coast

Variations in growth and chemical composition in connection to latitude, season, depth and hatchery treatments

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ALGET2 webinar

28.01.2021

Silje Forbord

SINTEF

Seaweed cultivation status in Norway 2019 (29.10)

~40 registered companies and 17 with production

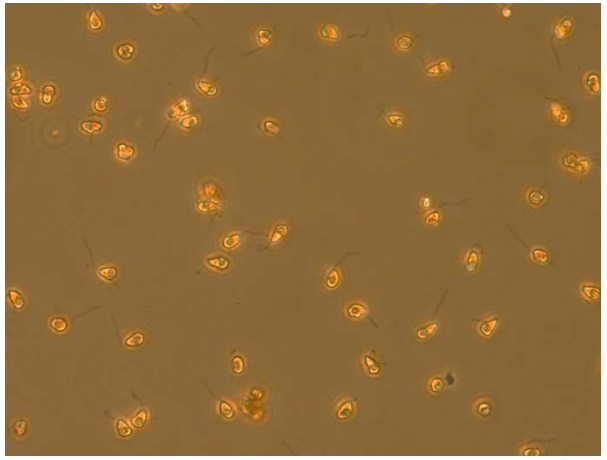
475 licenses distributed over 97 cultivation sites

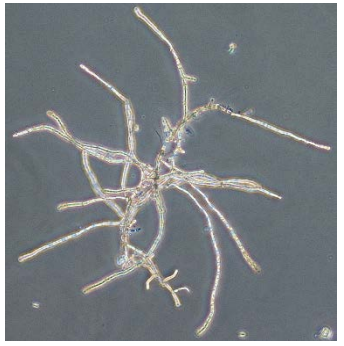
117 tons ww harvested (178 t in 2018)

Value of ~440 000 EUR

Source: Directorate of Fisheries

Life cycle of *Saccharina latissima* (sugar kelp)





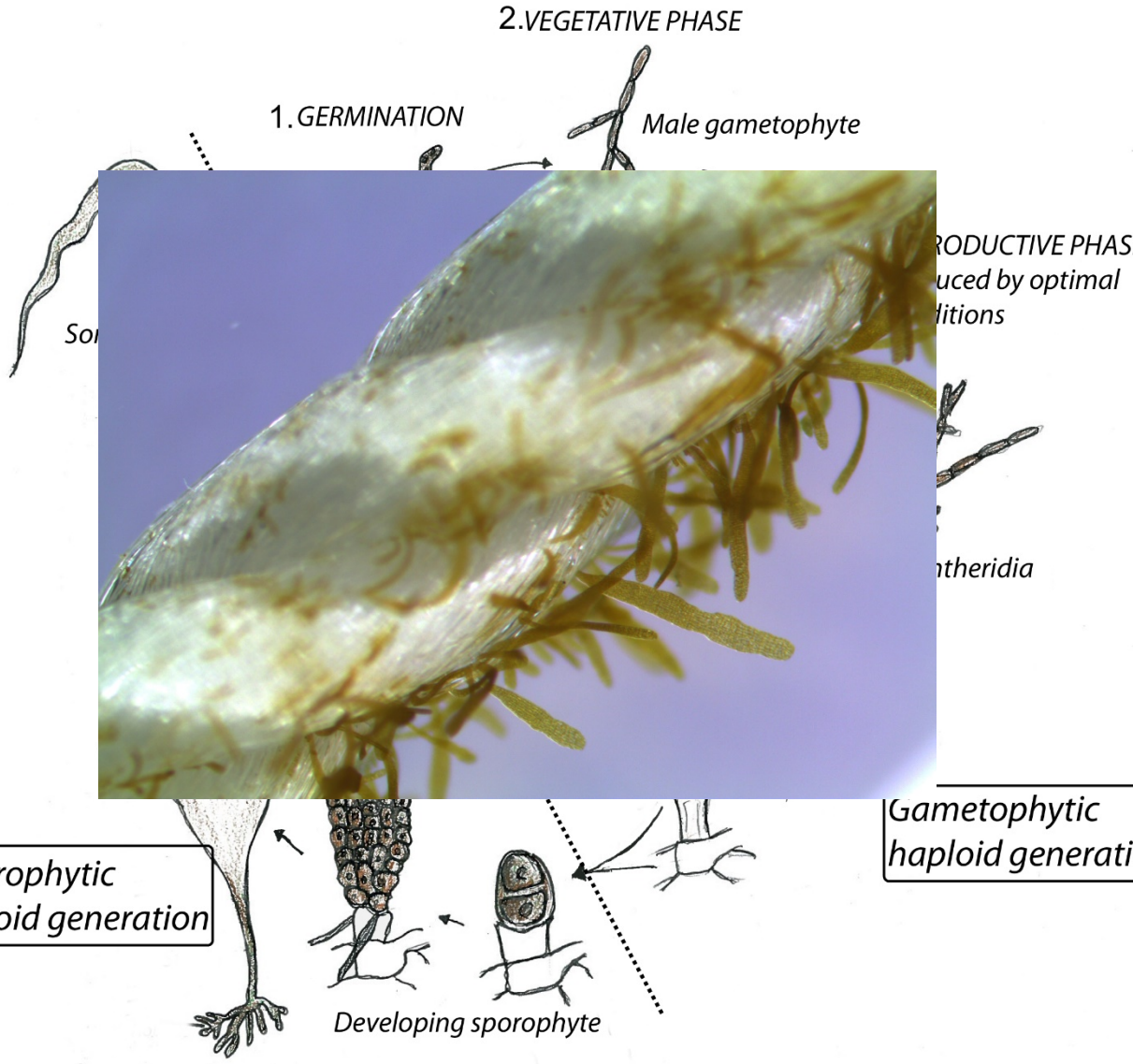


Illustration: Sanna Matsson

Chemical content

- 75-90 % water
- **Proteins and other N-containing components**
- Carbohydrates
- Minerals (iron, calcium, iodine, potassium, selenium)
- Vitamins (A, C and B12)
- The only non-fish sources of natural omega-3 long-chain fatty acids

Variation is dependent on location, season and depth

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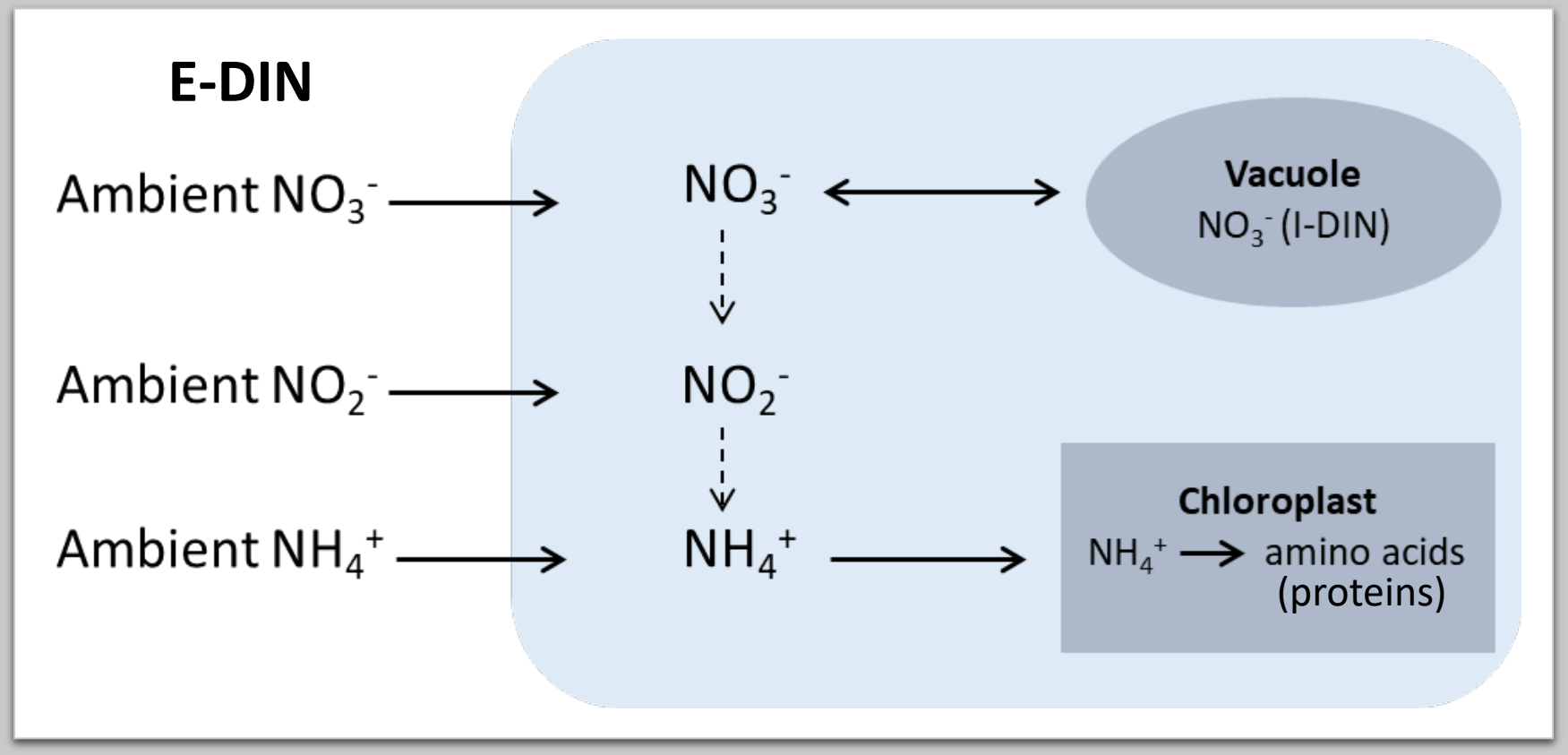

Illustration modified from Syrett (1981)

A simplified overview showing the main pathway of inorganic nitrogen inside a seaweed cell from uptake to the conversion of biomolecules like amino acids

What characterize cultivated seaweed biomass of high quality?

- High yield

Barbier et al. 2019

What characterize cultivated seaweed biomass of high quality?

- High yield
- Resistance to epiphytes

Barbier et al. 2019

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Barbier et al. 2019

What characterize cultivated seaweed biomass of high quality?

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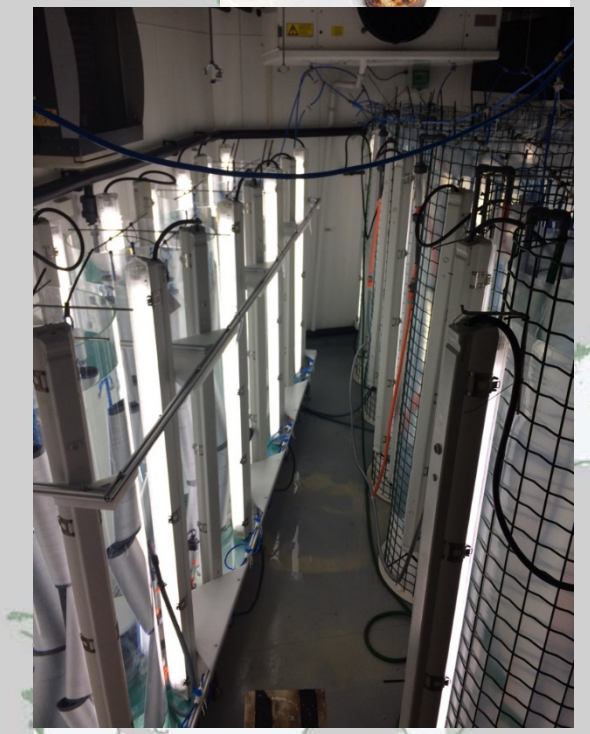
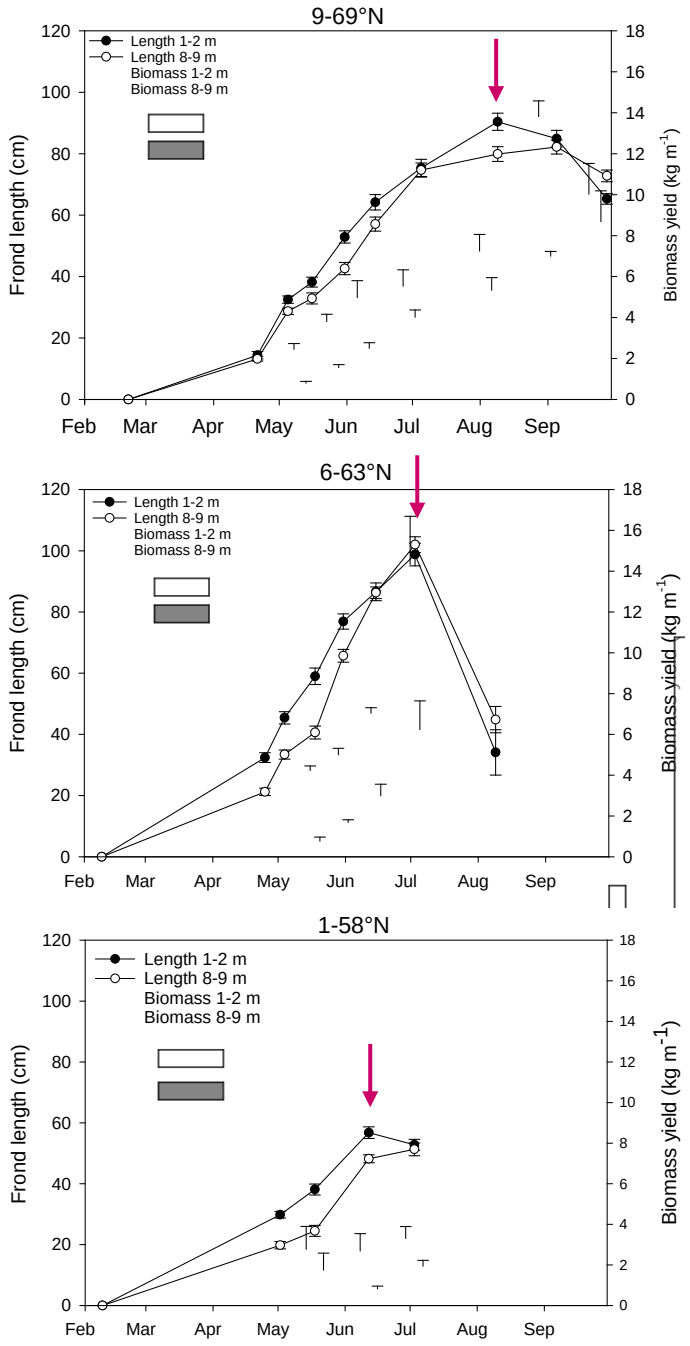
- Resistance to epiphytes
- High amount of targeted compounds
- High nutrient uptake rates
- Resilience to changing abiotic factors

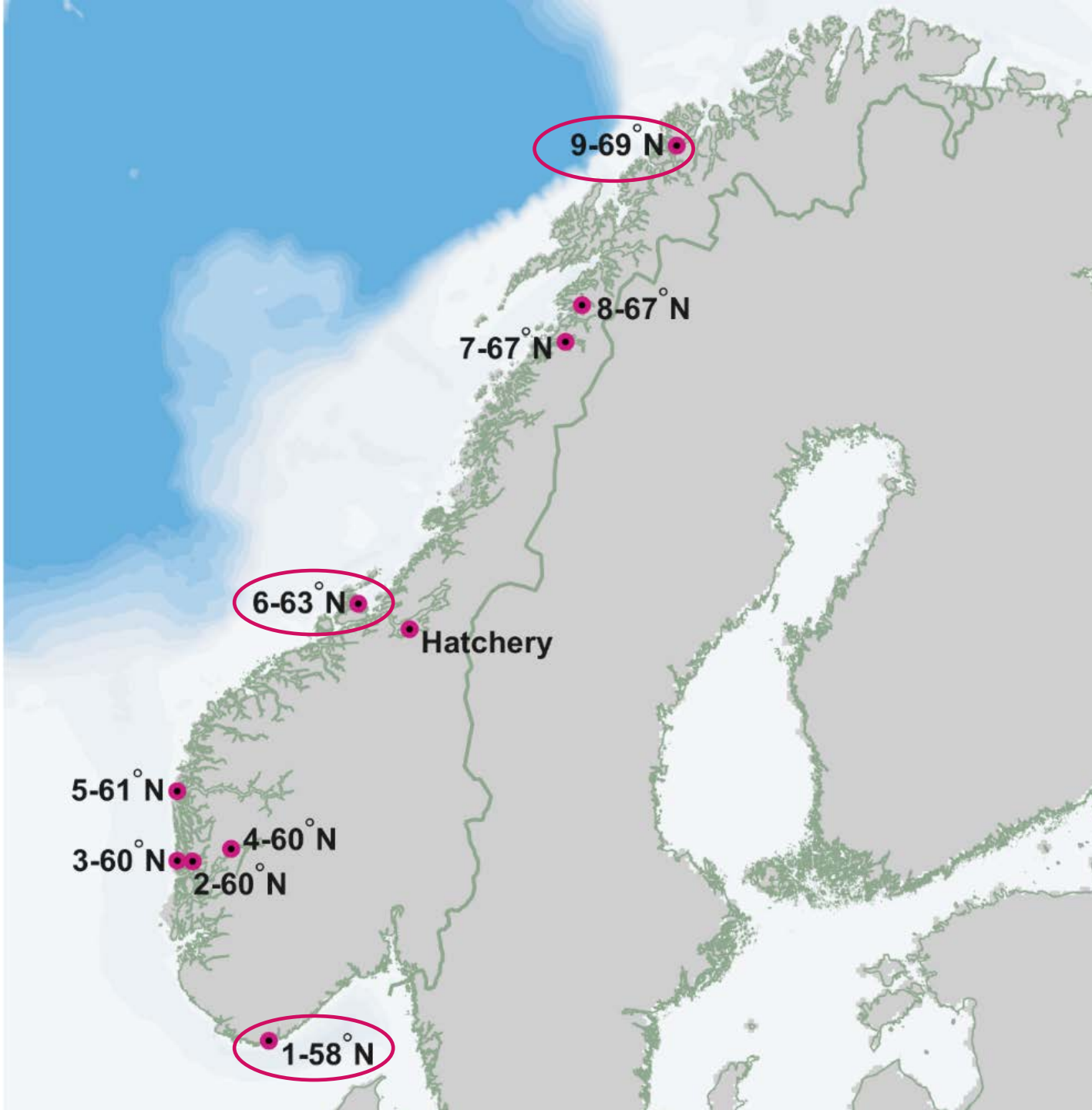
Barbier et al. 2019

Latitudinal, seasonal and depth-dependent variation in growth, chemical content and biofouling of cultivated *Saccharina latissima* (Phaeophyceae) along the Norwegian coast

- A selection of commercial farms over 10 degrees in latitude
  - ★ 3 fjord locations
- One hatchery producing seed lines
- Deployment in February 2017
  - 1-2 m and 8-9 m depths
- Sampling from April-Sept
  - Growth
  - Chemical content
  - Biofouling

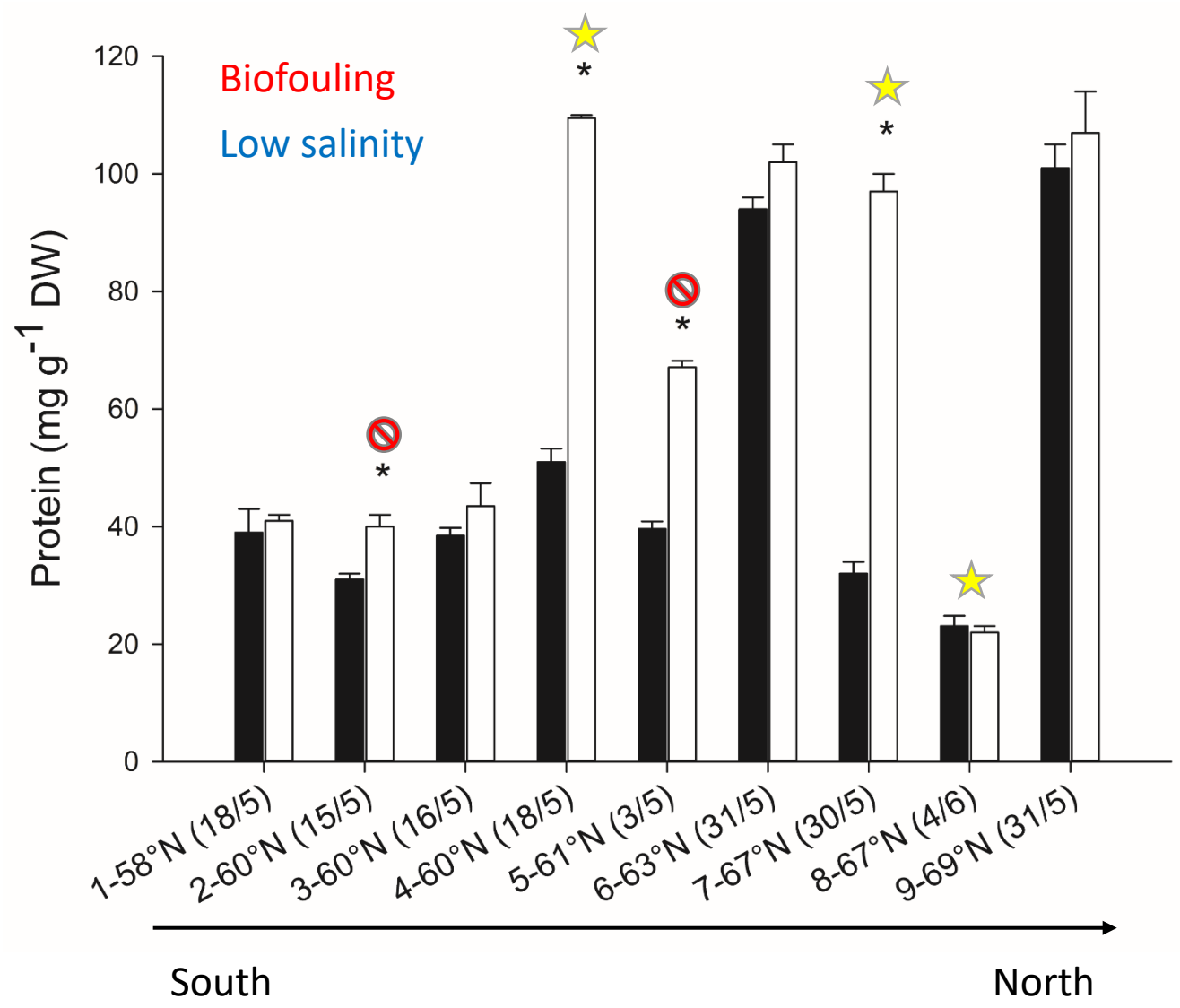


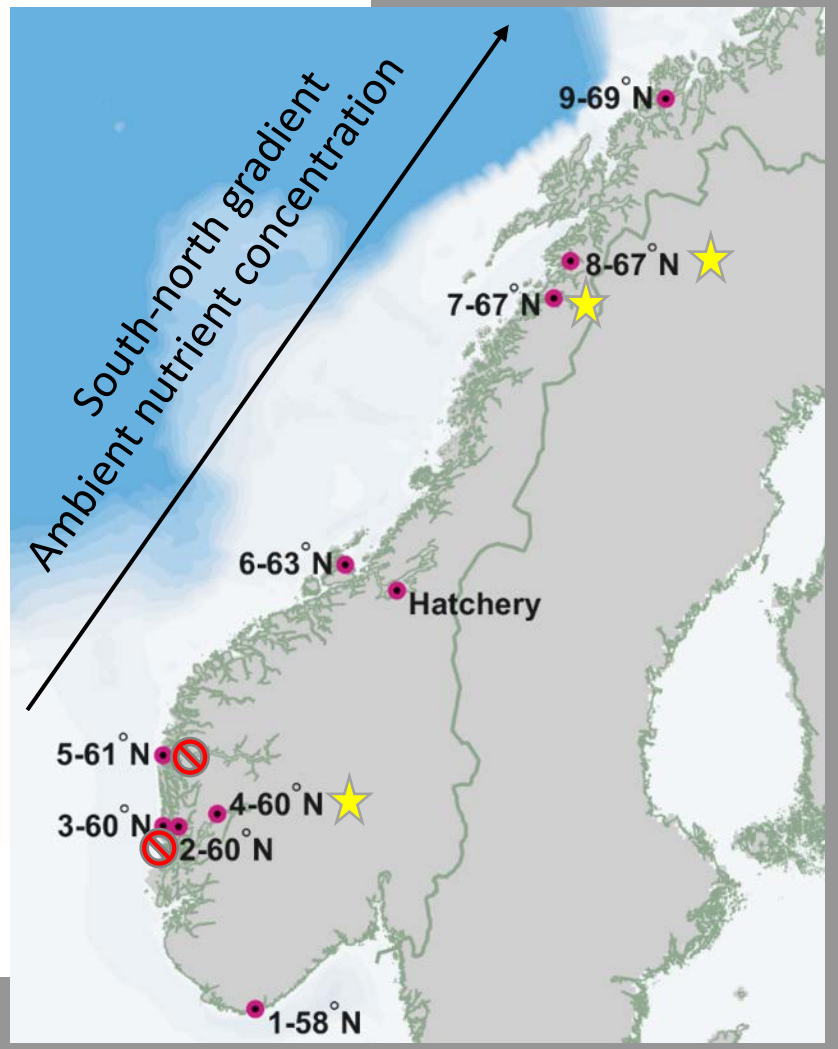

9-69°N
6-63°N
1-58°N
Length 1-2 m
Length 8-9 m
Biomass 1-2 m
Biomass 8-9 m
Frond length (cm)
Biomass yield (kg m-1)
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


9-69 °N
8-67 °N
7-67 °N
6-63 °N
Hatchery
5-61 °N
4-60 °N
3-60 °N
2-60 °N
1-58 °N

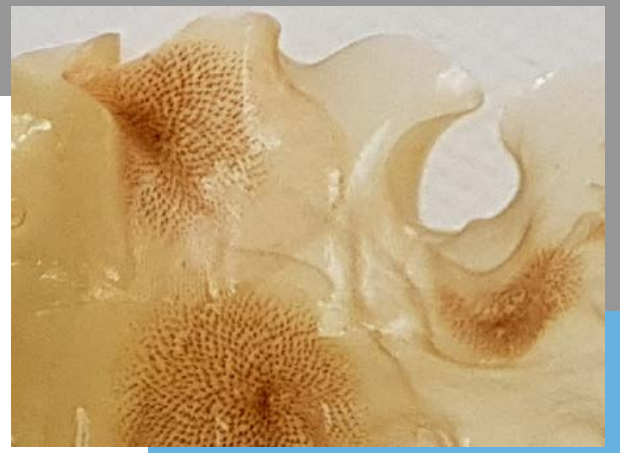
SINTEF

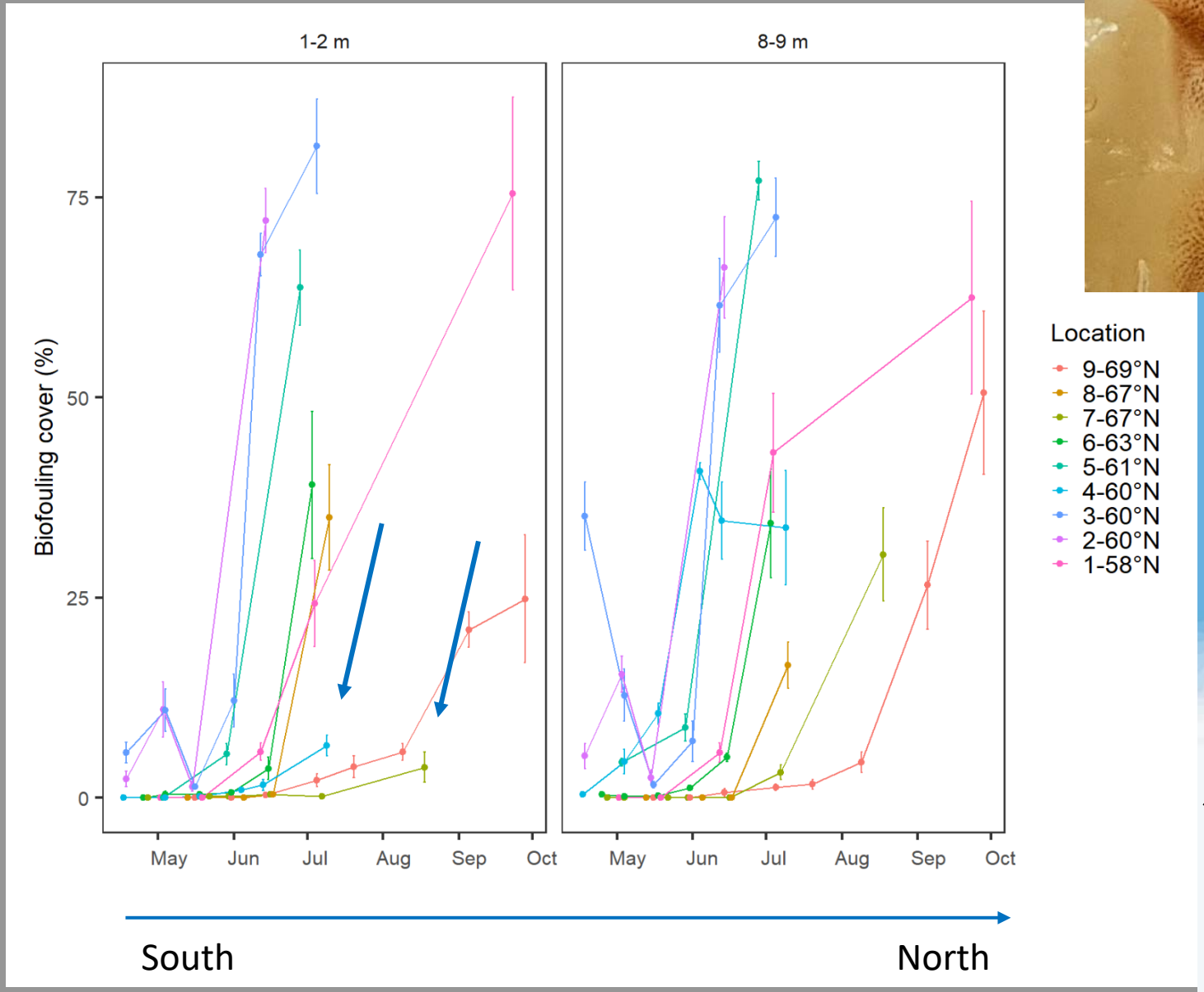
Variation in protein content along a latitudinal gradient

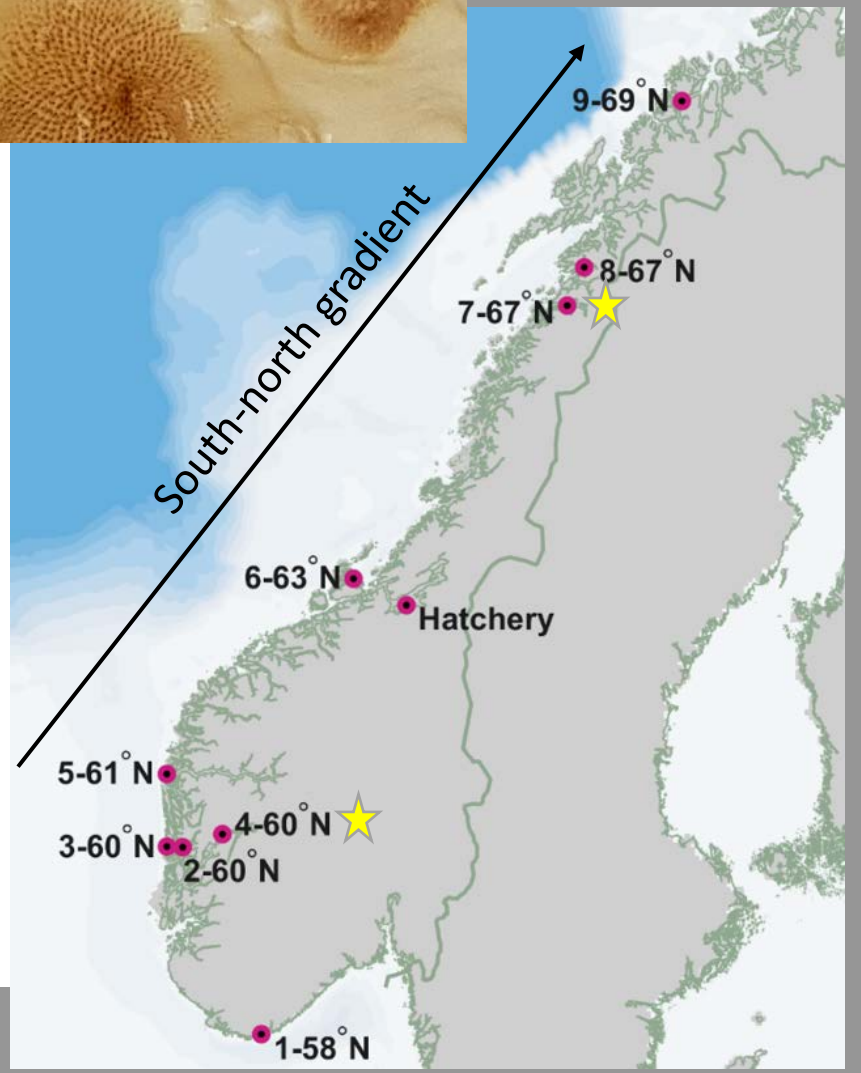




Cover of biofouling

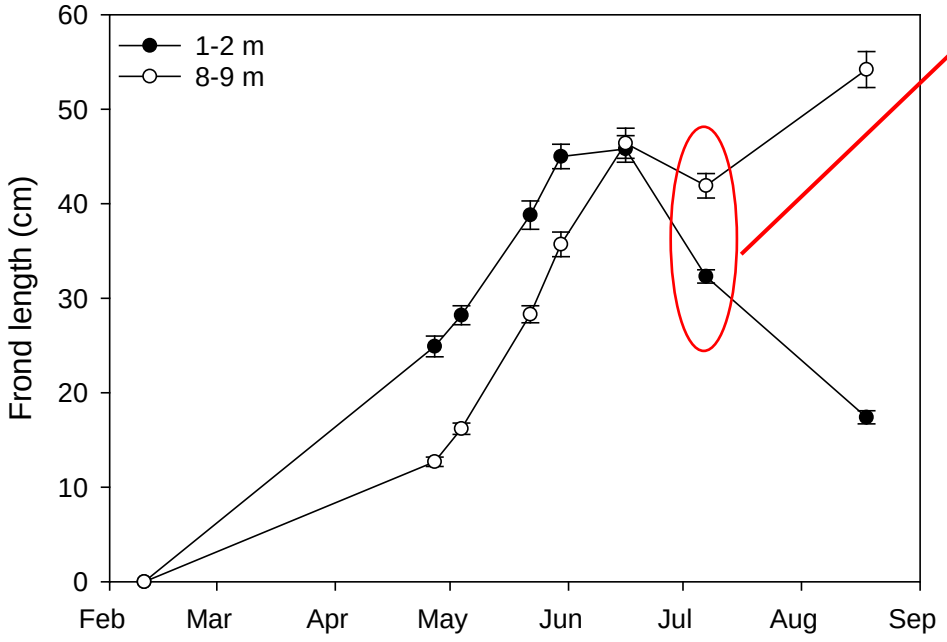






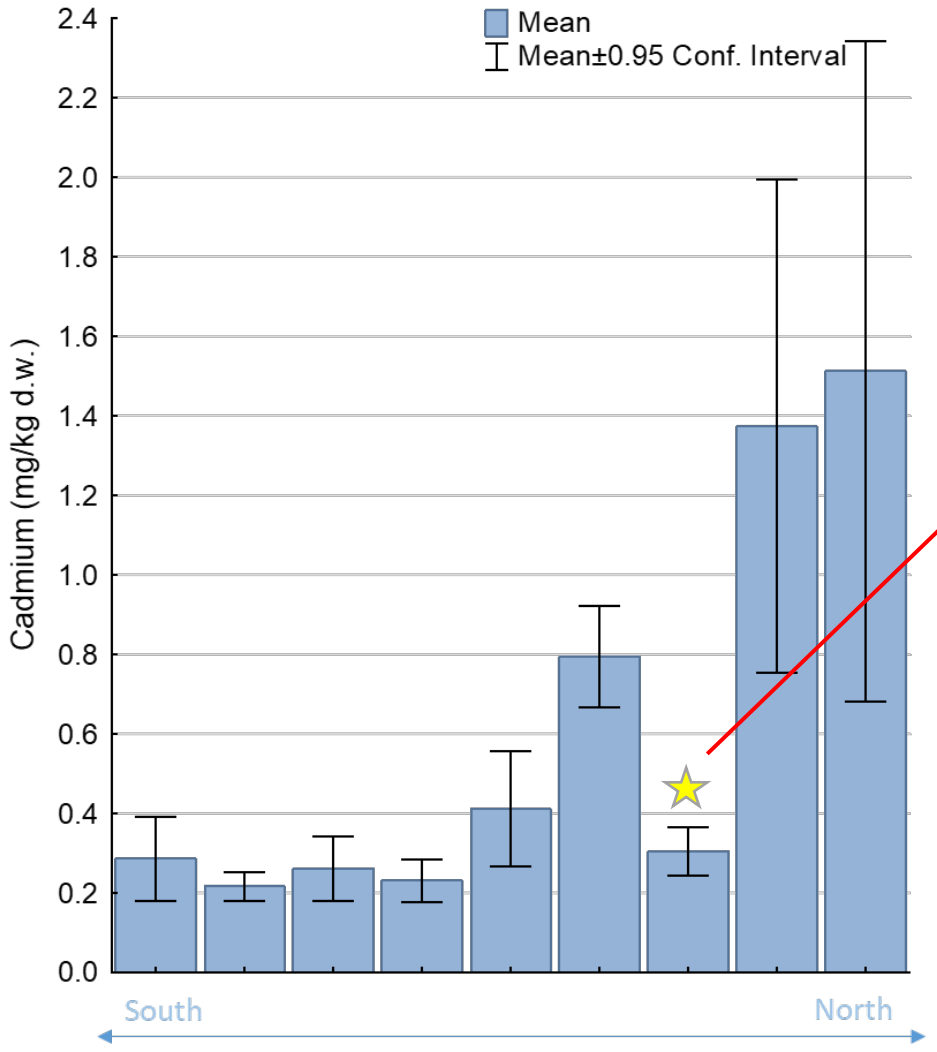
Low salinity strongly influences the biomass

- Low biofouling at 1-2 m cultivation depth
- High protein content at deeper depths
- Poor growth in frond length and biomass yield



Low salinity strongly influences the biomass

1-2 m cultivation depth, before biofouling settlement



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HAVFORSKNINGSINSTITUTTET
INSTITUTE OF MARINE RESEARCH

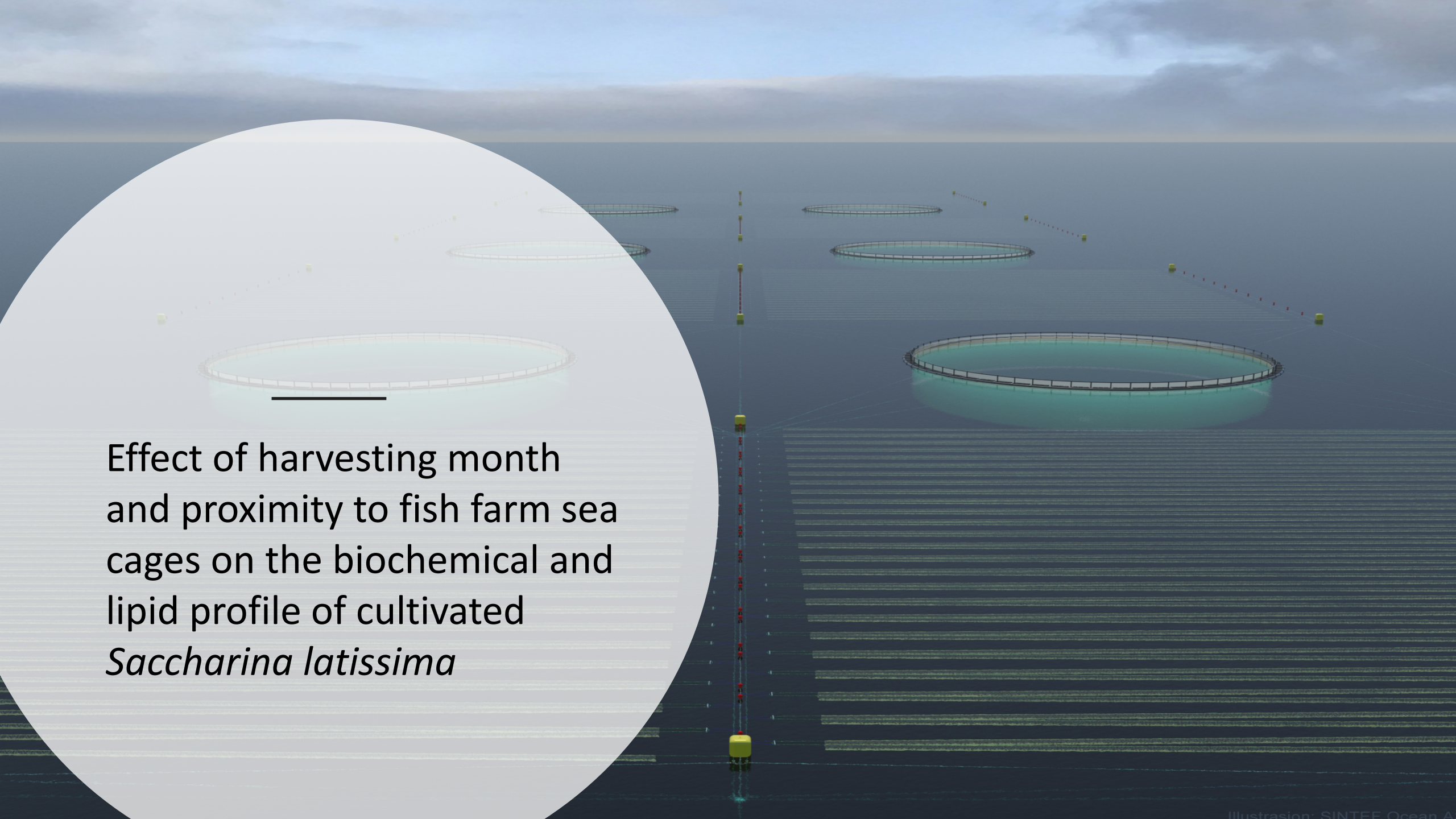
Conclusions and take-home message

The variations in measured variables were mainly caused by seasonality and depth, varying systematically along a latitudinal gradient

Production (frond length and biomass yield), was higher at shallow cultivation depths than at deeper, whereas protein, ash, Q_N and I-DIN were generally higher at greater depths

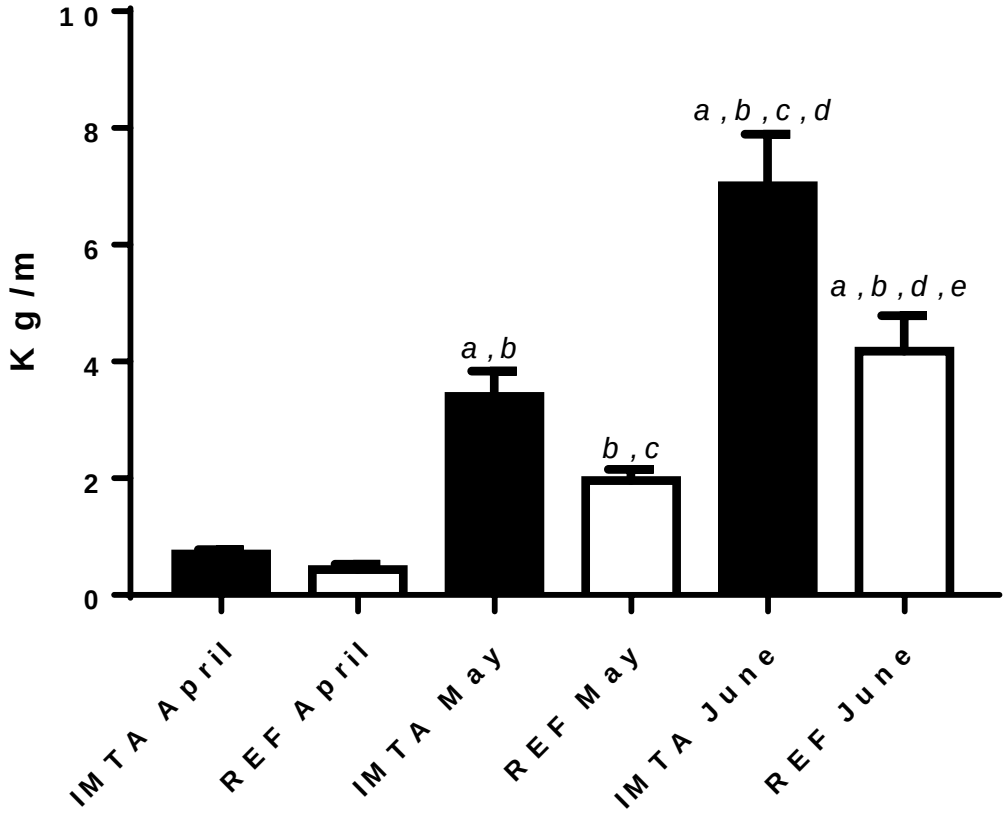
The variation in timing of yield and chemical content along a latitudinal gradient can suppling the consumer market or processing industry for an extended period

Forbord S, Matsson S, Brodahl G, Bluhm B, Broch OJ, Handå A, Metaxas A, Skjermo J, Steinhovden KB, Olsen Y (2020). Latitudinal and seasonal variation of growth, chemical content and biofouling of cultivated *Saccharina latissima* (Phaeophyceae) along the Norwegian coast. Journal of Applied Phycology. 32:2215-2232



Effect of harvesting month and proximity to fish farm sea cages on the biochemical and lipid profile of cultivated *Saccharina latissima*

Nitrogen availability and biomass growth

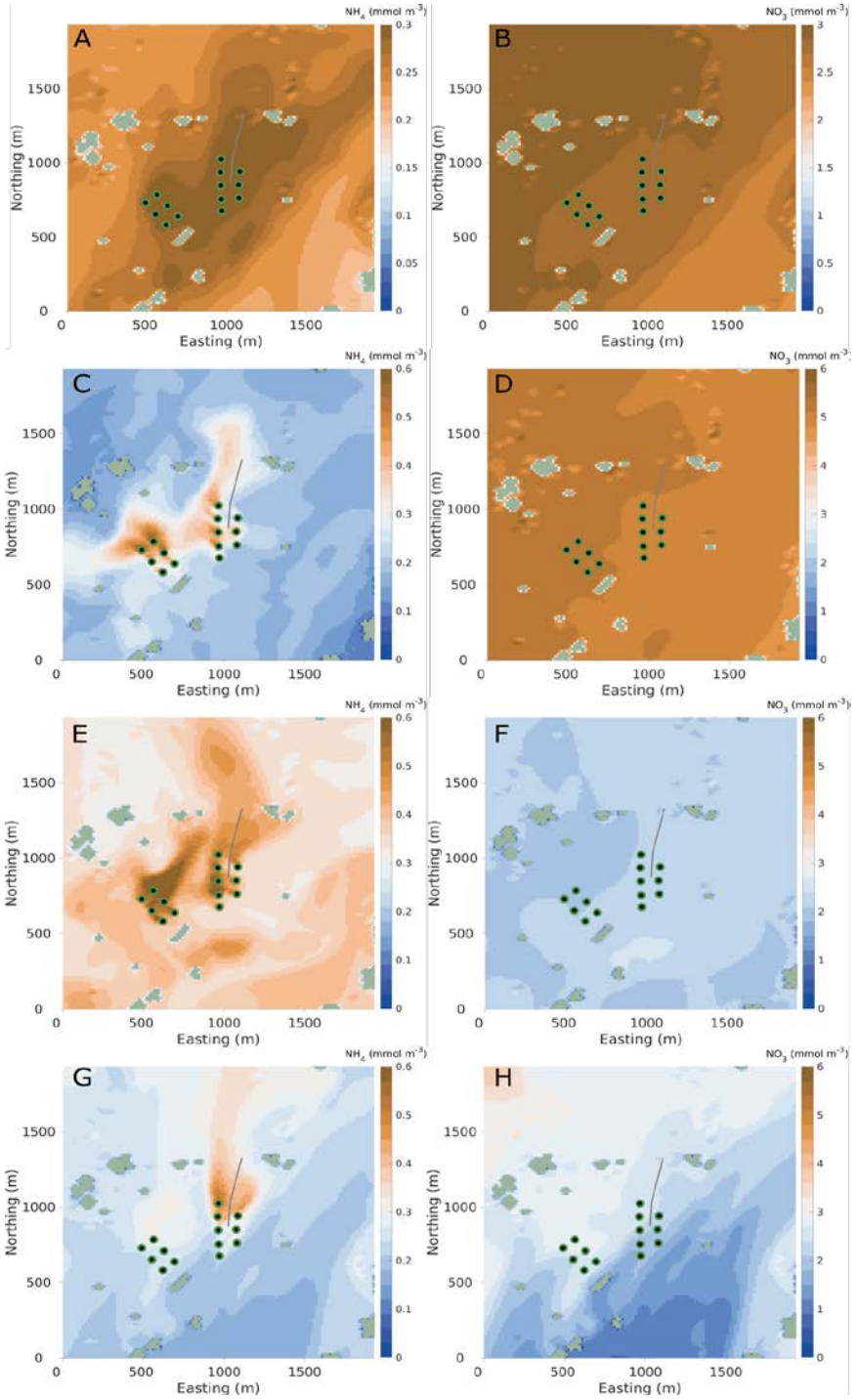


Average April-June

April snapshot

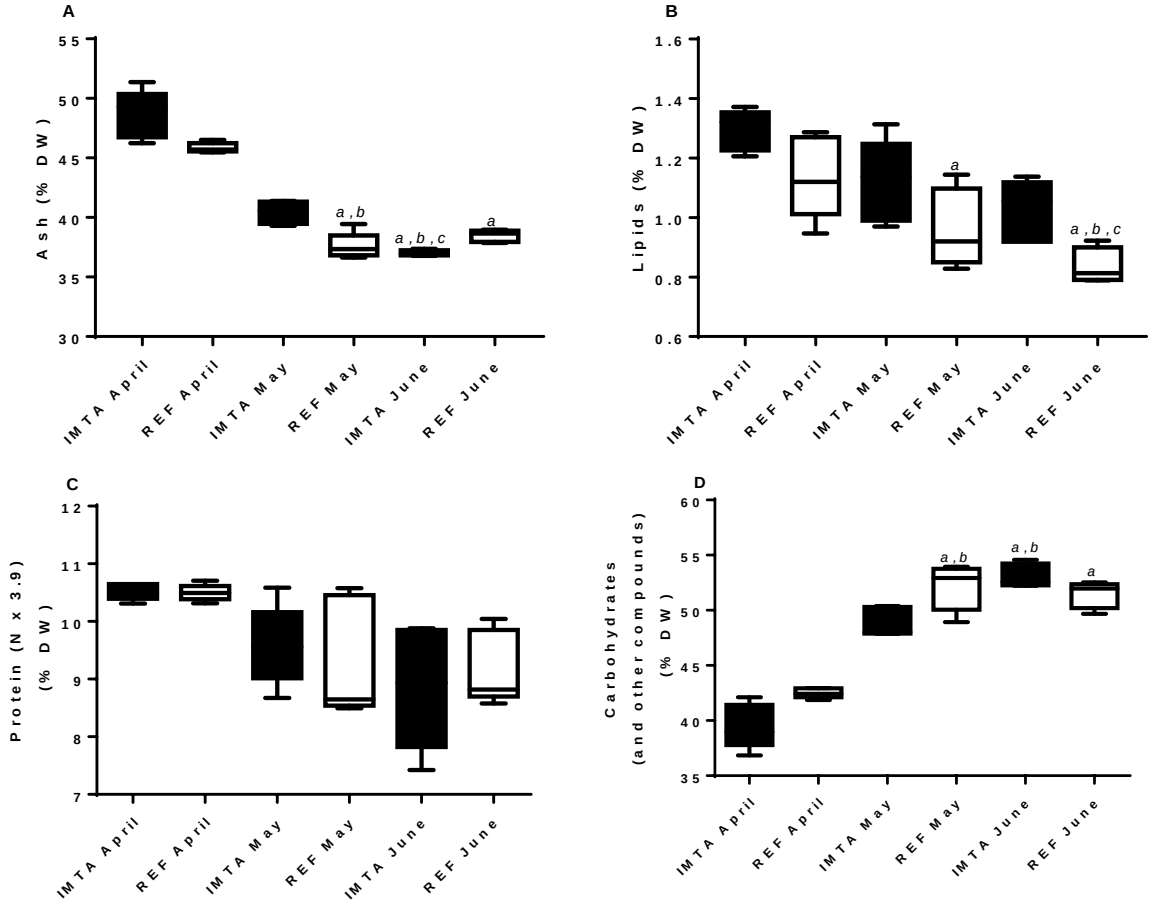
May snapshot

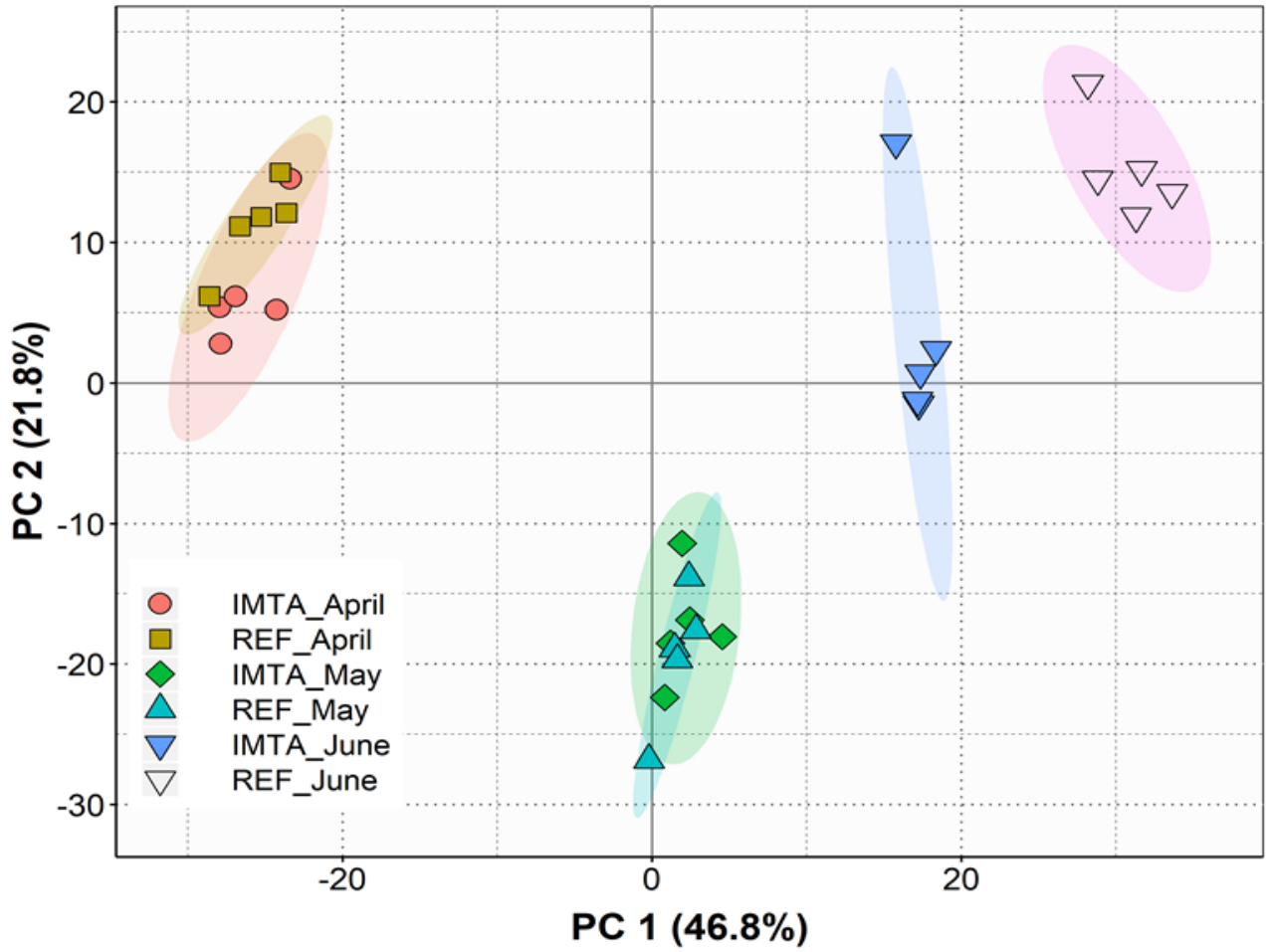
June snapshot



SINTEF GENIALG Monteiro et al. 2021

The differences recorded for elemental, biochemical and lipid composition of *S. latissima* occurred consistently with harvesting period rather than with the distance to fish farm, evidencing that farming kelp in IMTA setups does not compromise nutritional quality while promoting increased biomass yield.



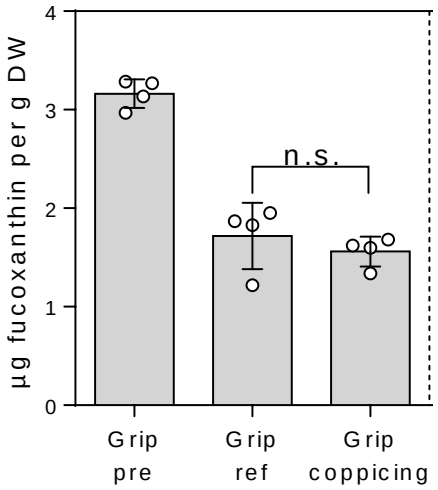


Monteiro J.P, Melo T, Skjermo J, Forbord S, Broch O.J, Domingues P, Calado R, Domingues M.R. (2021). Effect of harvesting month and proximity to fish farm sea cages on the biochemical and lipid profile of cultivated *Saccharina latissima*. Algal Research 54:102201

Effect of partial harvesting and preservation method on the antioxidant composition

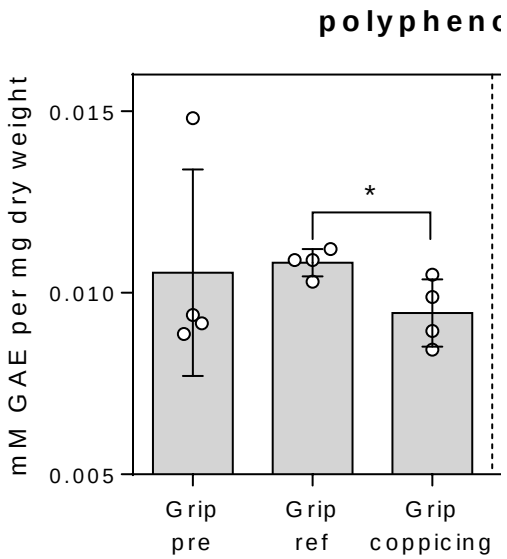
Coppicing experiments, antioxidants

"pre"
Harvested in **early June**



Reduced fucoxanthin content when harvested later in the season, irrespective of coppicing

"ref"
Harvested in **late August**

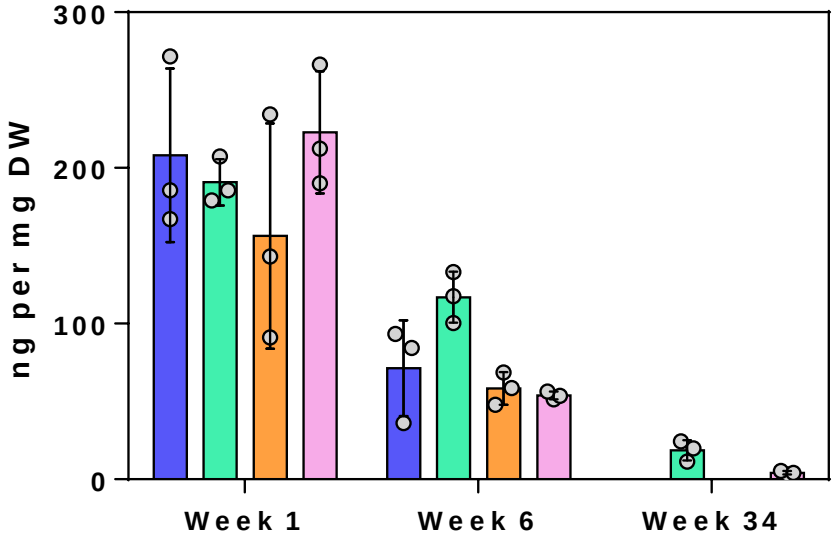


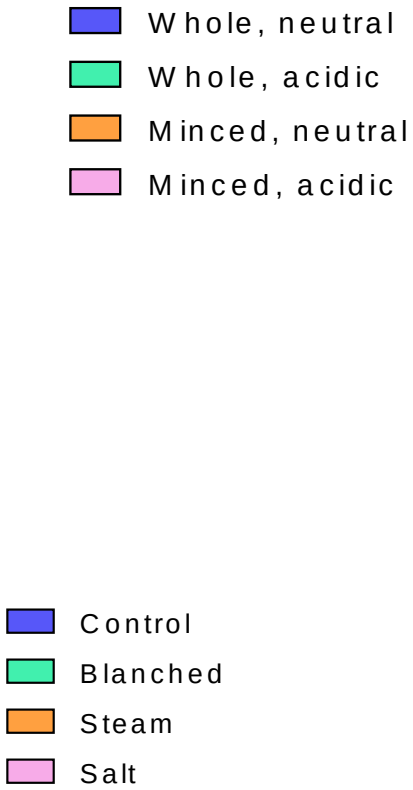
Increased polyphenol content when harvested later in the season, reduced upon coppicing

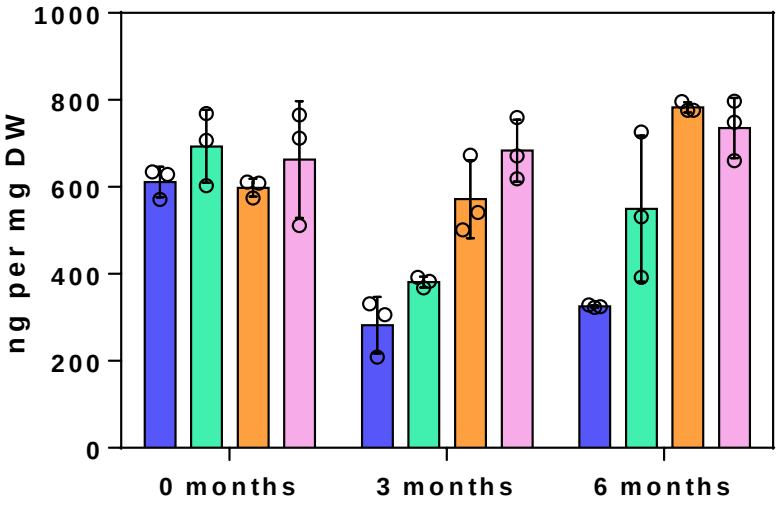
"coppicing"
Harvested in **late August**

TAREAL2 Møre og Romsdal fylkeskommune SINTEF

Fucoxanthin: preservation methods







ISBIT 2.0

Norwegian Seaweed Biorefinery Platform

Nord AQUA

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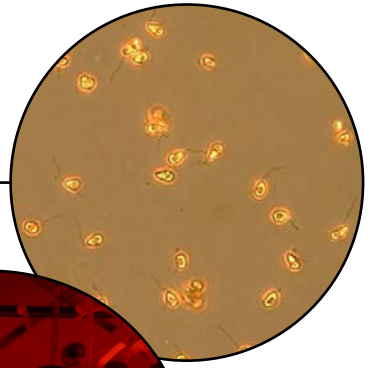
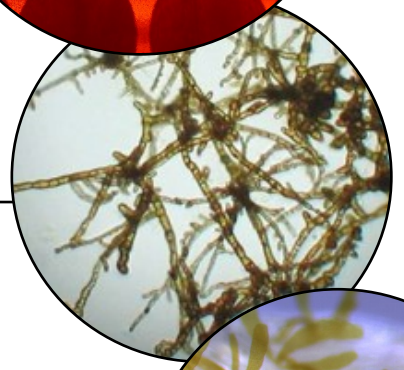
Effect of seeding methods and hatchery periods on sea cultivation of *Saccharina latissima* (Phaeophyceae): a Norwegian case study

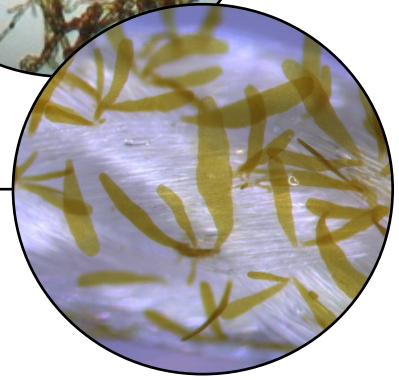


S: Incubation for 21, 28 and 42 days

G: Incubation for 14, 21 and 28 days



GF: Incubation for 14 and 0 days

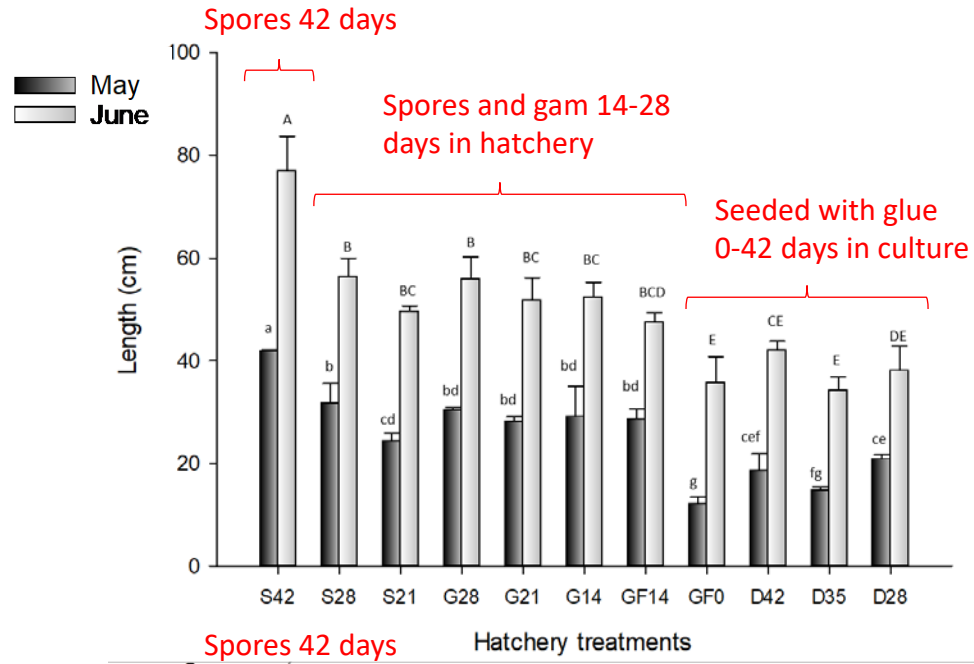


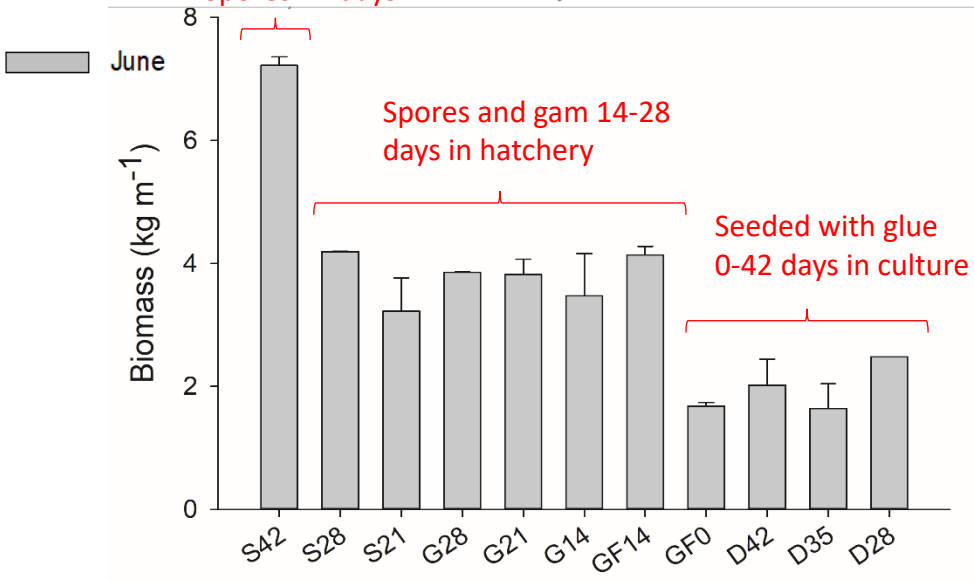
D: Culture for 28, 35 and 42 days

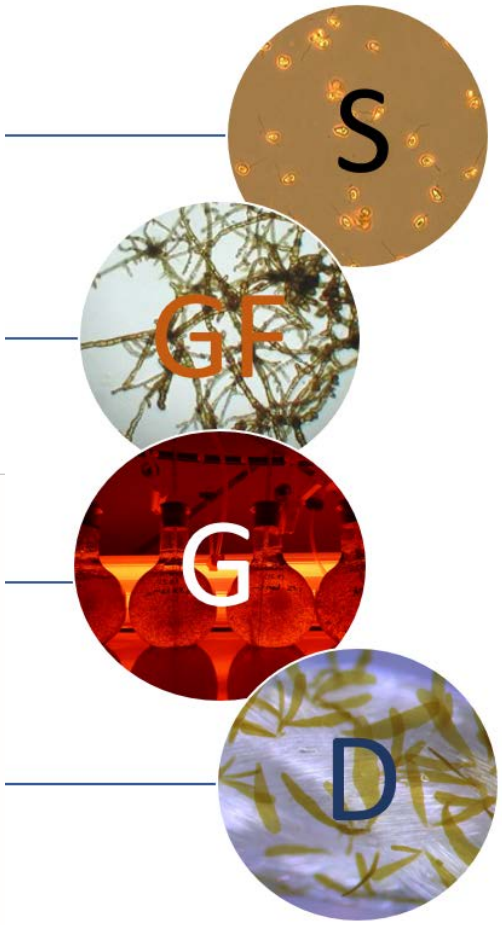
- Deployment in February 2018
- Registrations in May and June
  - Length
  - Width
  - Protein
  - Biomass (June)
  - Density (June)

Can manipulate size and biomass…

But probably not protein content







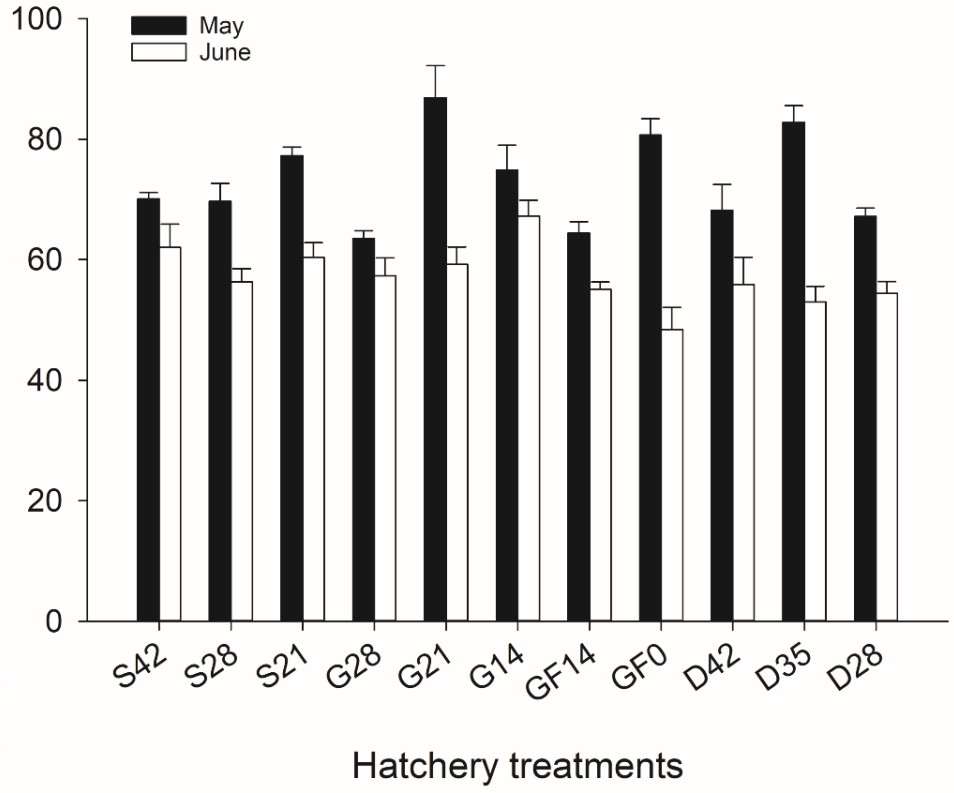
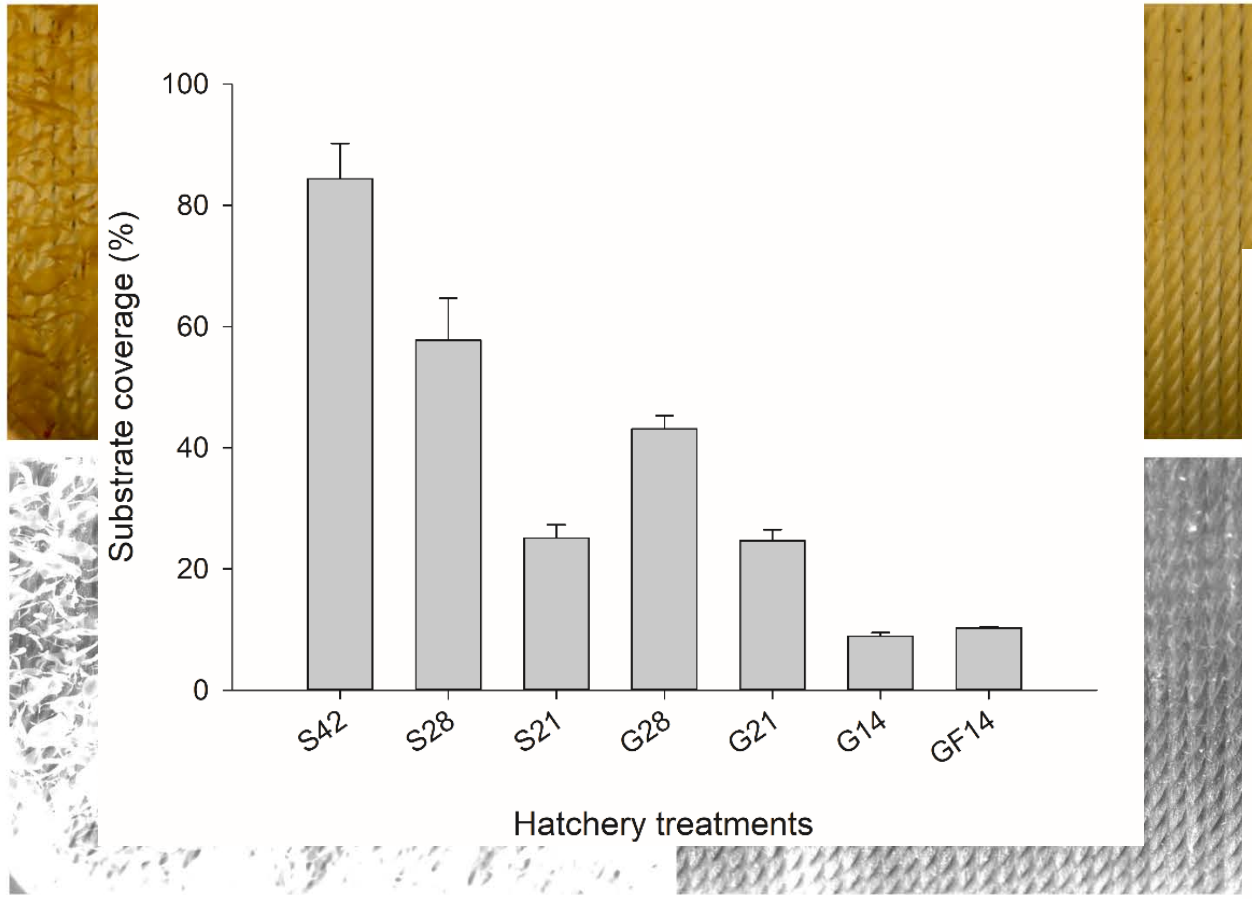
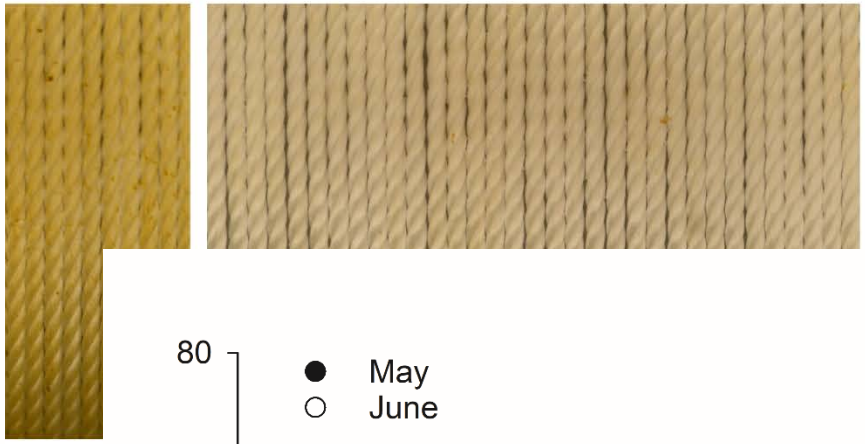


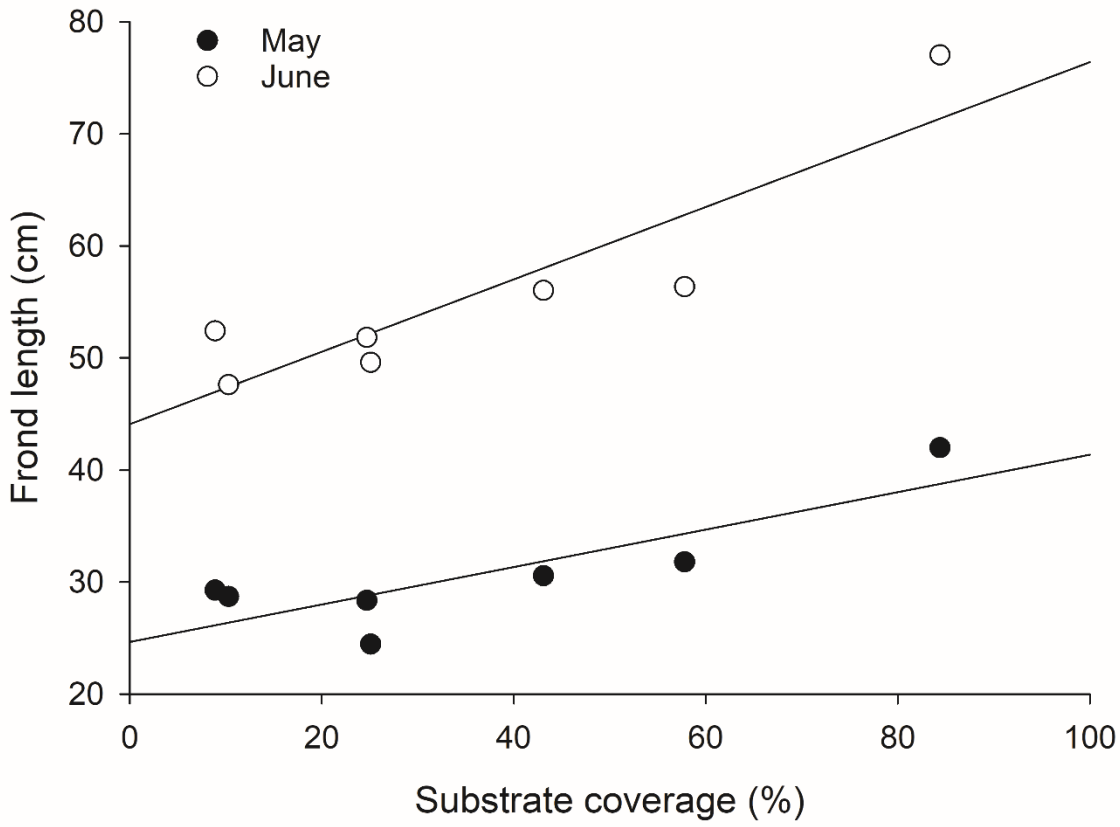
Image analysis for measuring substrate coverage



S42
Coverage: 84%



S28
Coverage: 58%



Conclusions and take home message

Different seeding methods and hatchery periods have a high impact on the growth performance of S. latissima at sea

Twine seeded with spores pre-cultivated in the hatchery for 42 days gave significantly better growth measurements than any of the other treatments

Direct seeded treatments poor, but a longer cultivation period might have levelled off the differences

Forbord S, Steinhovden KB, Solvang T, Handå A, Skjermo J (2019). Effect of seeding methods and hatchery period on sea cultivation of *Saccharina latissima* (Phaeophyceae): a Norwegian case-study. Journal of Applied Phycology. 32:2201–2212

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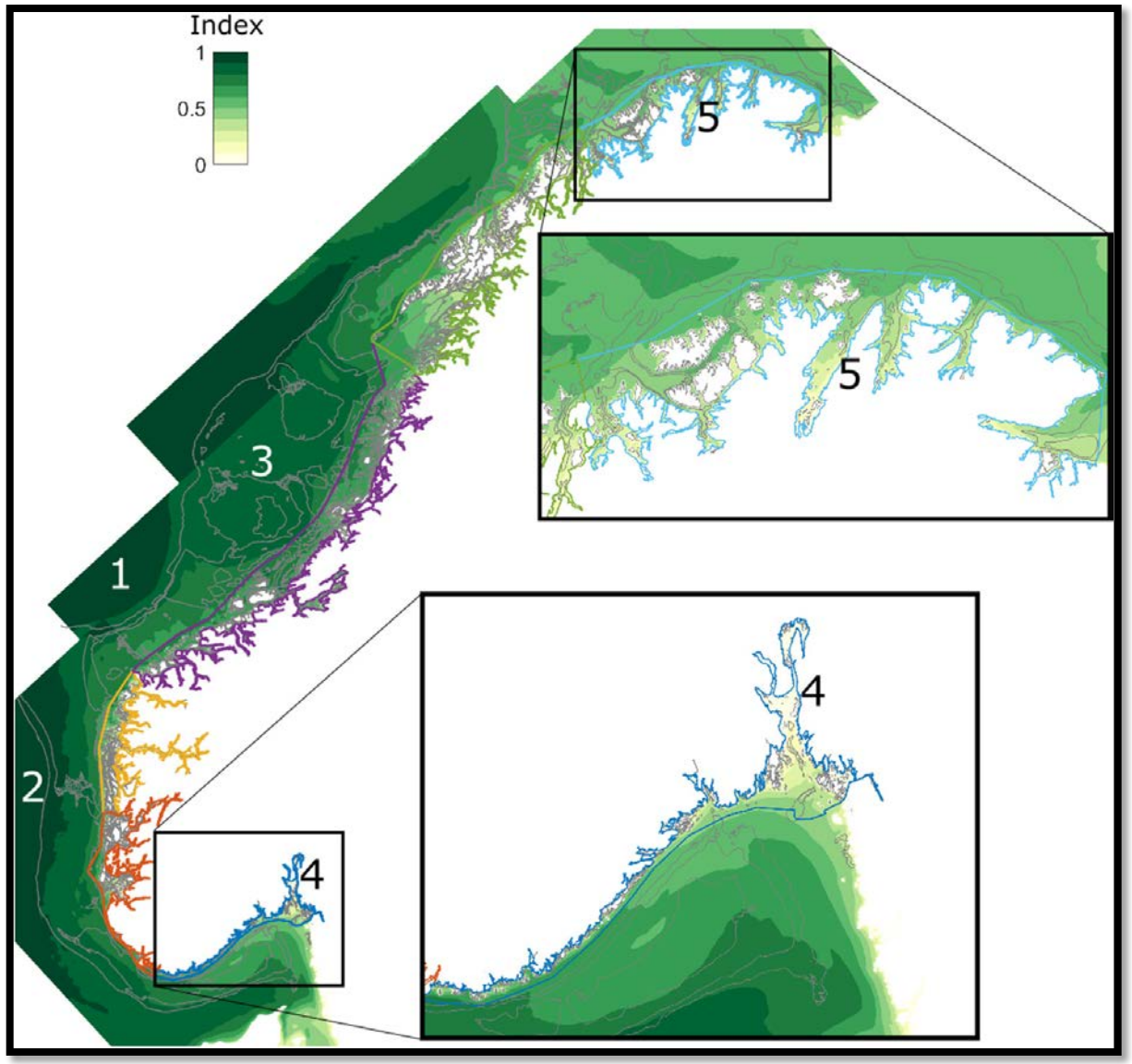
How can we ensure high quality seaweed?

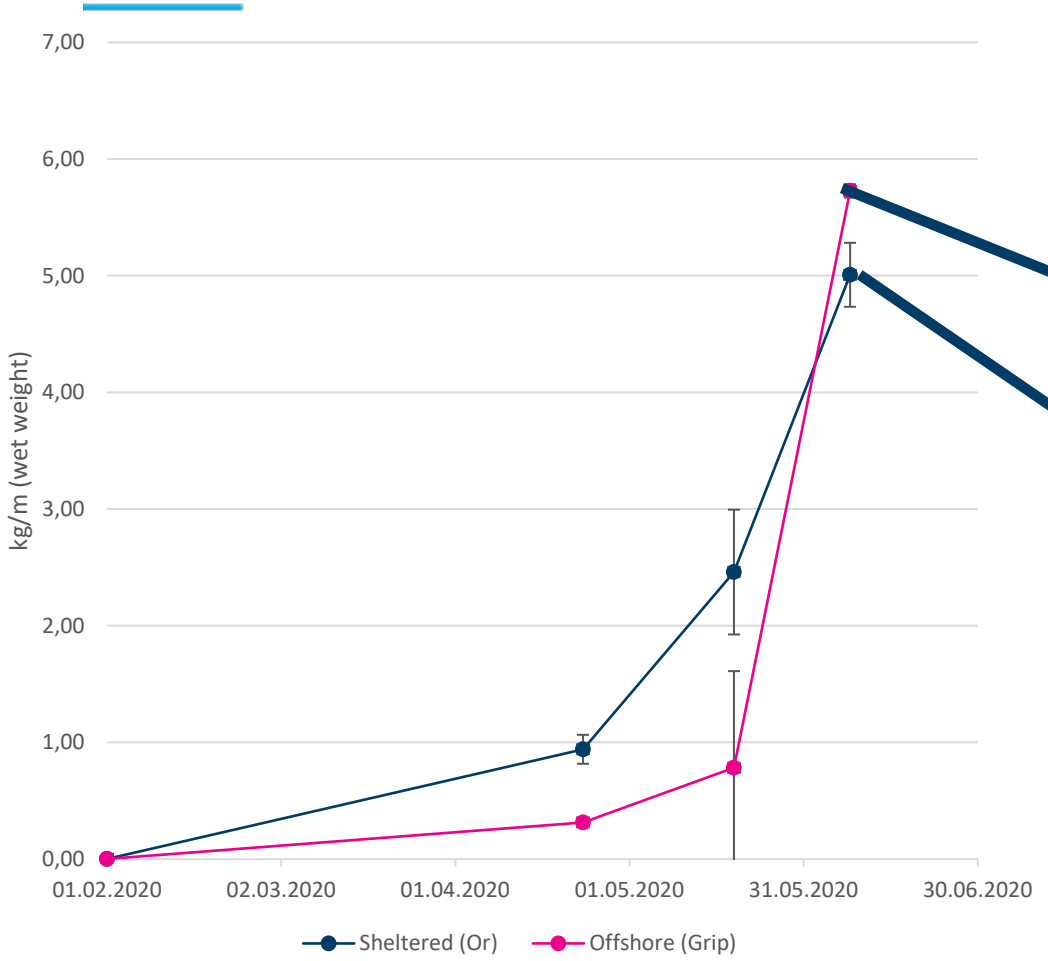
- High yield
- Resistance to epiphytes
- High amount of targeted compounds
- High nutrient uptake rates
- Resilience to changing abiotic factors

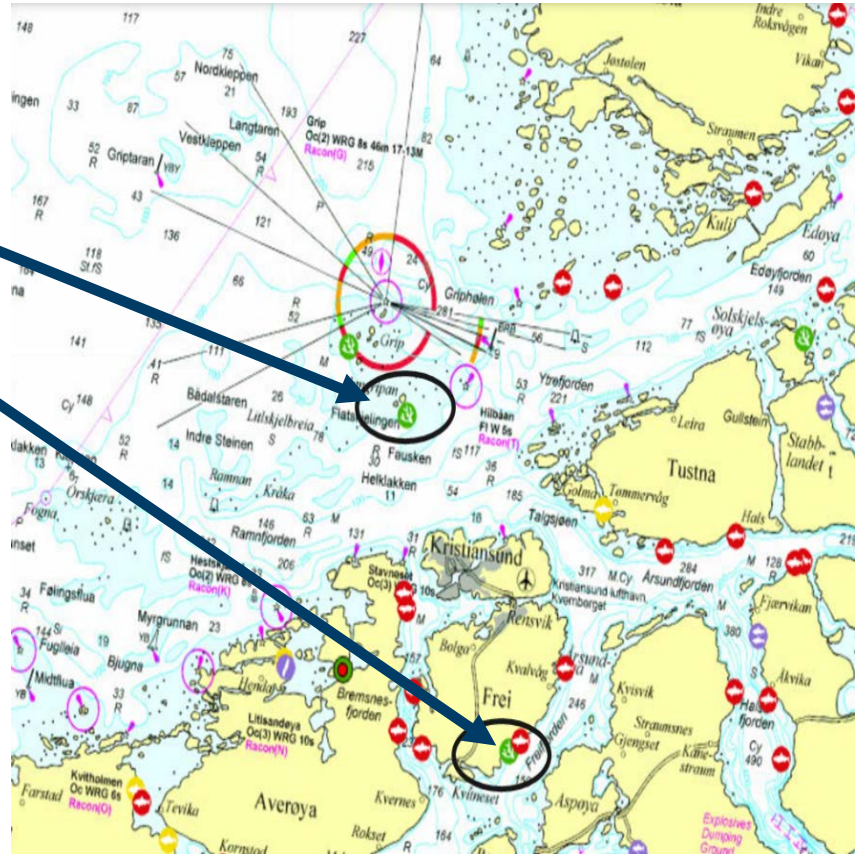
- Site selection



Broch et al., 2019

Cultivation of sugar kelp **offshore** has good potential





Skjermo, Broch, Endresen, Forbord, Lona 2020. Report from "TAREAL 2" (SINTEF Ocean/Møre & Romsdal Fylkeskommune)

Møre og Romsdal fylkeskommune

SINTEF

How can we ensure high quality seaweed?

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- Deployment and harvest time

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- Deployment and harvest time
- Cultivation depth

How can we ensure high quality seaweed?

- High yield
- Resistance to epiphytes
- High amount of targeted compounds
- High nutrient uptake rates
- Resilience to changing abiotic factors

- Site selection
- Deployment and harvest time
- Cultivation depth
- Seedling size and density

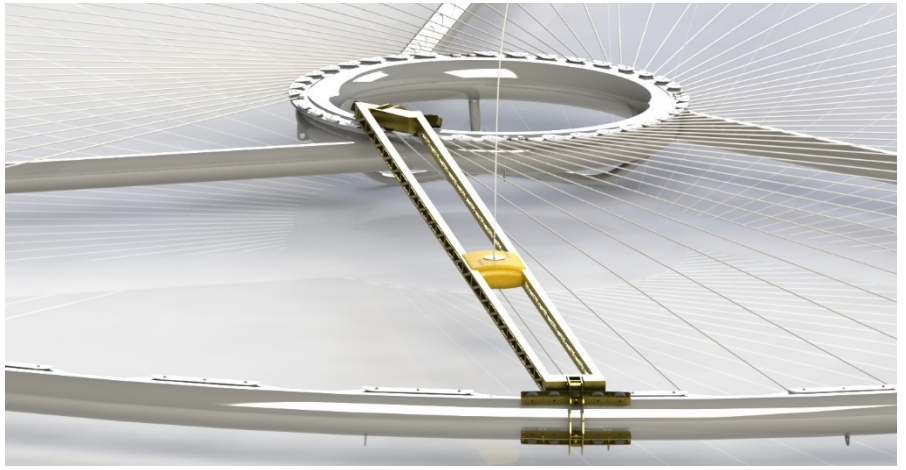
Future perspectives

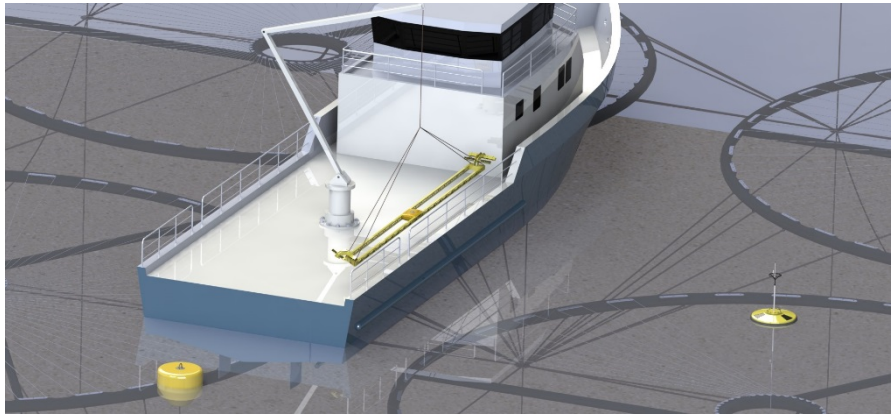
1. Develop the market segment
2. Developing cultivars for improved traits
3. Novel technology for industrial cost-effective cultivation with a high degree of mechanisation and automation
4. Use seaweed cultivation as a climate positive solution for the removal of CO_2

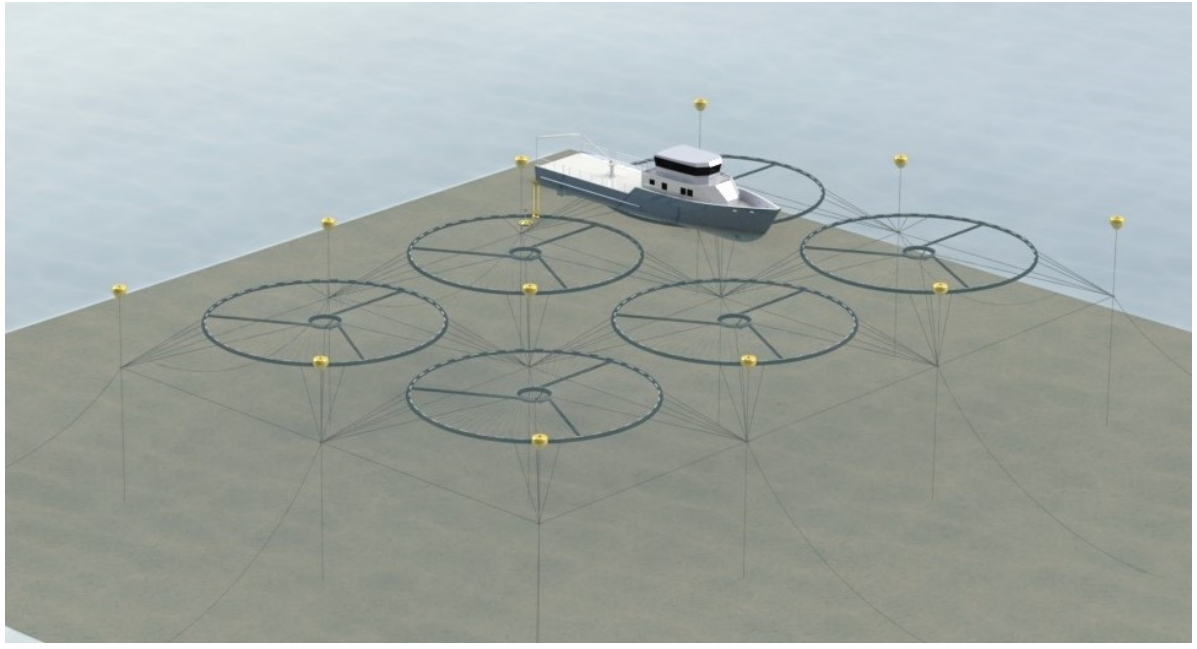
MACROSEA SPOKe concept

Standardized Production Of Kelp (SPOKe)

- Standardization and easy up-scaling
- Automated deployment and harvesting
- 100 ton/Ha







SINTEF

70 år
1950-2020

SEAWEED VESSEL 2020

DEVELOPMENT OF CONCEPT VESSEL WITH DECK EQUIPMENT AND QUALITY PRESERVING TECHNOLOGY FOR INDUSTRIAL SEAWEED CULTIVATION

The Research Council of Norway


MACROSEA


Norwegian Seaweed
Biorefinery Platform


Nord
AQUA


GENIALG


The Research Council
of Norway


Møre og Romsdal
fylkeskommune


SINTEF


Clarkson


PE REEFS
VITALIZE THE OCEAN


UiT / THE ARCTIC UNIVERSITY
OF NORWAY


Hortimare


Folla Alger AS


AlgeCenter Danmark


UiO : Universitetet i Oslo


SAMS


IOCAS


NIVA
Norsk institutt for vannforskning


UNIVERSITY OF BERGEN


SEAWEED
ENERGY
SOLUTIONS AS


AUSTEVOLL
SEAWEED
FARM


Akvaplan
niva


BIOKRAFT


NTNU


SEAWEED
FROM NORWAY


NORWAY SEAWEED


OCEAN
FOREST


Salten Algae

Many thanks to

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Guri E. Brodahl
Arne Duinker
João P. Monteiro
Torfinn Solvang
Antonio Sarno
Tom Ståle Nordtvedt
Rasa Slizyte
Inger Beate Standal
Aleksander Handå
Yngvar Olsen
Jorunn Skjermo