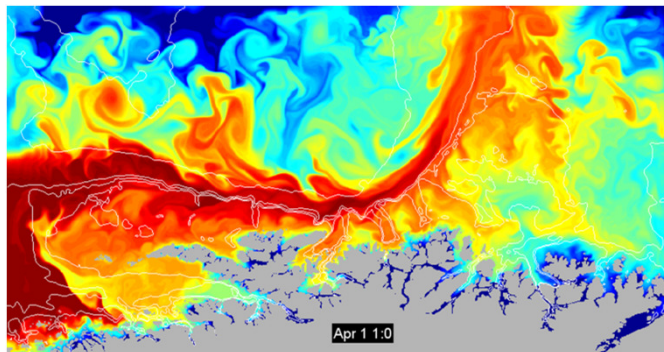


Seaweed Cultivation Strategies in Norway

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Norwegian Seaweed Technology Center



Seaweed Cultivation Strategies in Norway: Multidisciplinary Support Tools

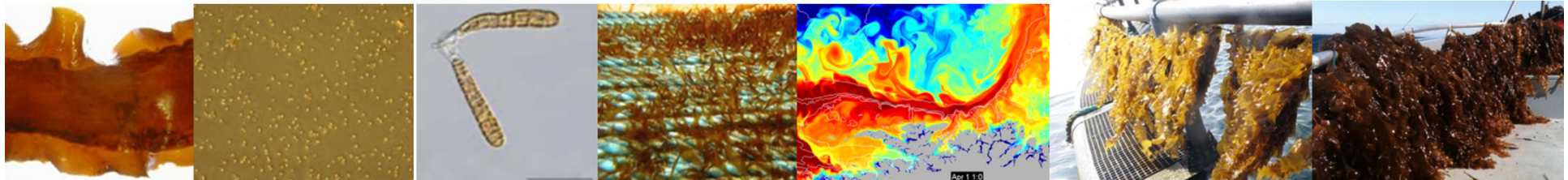
**Seaweed
for Biofuel**

1. Marine biology

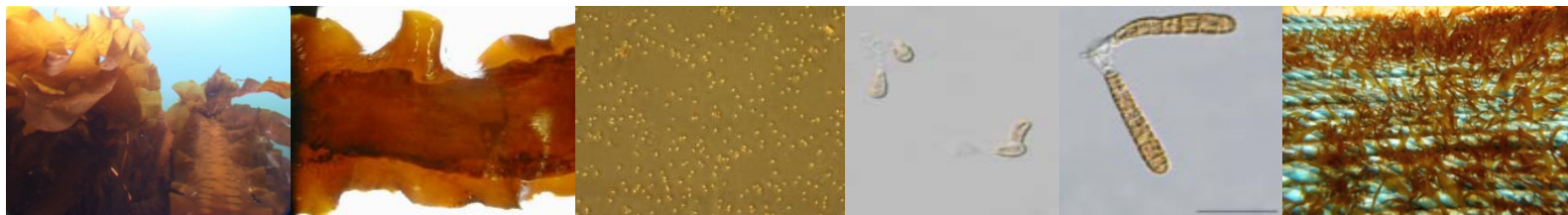
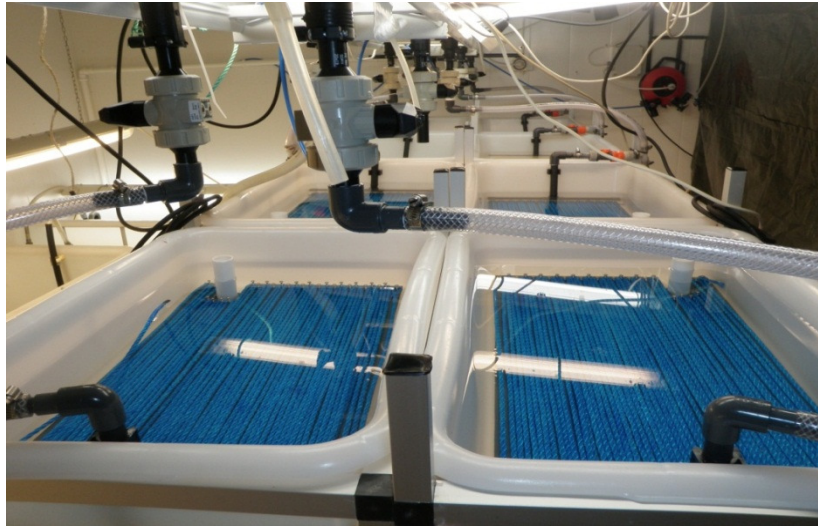
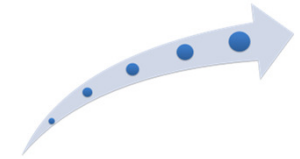
2. Modeling

3. Engineering

4. Inter-Regionality

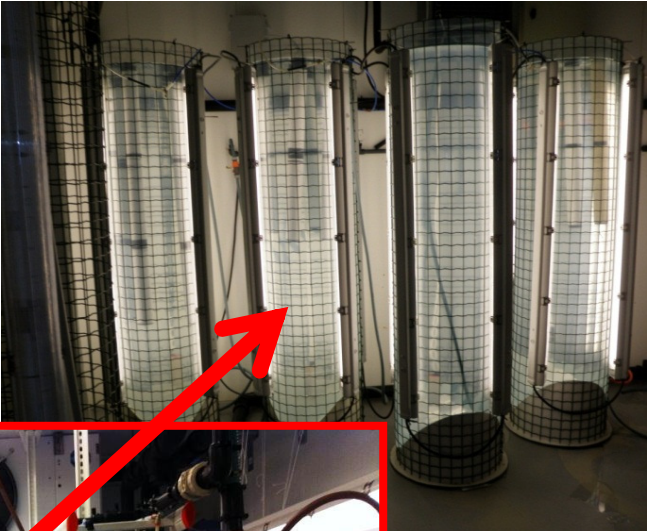


Hatchery systems: Step 1

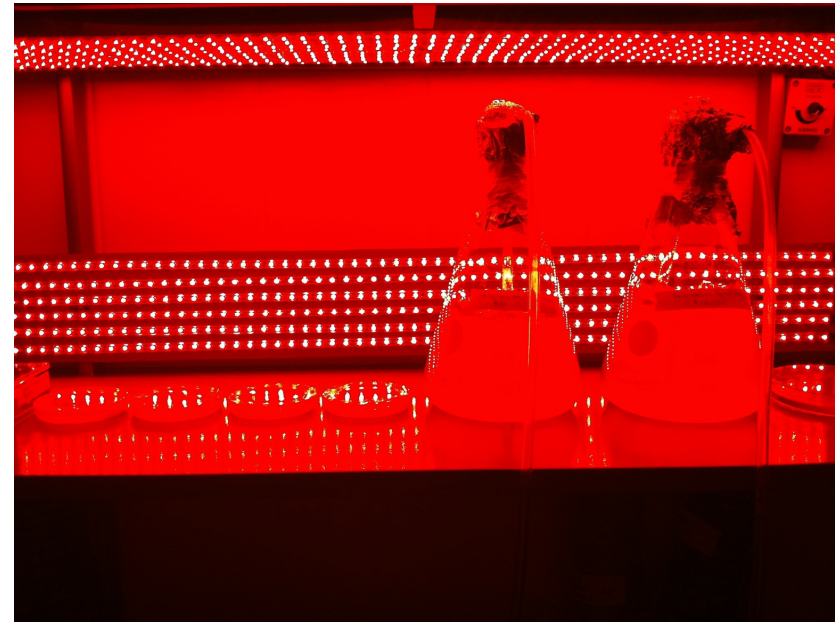
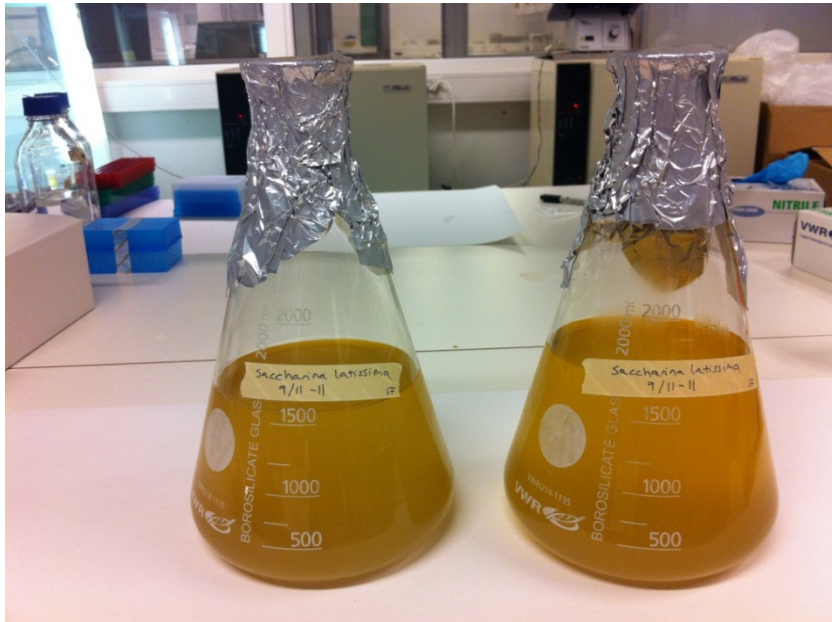
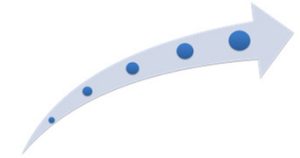


Forbord S., Skjermo J., Arff J., Handå A., Reitan K. I., Bjerregaard R., Lüning K. (2012) Development of *Saccharina latissima* (Phaeophyceae) kelp hatcheries with year-round production of zoospores and juvenile sporophytes on culture ropes for kelp aquaculture. *J Appl Phycol* 24:393-399

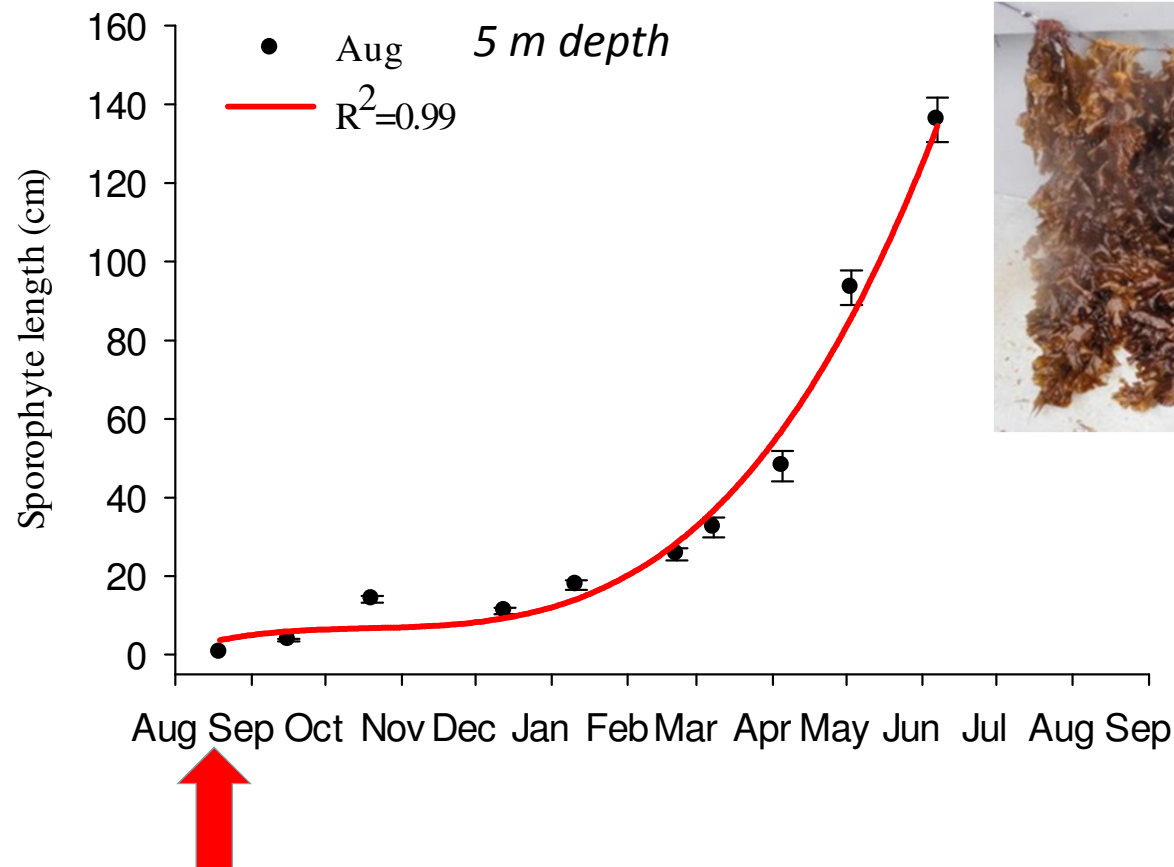
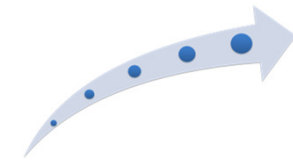
Hatchery systems: Step 2



Hatchery systems: Step 3

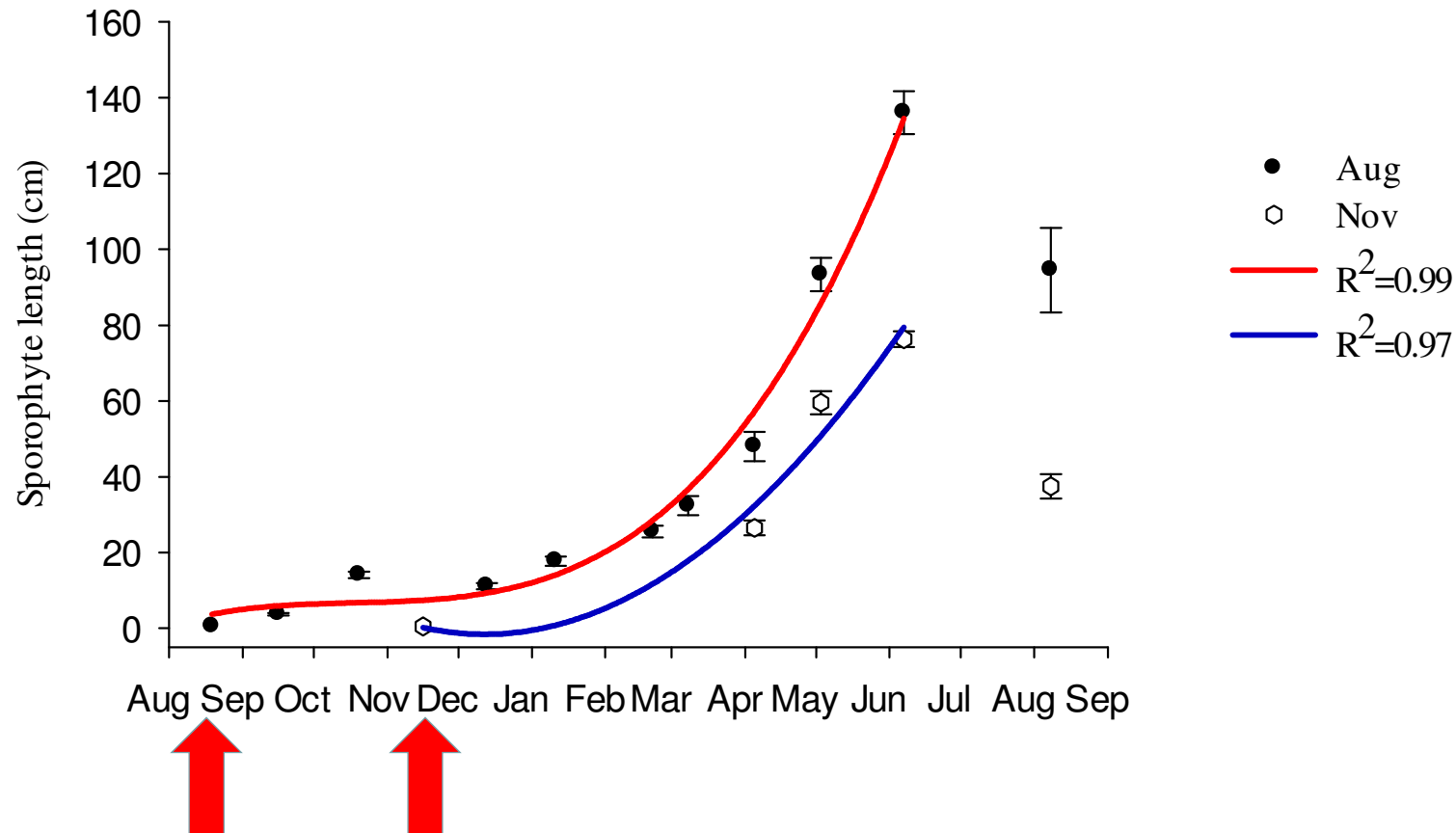


Effect of deployment time on growth of *S. latissima* in mid-Norway



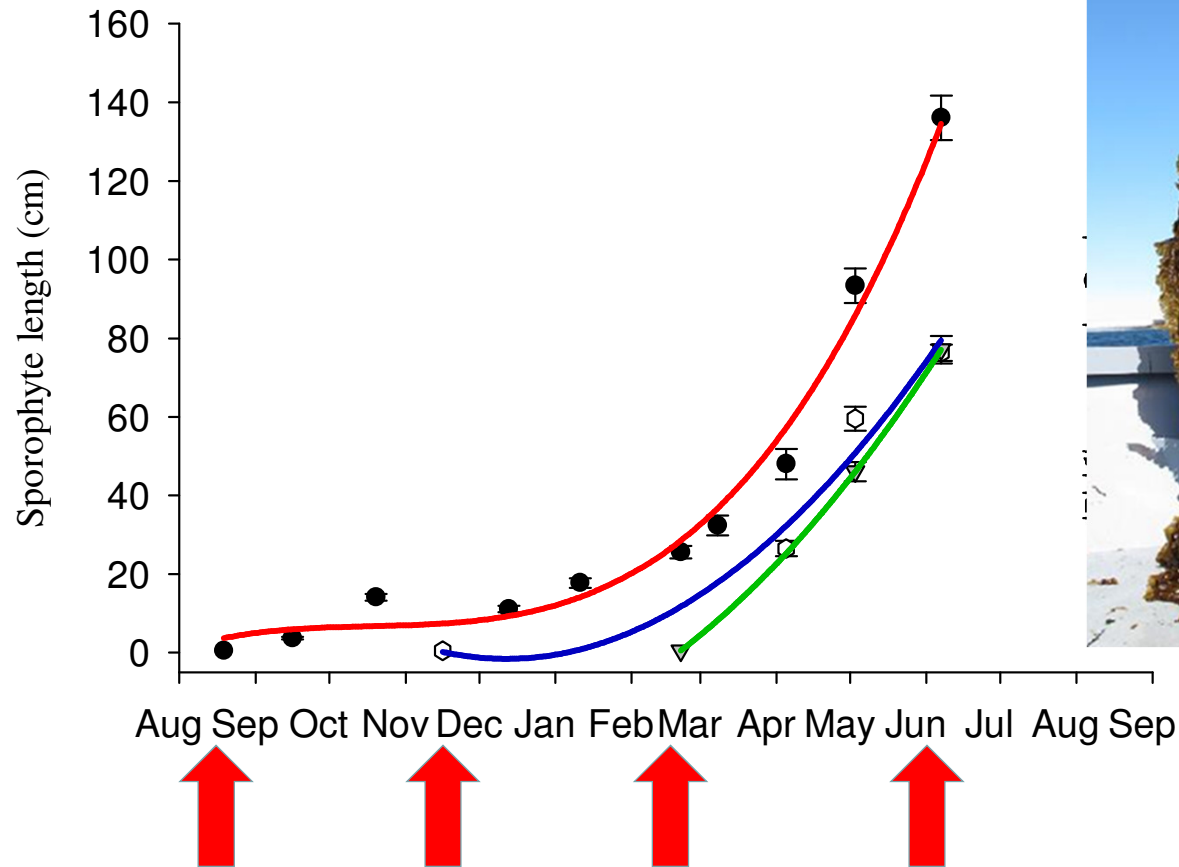
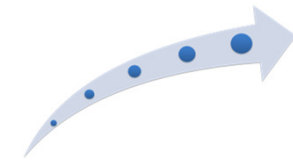
Handå, A., Forbord S., Wang., Broch, O.J.B., Dahle, S.W., Størseth, T.R., Reitan, K.I.R., Olsen, Y., Skjermo, J. Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Subm.*

Effect of deployment time on growth of *S. latissima* in mid-Norway



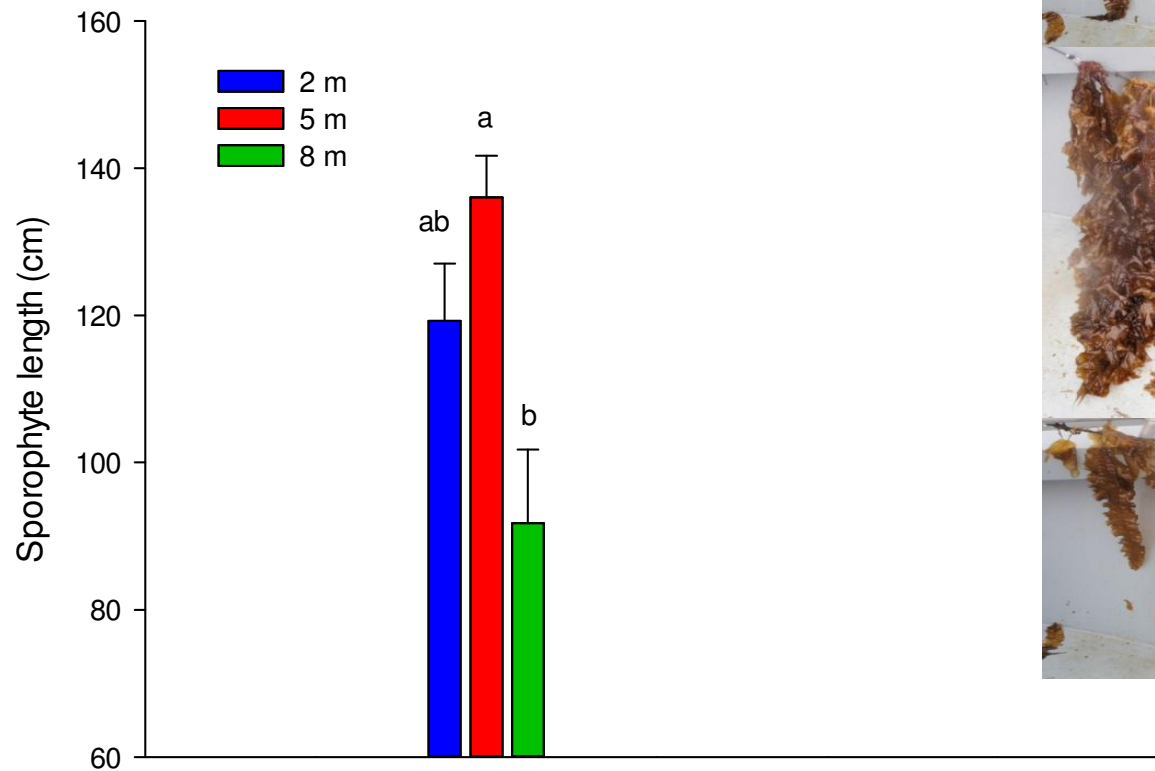
Handå, A. et al., Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

Effect of deployment time on growth of *S. latissima* in mid-Norway



Handå, A. et al., Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

Dept-dependent peak length in June in mid-Norway



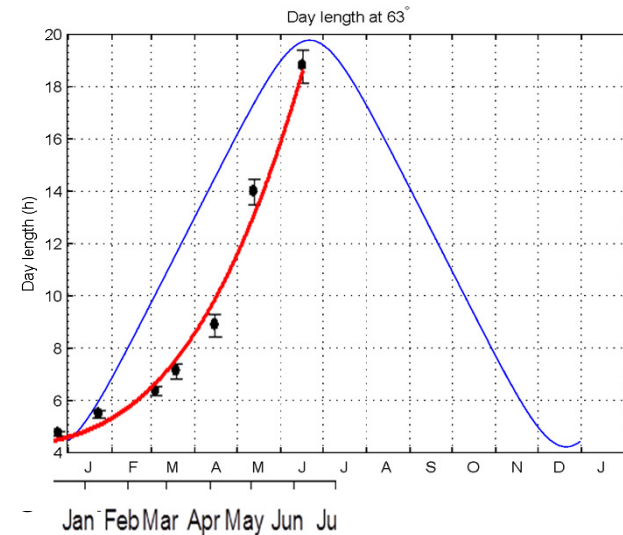
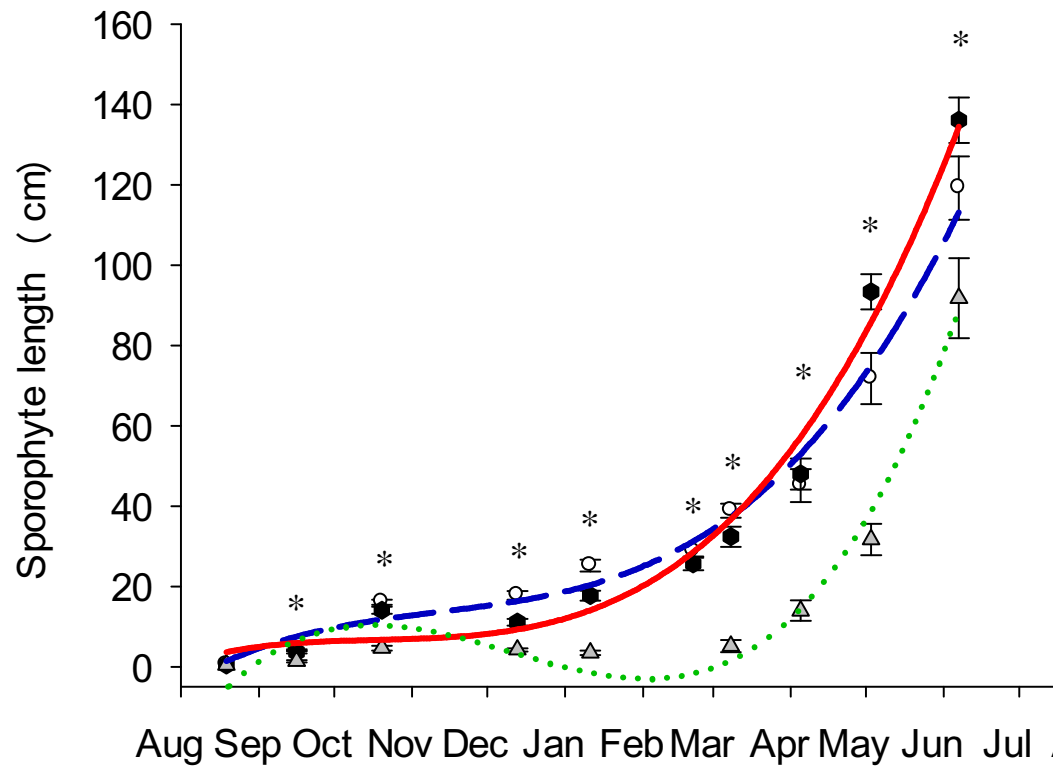
2 m

5 m

8 m

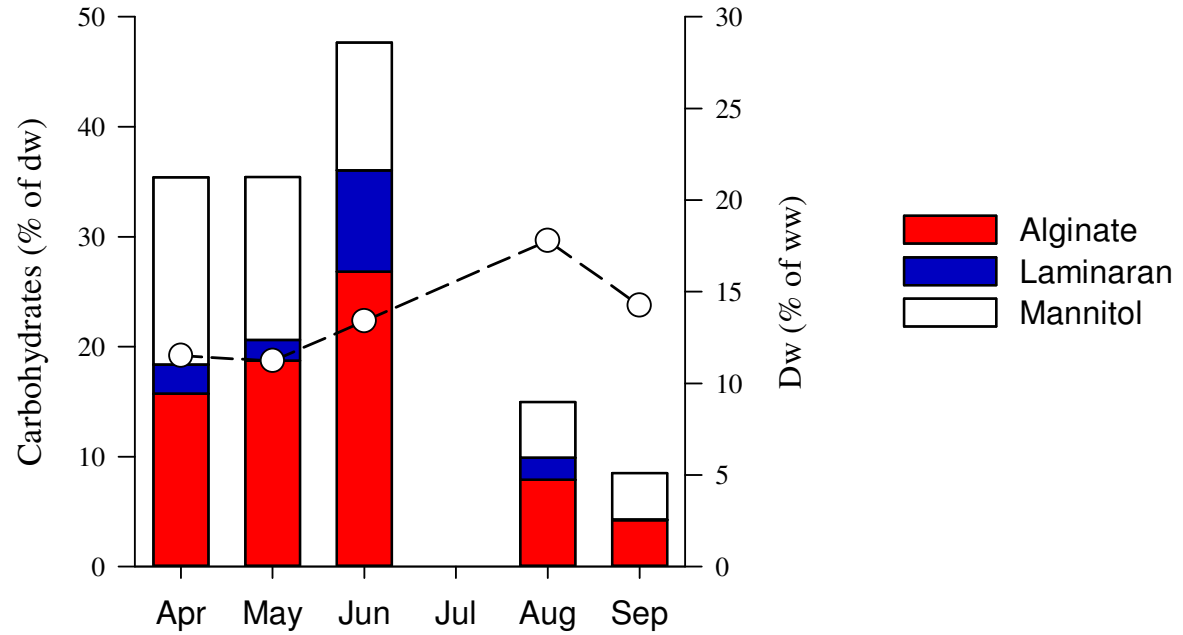
Handå, A. et al., Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

Depth-dependent growth of *S. latissima* in mid-Norway



Handå, A. et al., Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

Carbohydrates



Cultivation strategies: Environmental conditions



Low productive areas

High productive areas

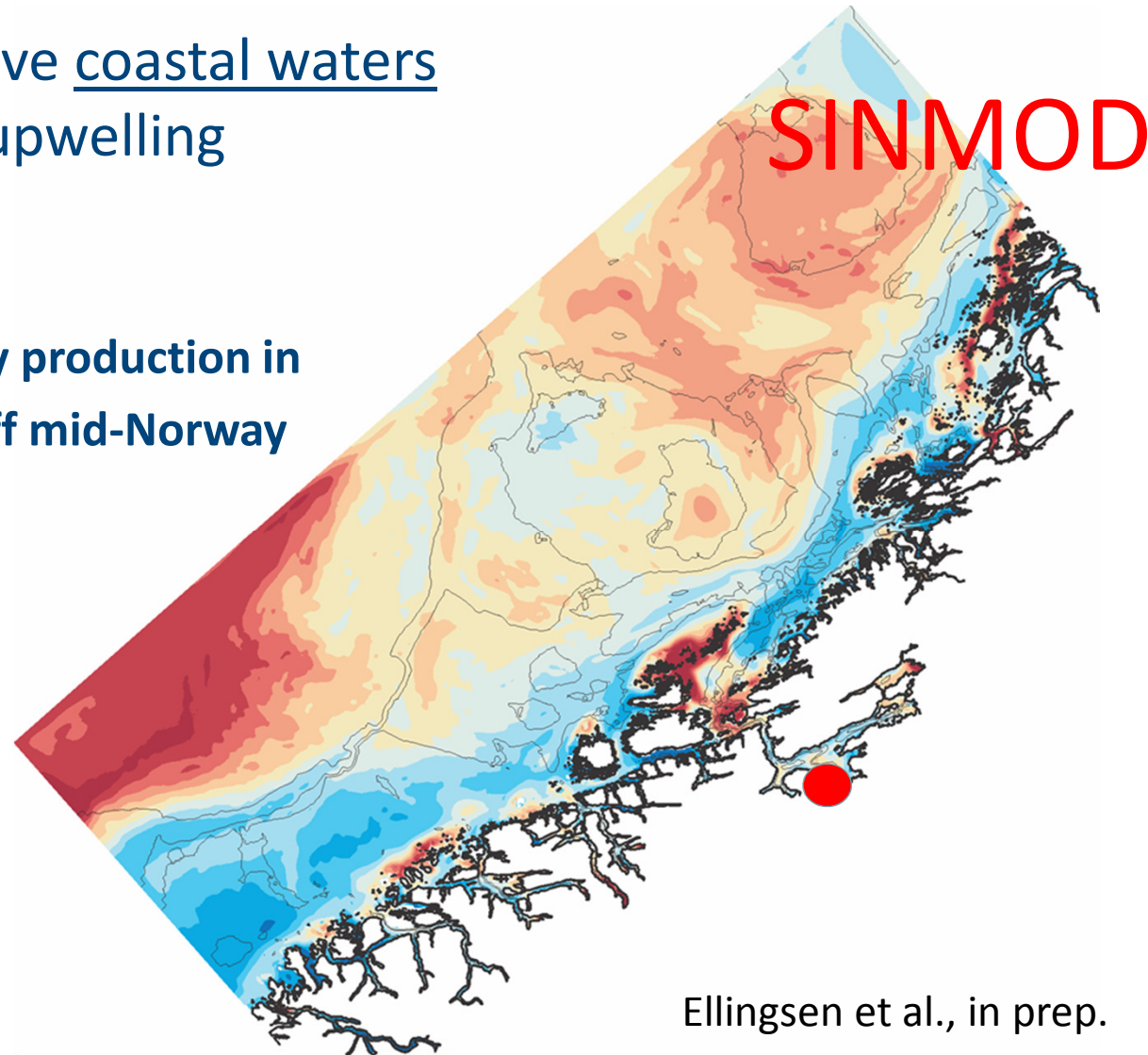
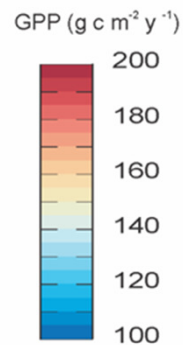


2. Modelling

3D coupled hydrodynamic and biological model system

High productive coastal waters
with natural upwelling

- Gross primary production in coastal waters off mid-Norway



High productive fjords

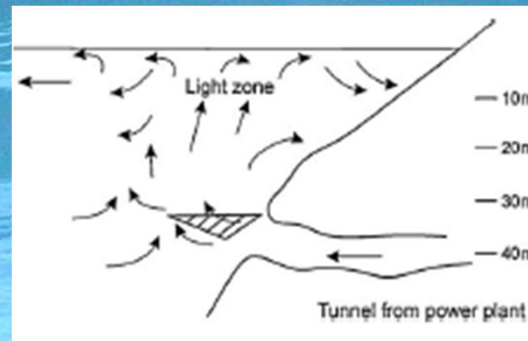
Artificial upwelling



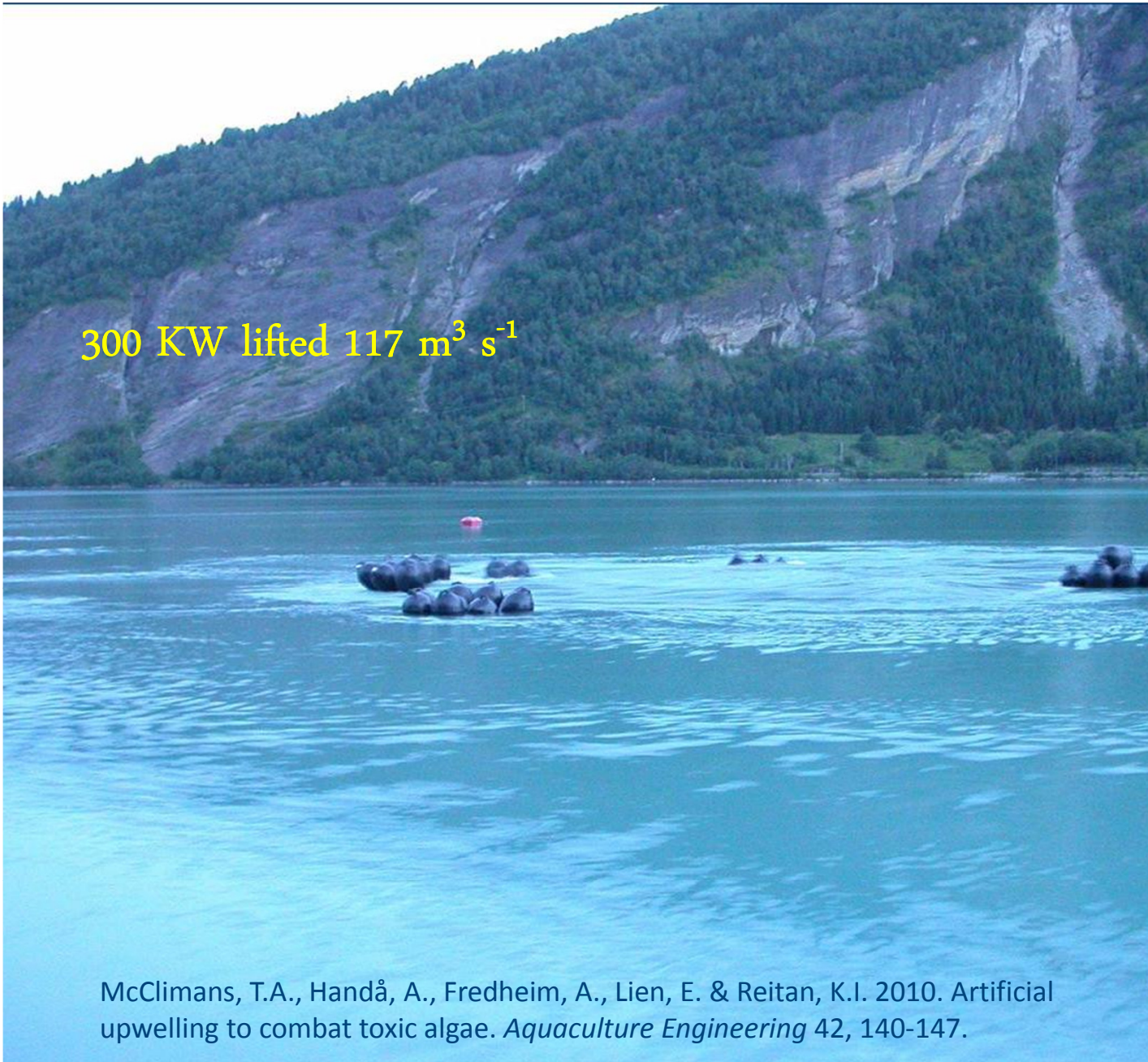
390 KW lifted $60 \text{ m}^3 \text{ s}^{-1}$



McClimans, T.A., Handå, A., Fredheim, A., Lien, E. & Reitan, K.I. 2010. Artificial upwelling to combat toxic algae. *Aquaculture Engineering* 42, 140-147.

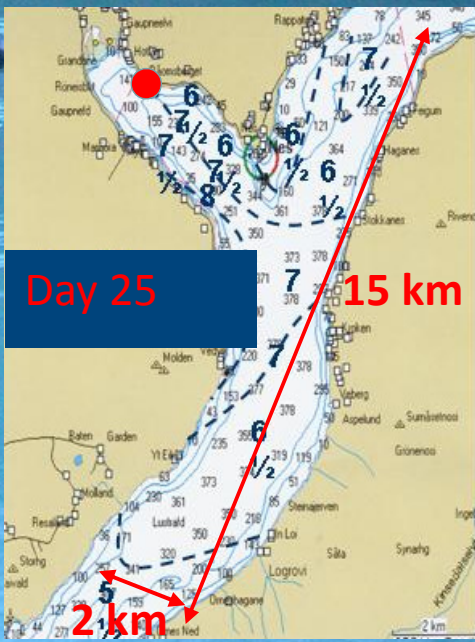
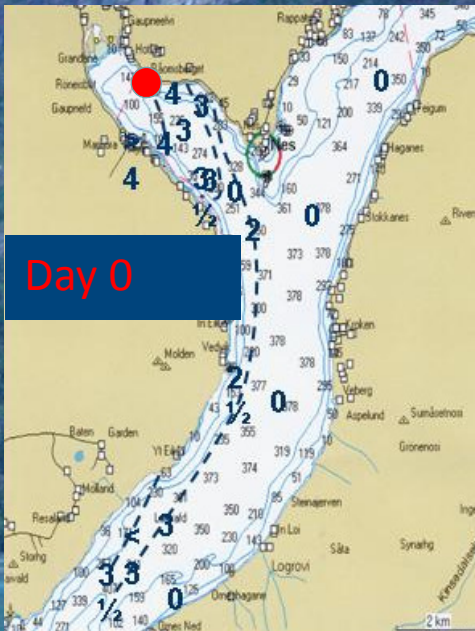


McClimans, T.A., Handå, A., Fredheim, A., Lien, E. & Reitan, K.I. 2010. Artificial upwelling to combat toxic algae. *Aquaculture Engineering* 42, 140-147.

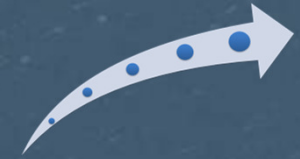


300 KW lifted $117 \text{ m}^3 \text{ s}^{-1}$

McClimans, T.A., Handå, A., Fredheim, A., Lien, E. & Reitan, K.I. 2010. Artificial upwelling to combat toxic algae. *Aquaculture Engineering* 42, 140-147.



Nutrient Sources for Seaweed



Aquaculture



Upwelling



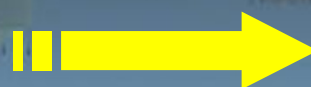
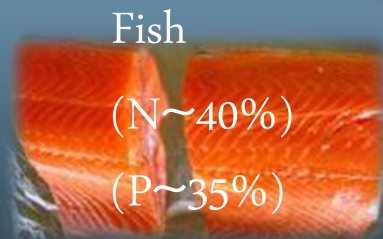


Norway 2011: > 1.100.000 tons
salmon and trout

Nutrient mass-balance budget for Norwegian salmon aquaculture



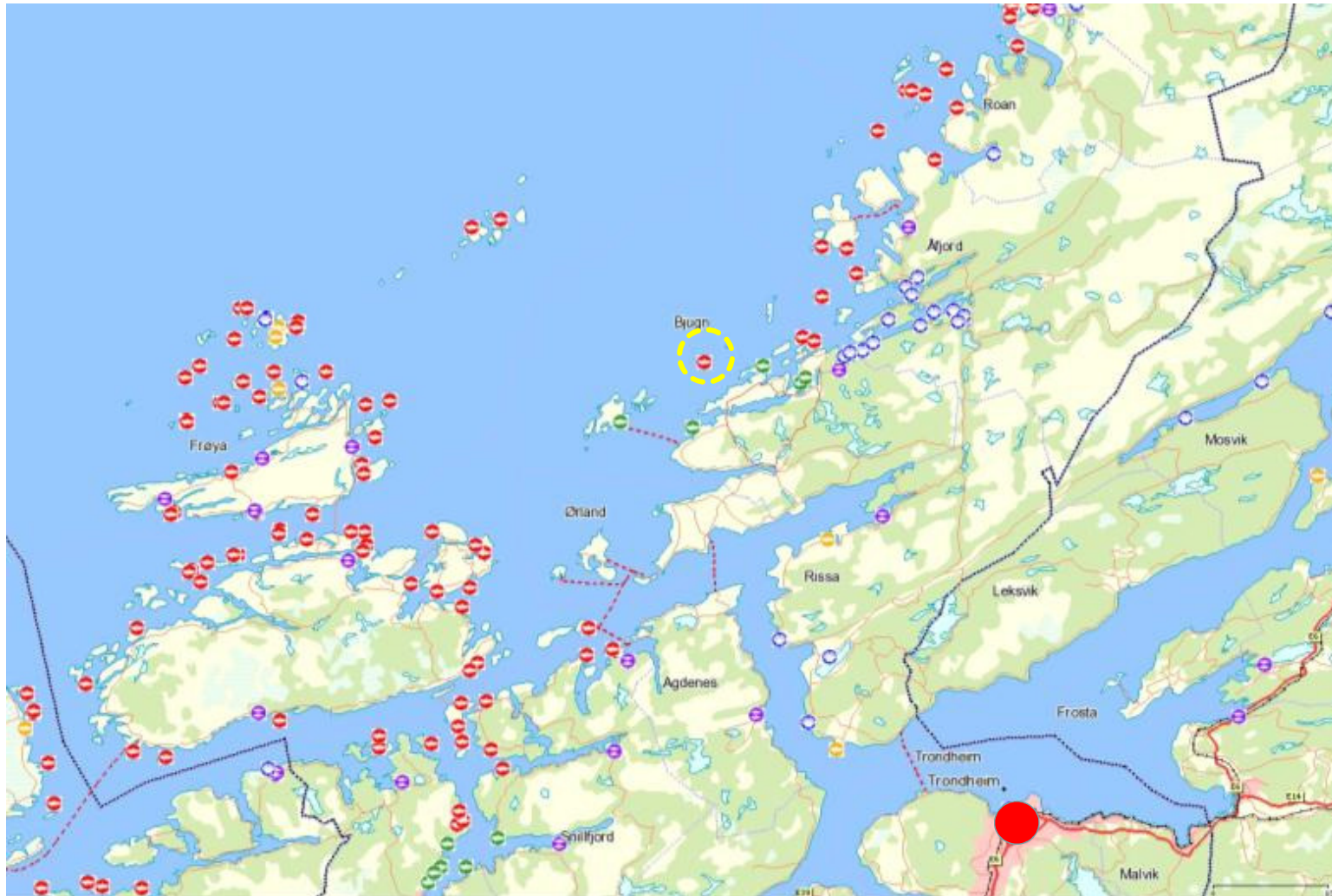
Particulate
nutrients
(~15% N)
(~44% P)



Dissolved nutrients
(~45% N)
(~21% P)

Wang et al., 2012. Aquaculture and Environment Interactions, 2:267-283

Salmon farms in mid-Norway



IMTA with salmon (*Salmo salar*), sugar kelp (*Sacharina latissima*) and blue mussels (*Mytilus edulis*) in mid-Norway

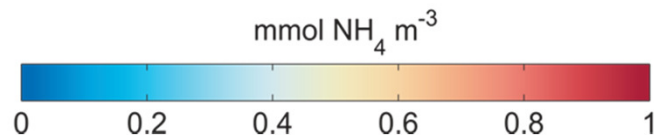
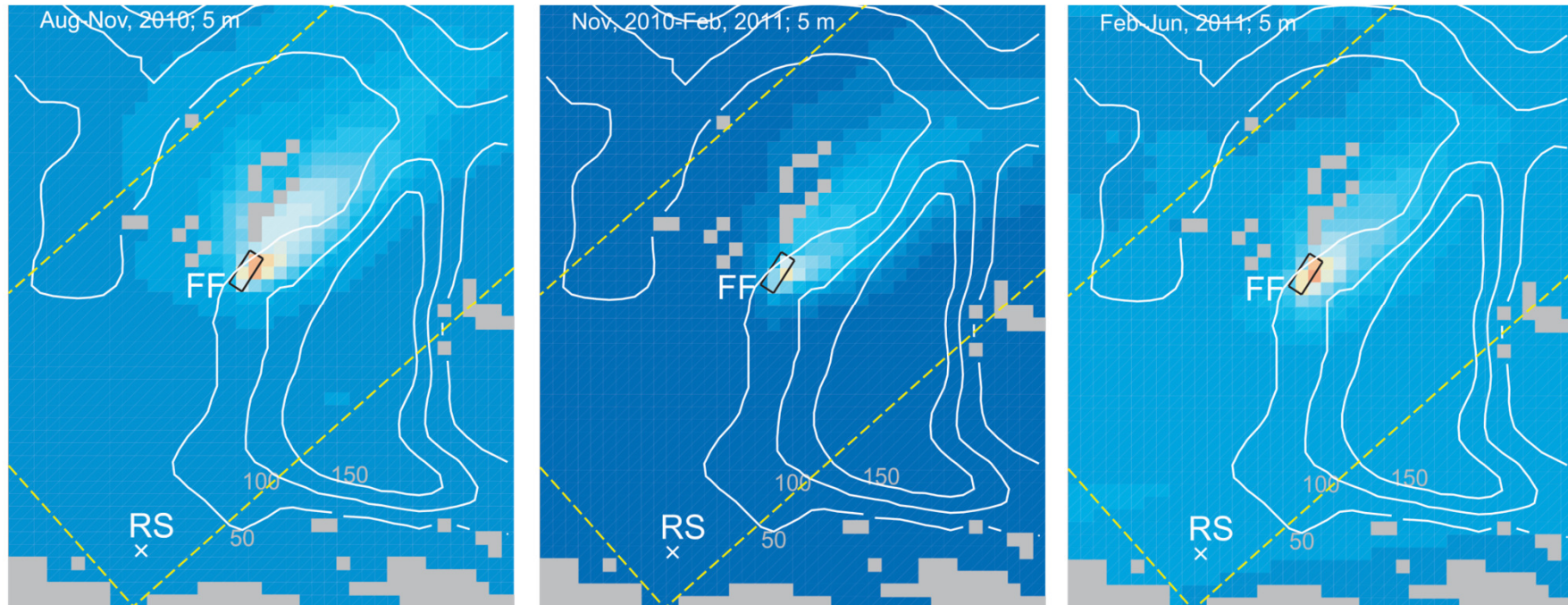


Handa, A., Min, H., Wang, X., Broch, O.J., Reitan, K.I., Reinertsen, H., Olsen, Y. 2012: Incorporation of fish feed and growth of blue mussels (*Mytilus edulis*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for integrated multi-trophic aquaculture in Norwegian coastal waters. *Aquaculture*, 356-357: 328 – 341

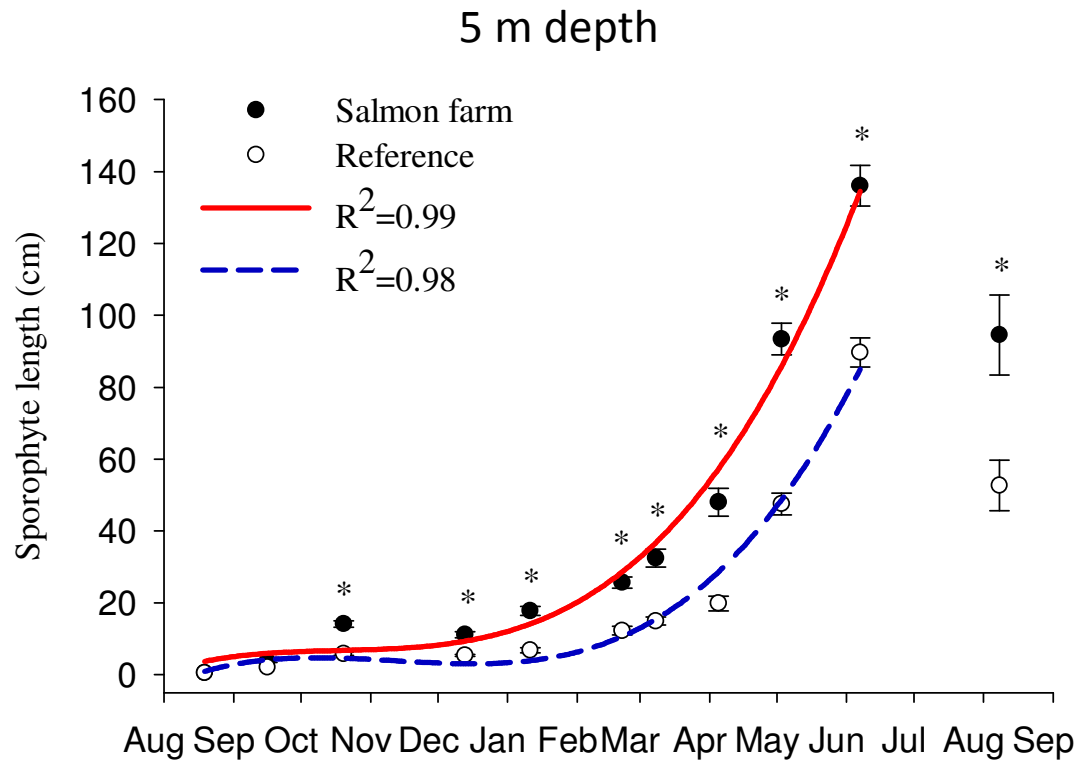
Handå, A., Forbord, S., Wang, Broch, O.J.B., Dahle, S.W., Størseth, R.R., Reitan, K.I.R., Olsen, Y., Skjermo, J. Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

Nitrogen from fish farming: Ammonium

SINMOD



Length of *S. latissima* in IMTA with *Salmo salar*



Reference

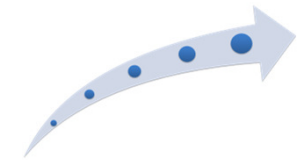
Salmon farm



50% better growth in IMTA

Handå, A. et al., Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Submitted*

3. Engineering – farm design and systems



Its only a matter of effort!



Fossil fuel



2012

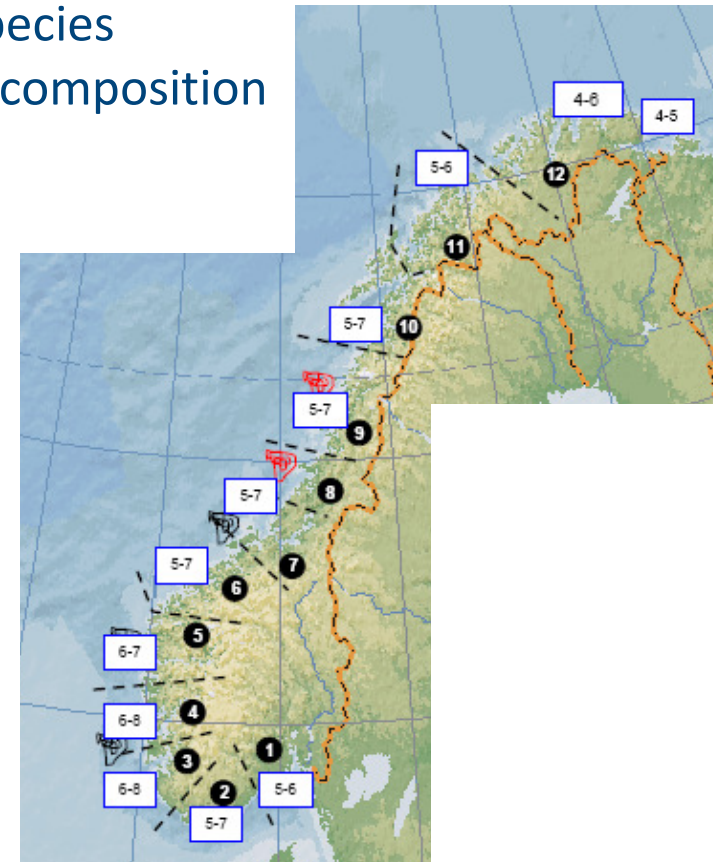


4. Inter-Regional Cultivation Strategy



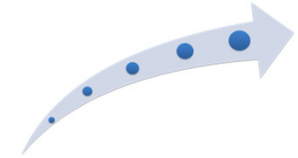
Coordinated cultivation of complementary species depending on: Growth, fouling and chemical composition

1. Light
2. Nutrients
3. Temperature
4. Available area

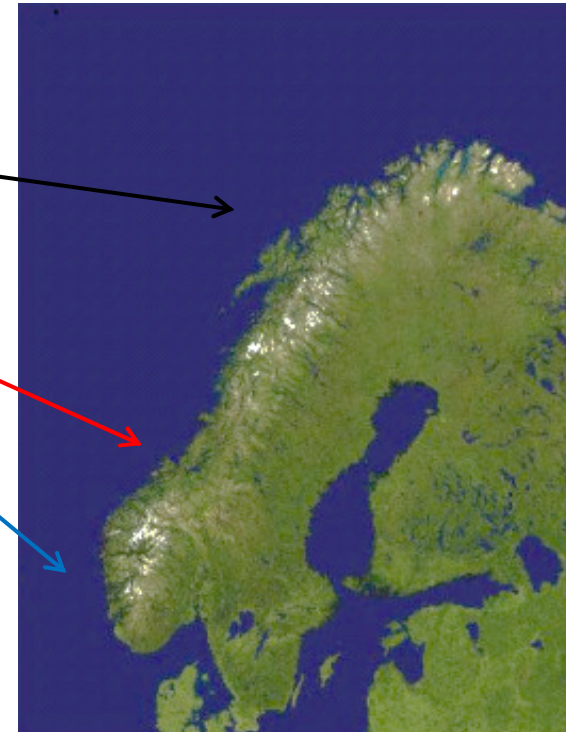
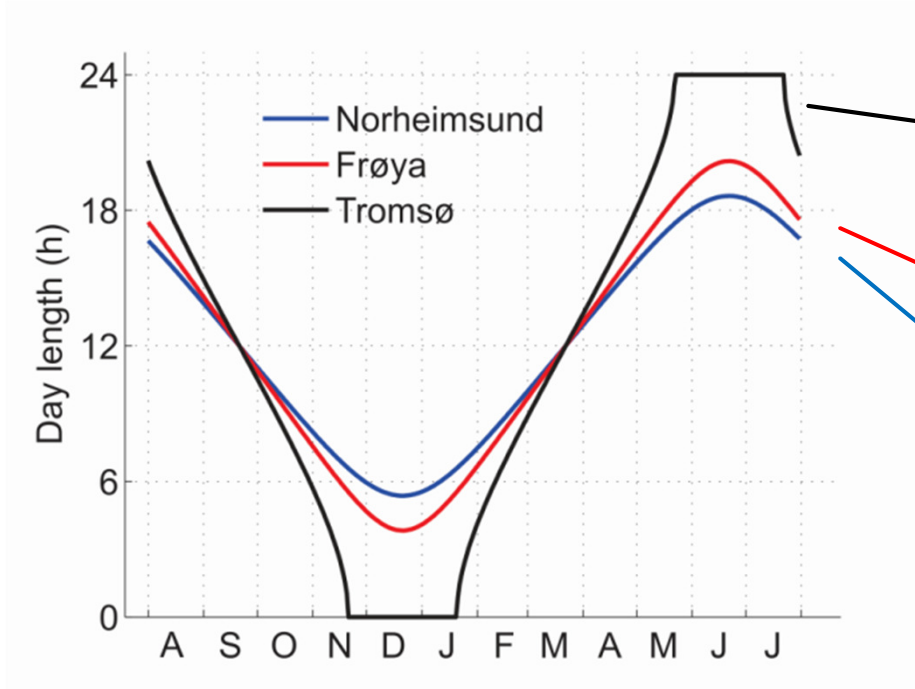


100.000 km coastline!

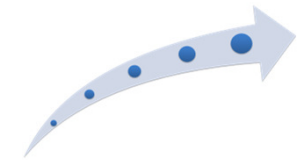
Inter-Regional Cultivation Strategy



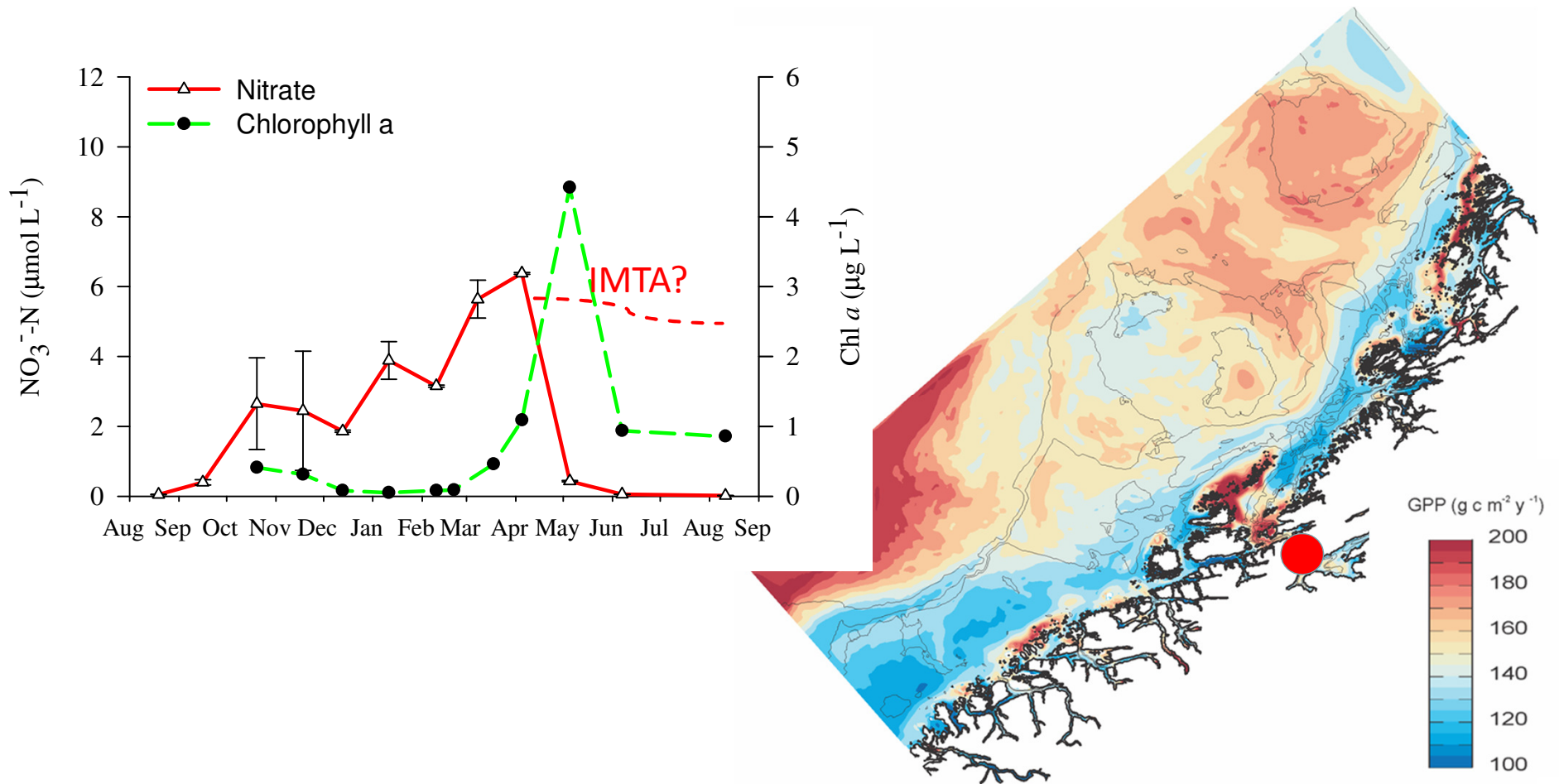
1. Light – day length



Inter-Regional Cultivation Strategy



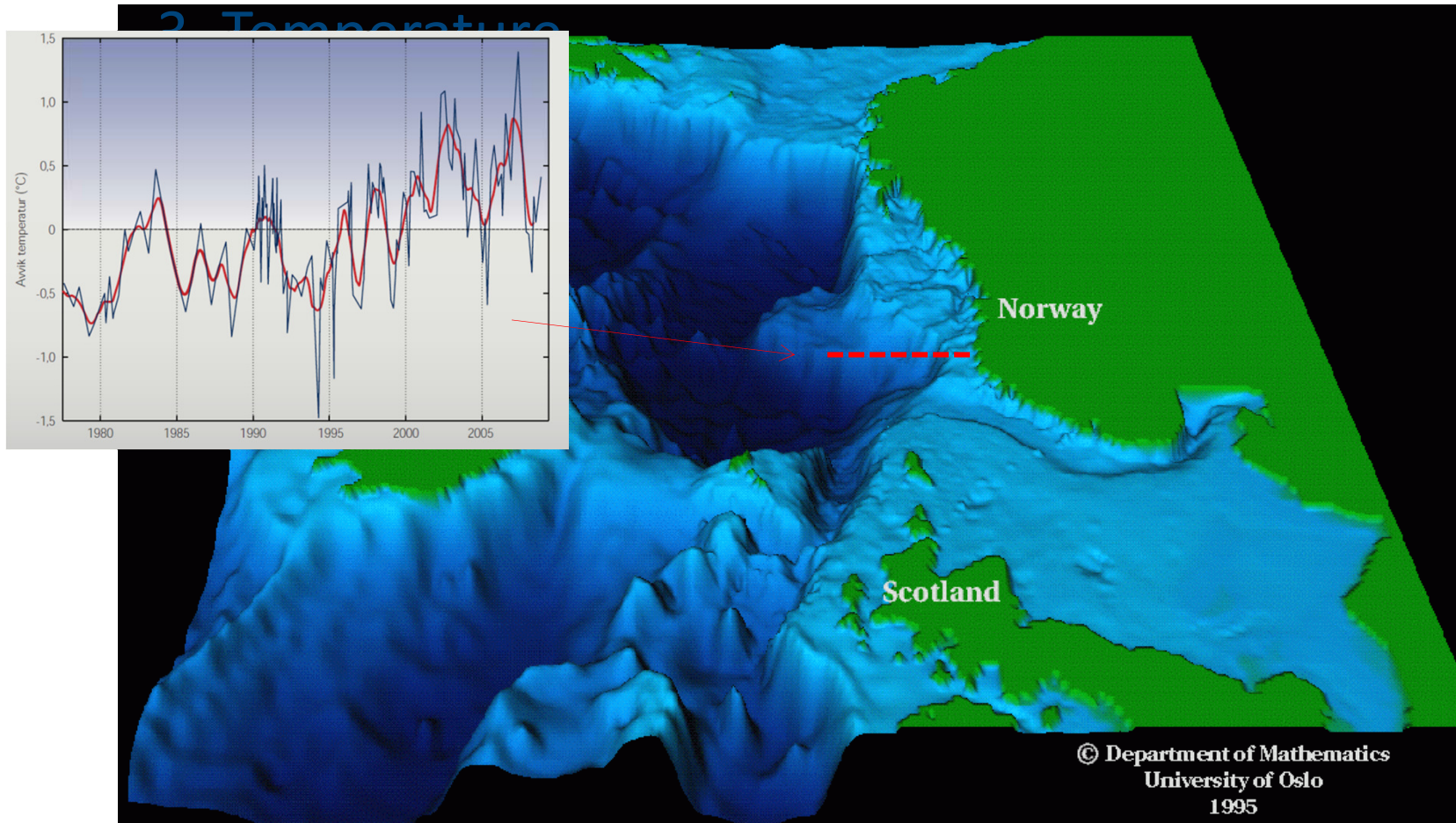
2. Nutrients



Inter-Regional Cultivation Strategy

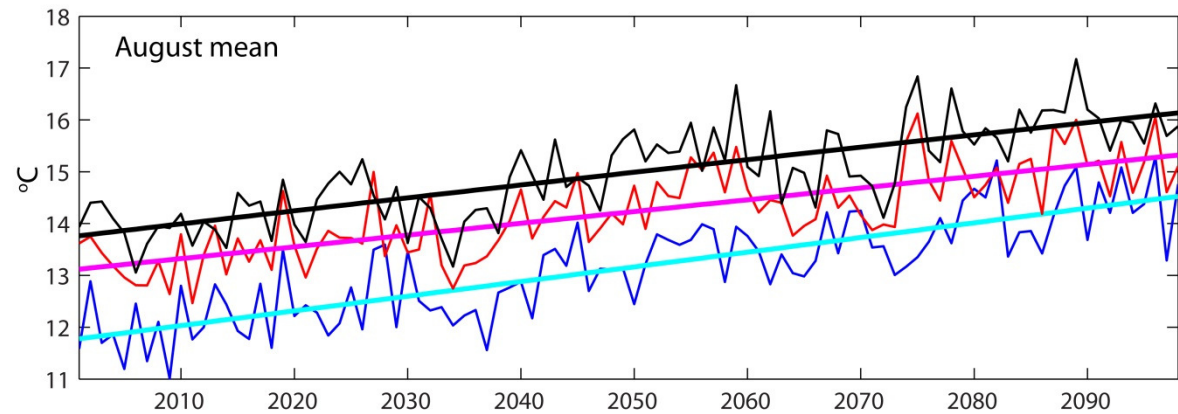
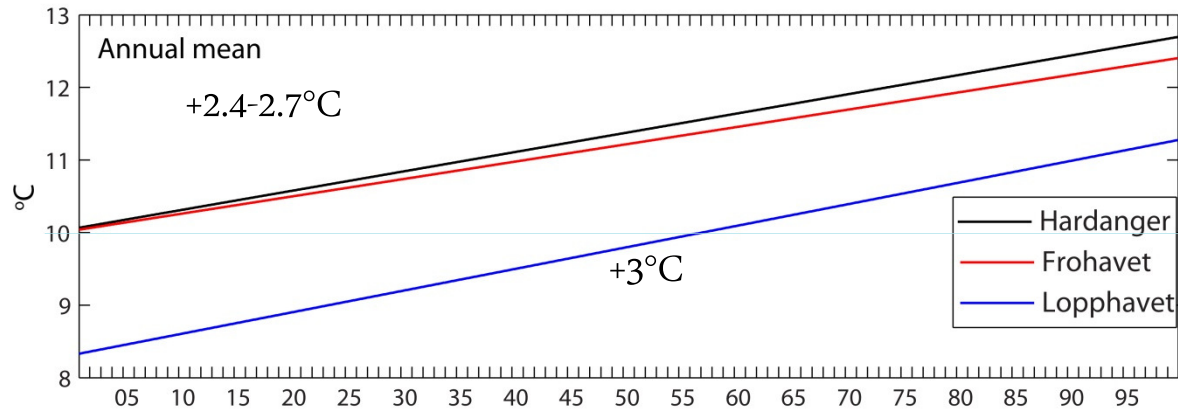


3. Temperature



Measured by Marine Institute

Projected changes in sea surface temperature along the Norwegian coast

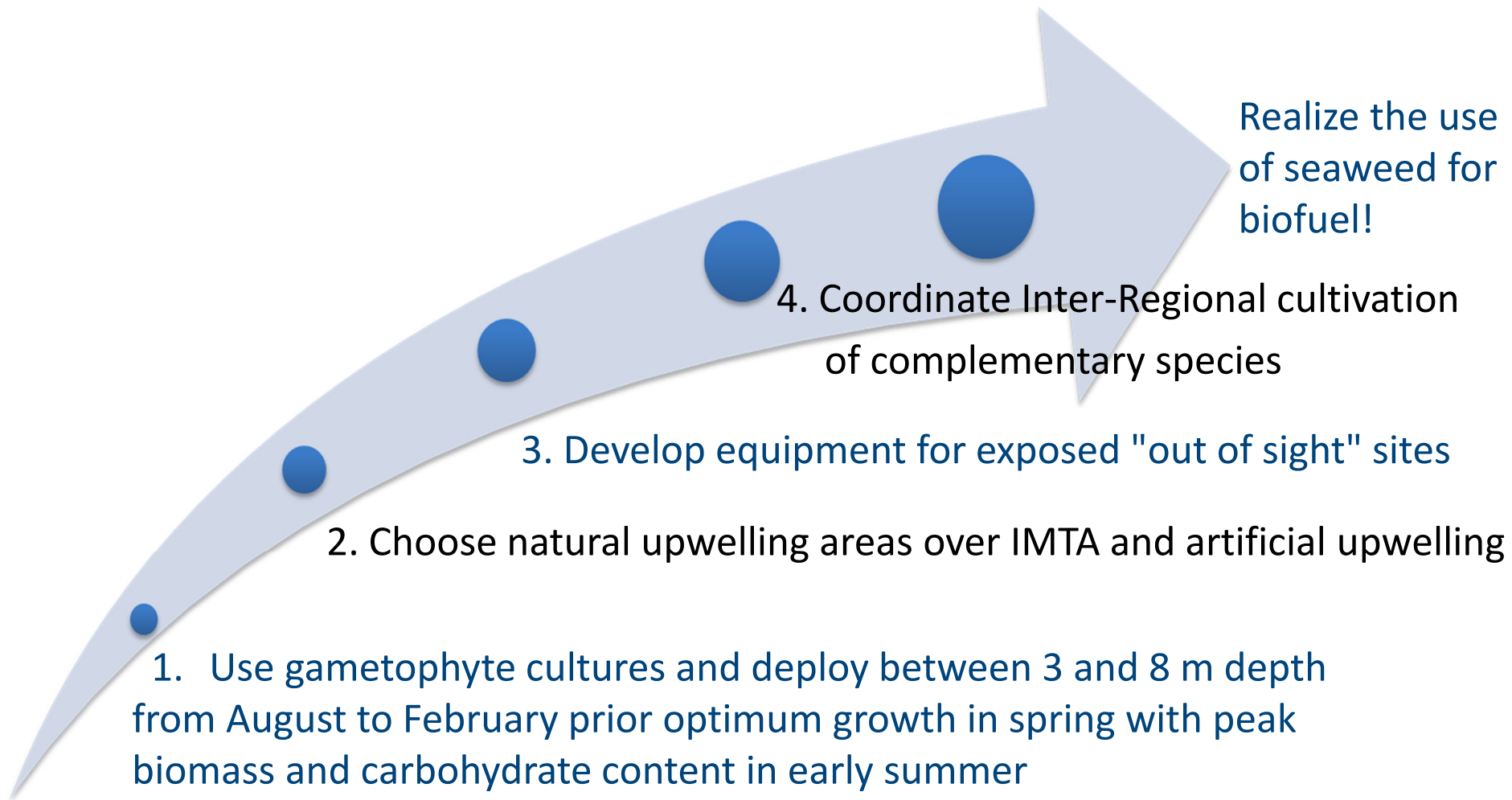


SINMOD

D. Slagstad/SINTEF

Seaweed Cultivation Strategies in Norway

Multidisciplinary Support Tools Recommendations:



Thank you!

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