Seaweed farming: Fertilized by effluents from fish aquaculture

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International Marine Ingredients Conference 2013
SEPTEMBER 22-24 / OSLO, NORWAY

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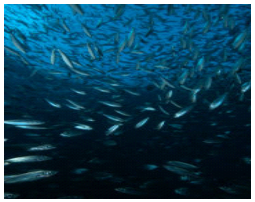
Aquaculture in Norway

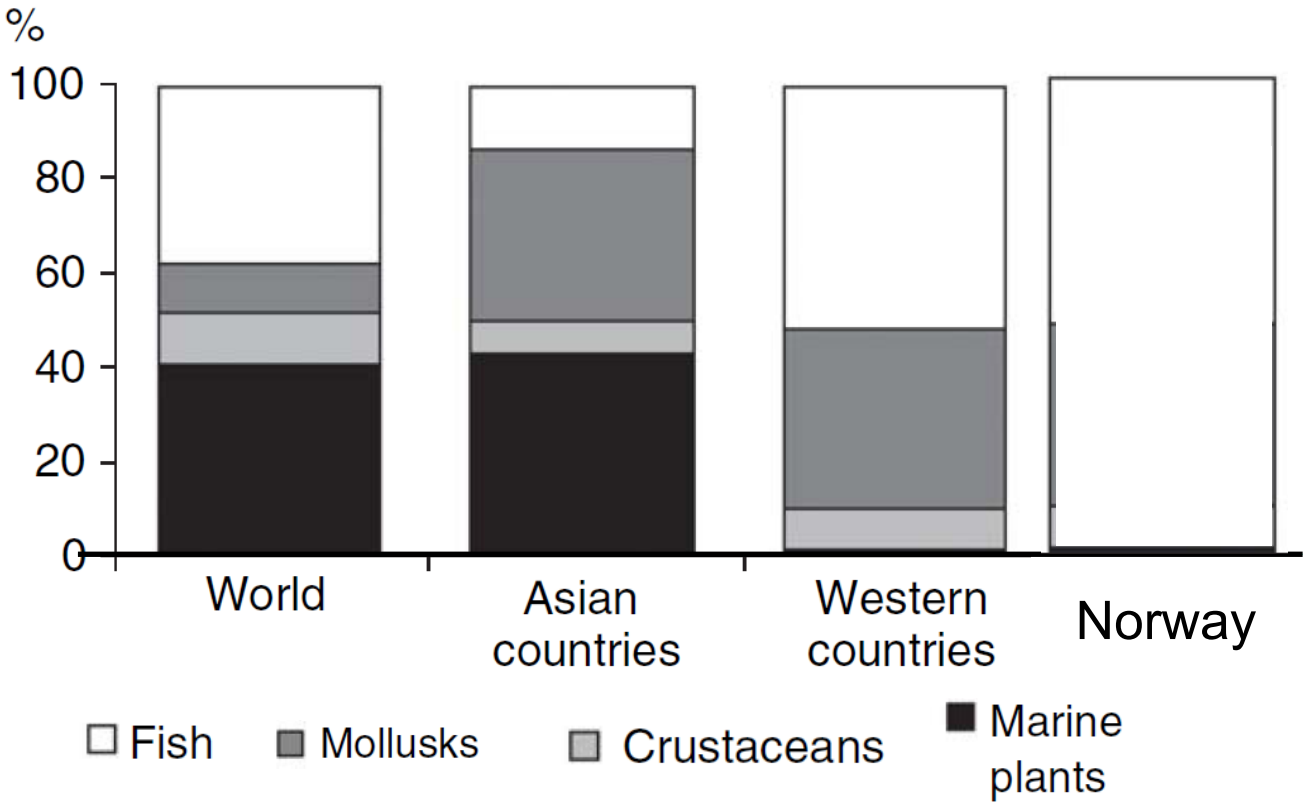
Statistics for aquaculture production in Norway in 2011

Areas	Environments	Species	Production volumes (t)	Values (1000 USD)
Inland waters	Fresh water	Salmon, Rainbow trout	72	982
Coastal waters	Sea water	Crustaceans (Lobster, crabs, prawns)	Less than 1	Less than 1
		Molluscs (mussels, oysters)	1 926	4 528
		Salmonid fishes (Salmon, Rainbow trout)	**1 118 545**	**5 153 352**
		Other fishes (cod, halibut, turbot)	18 253	81 417
		Aquatic plants (algae)	0	0
		Total Norway	1 138 797	5 240 334

(FAO - Fisheries and Aquaculture Information and Statistics Service – 2013)

World aquaculture production of fish, mollusks, crustaceans and marine plants





Statistics for global aquaculture production FAO 2013

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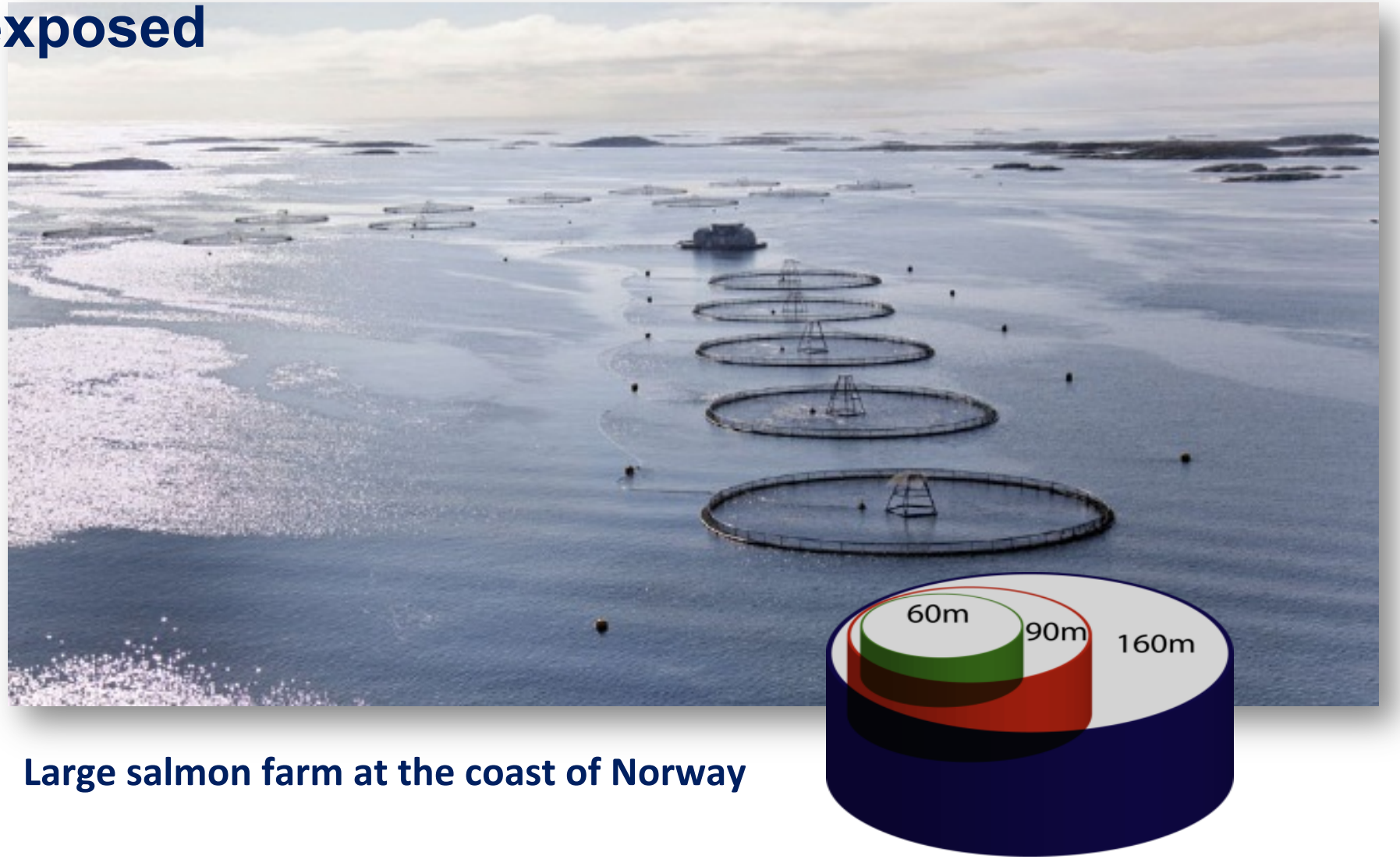
Development of fish farming sites: Bigger and more exposed



Large salmon farm at the coast of Norway

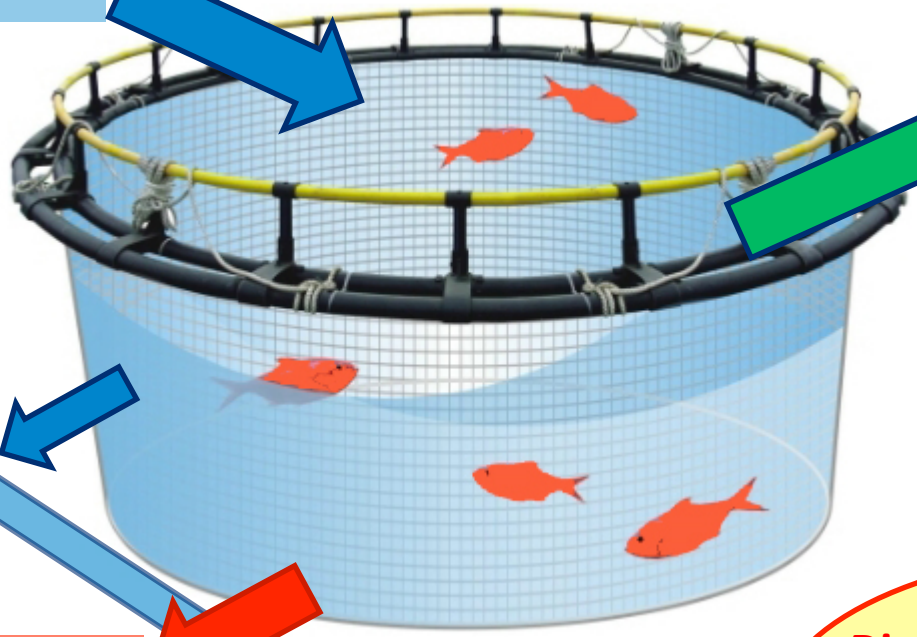
Aquaculture of salmon – Open ocean farming

One example (Akvagroup AC 450):

- Feed barge with a feed capacity of 450 tons and 4-feeding lines.
- The fleet can serve a biomass of 2250 tons of salmon, which under good conditions need a daily feeding of 22-25 tons

Feed barge

The flow and fate of nutrients in cage aquaculture (Atlantic salmon)



Feed supplied
C, N, P

Feed consumed by fish
C, N, P

Accumulated in fish biomass
C, N, P

Feed losses
POC, PON, POP

Faecal
POC, PON, POP

Resuspended
DOC, DON, DOP

Dissolved in the water column

Respired CO_2 or
excreted DIN, DIP

Settle out in seafloor, POC, PON, POP

Wang, X., Olsen, L.M., Reitan, K.I., Olsen, Y., 2012. Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture. Aquaculture Environment Interactional. 2: 267-283

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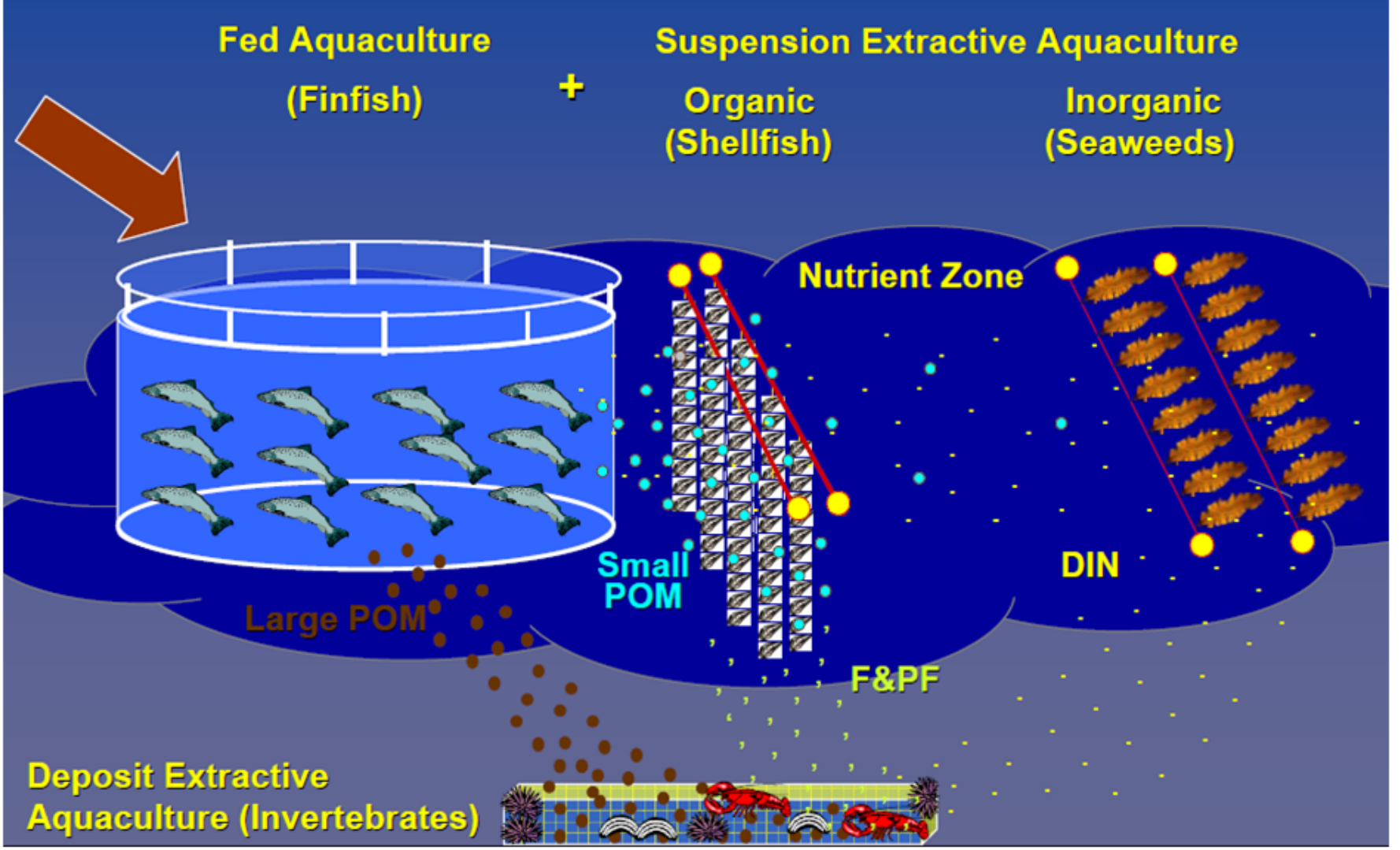
Can these resourses be utilised??

How can the nutrients from fish farming be utilized?



Illustrastration: Prof. Tierry Chopin (University of New Brunswick)

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Integration of fed aquaculture species with extractive species at lower trophic levels.

IMTA concept (Integrated MultiTrophic Aquaculture)

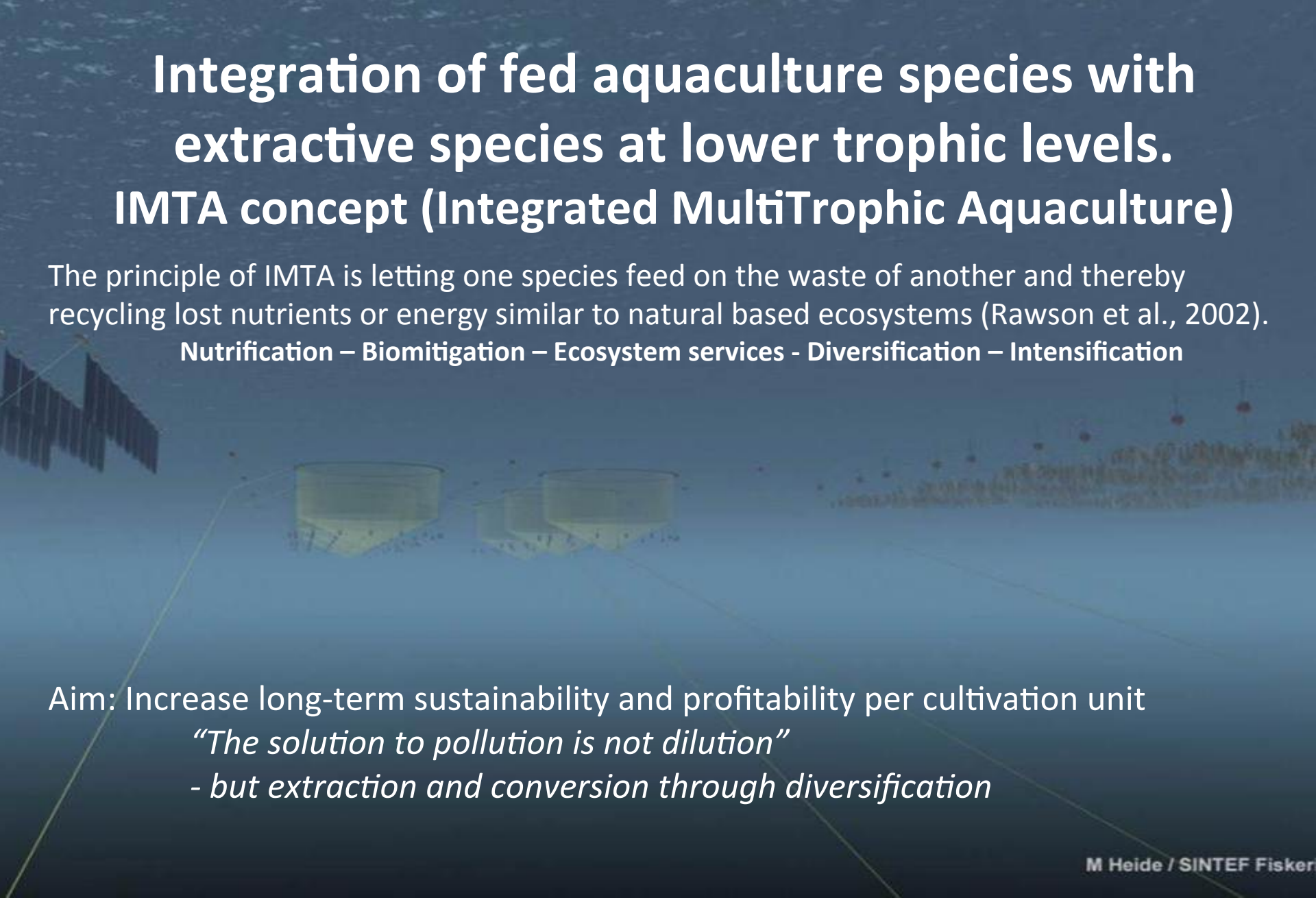
The principle of IMTA is letting one species feed on the waste of another and thereby recycling lost nutrients or energy similar to natural based ecosystems (Rawson et al., 2002).

Nutrification – Biomitigation – Ecosystem services - Diversification – Intensification

Aim: Increase long-term sustainability and profitability per cultivation unit

"The solution to pollution is not dilution"

- but extraction and conversion through diversification



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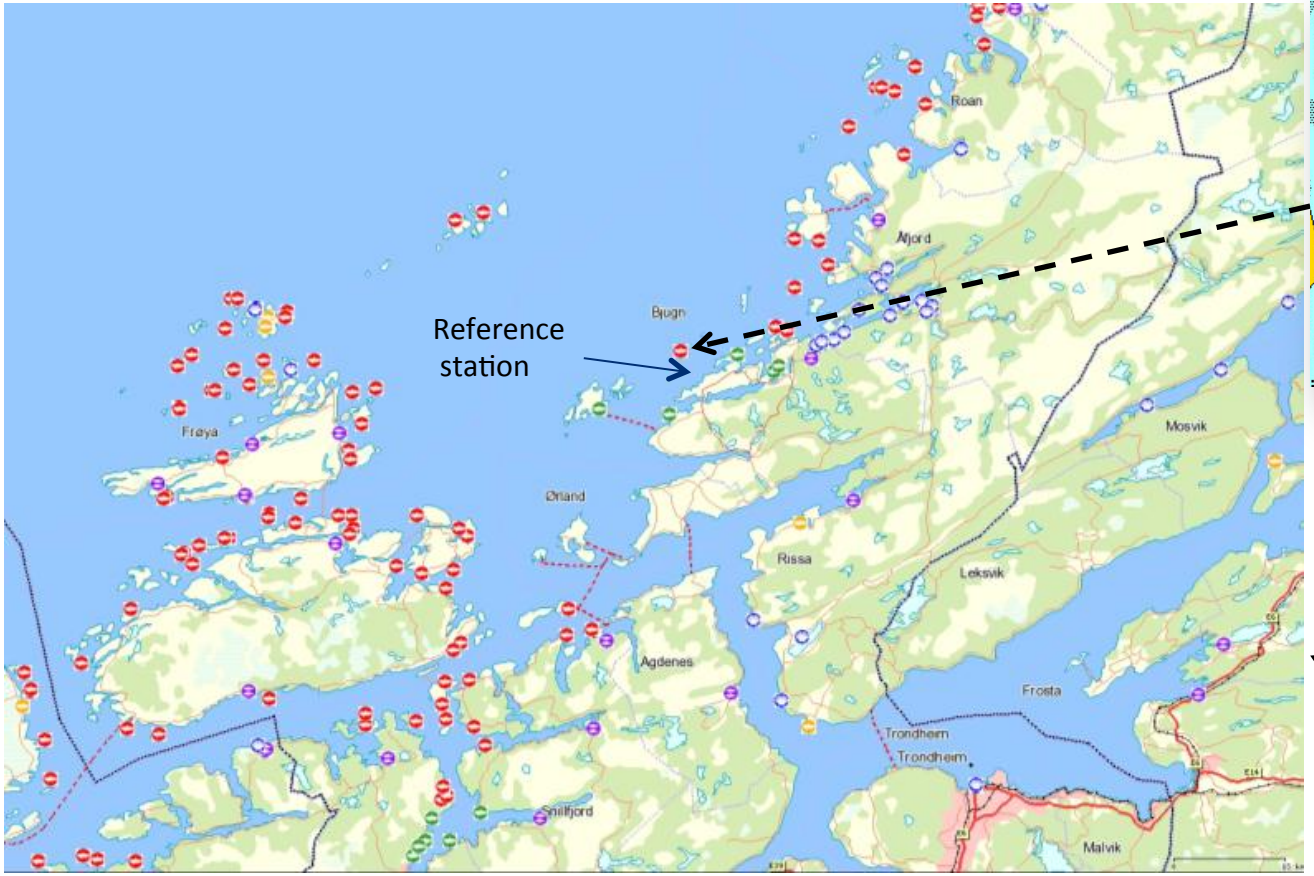
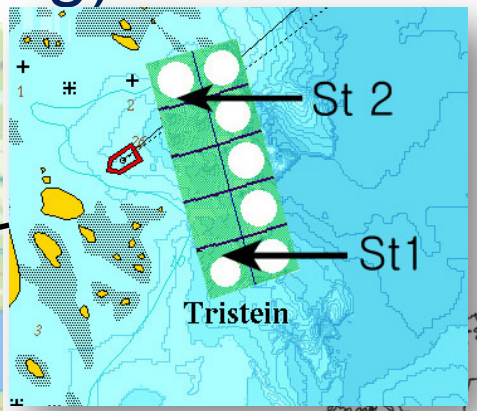
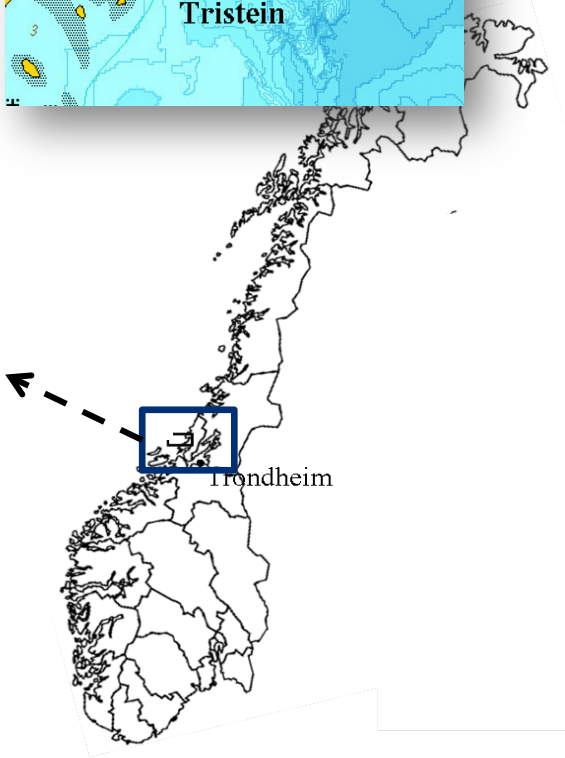
Testing of seaweed growth at a salmon fish farm
ACE (Aquaculture Engineering)







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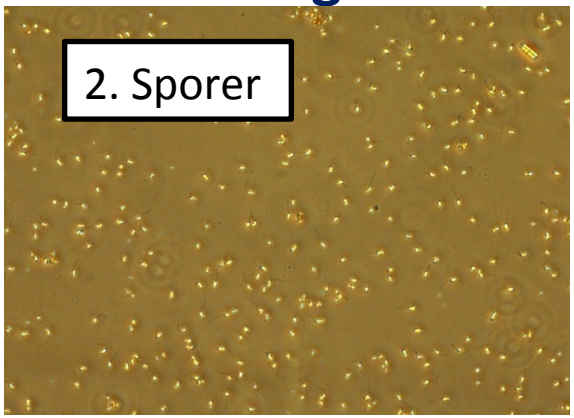
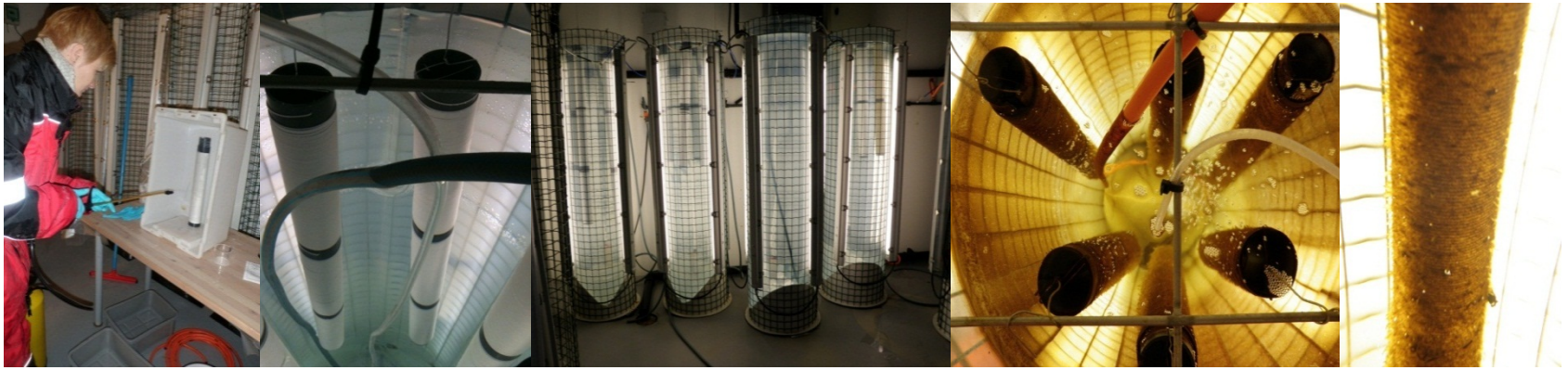
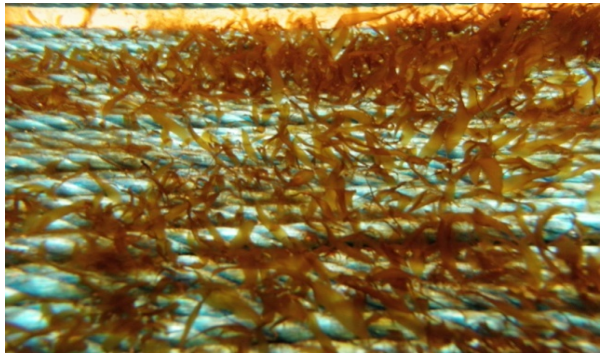
Year round cultivation of seedlings of *Saccharina latissima*







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. Journal of Applied Phyciology. 24: 393-399.

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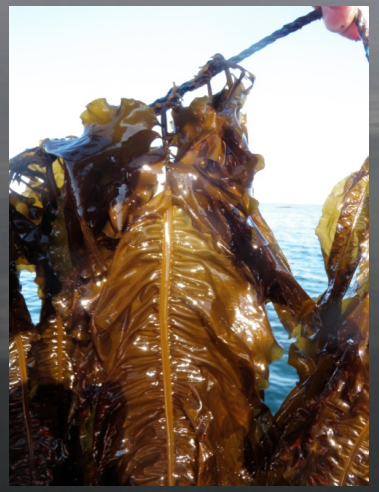
Cultivation of seaweed in open ocean location
- Integrated with salmon cage aquaculture

Saccharina latissima

Alaria esculenta



Handå, A., Forbord, S., Wang, X., Broch, O.J., Dahle, S.W., Størseth, T.R., **Reitan, K.I.**, Olsen, Y., Skjermo, J. 2013. 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. Aquaculture 414-415: 191-201.

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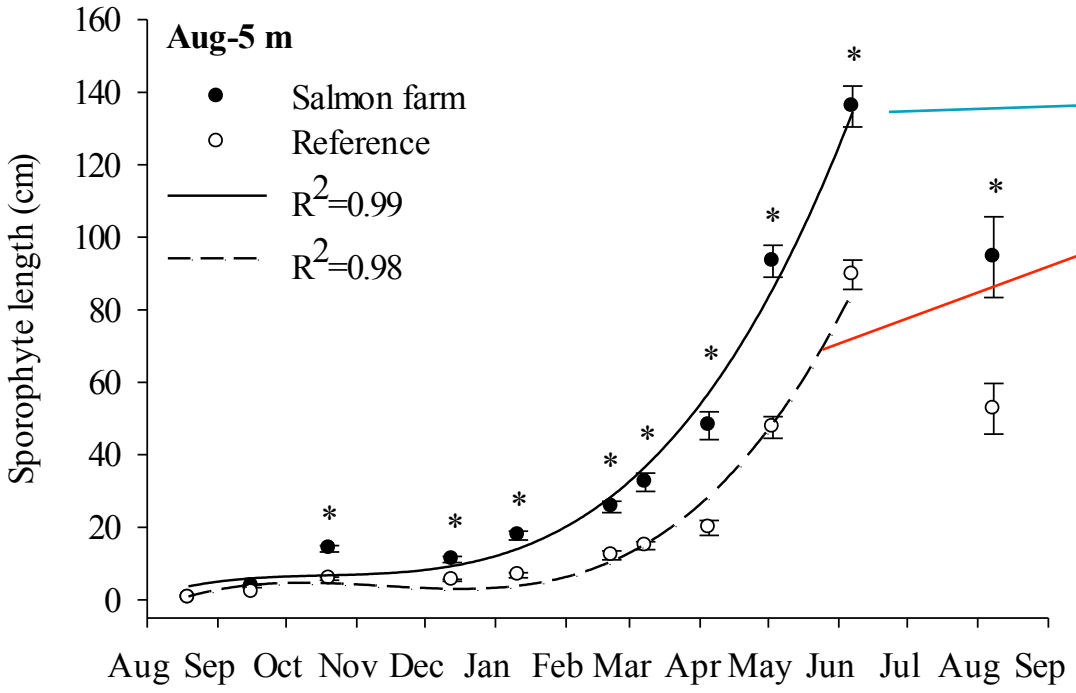
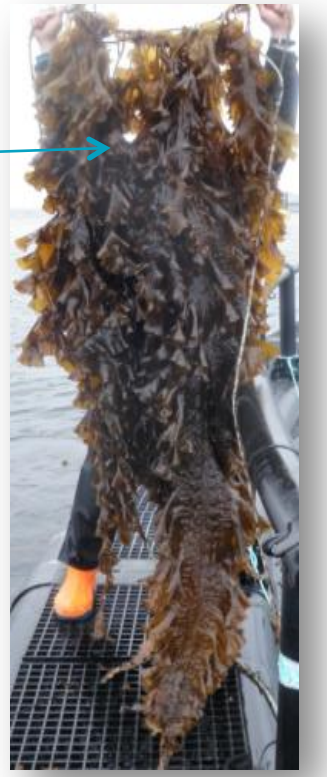
Growth in length of *Saccharina latissima* cultured together a salmon cage farm - 5 meters depth



Reference station

Salmon farm



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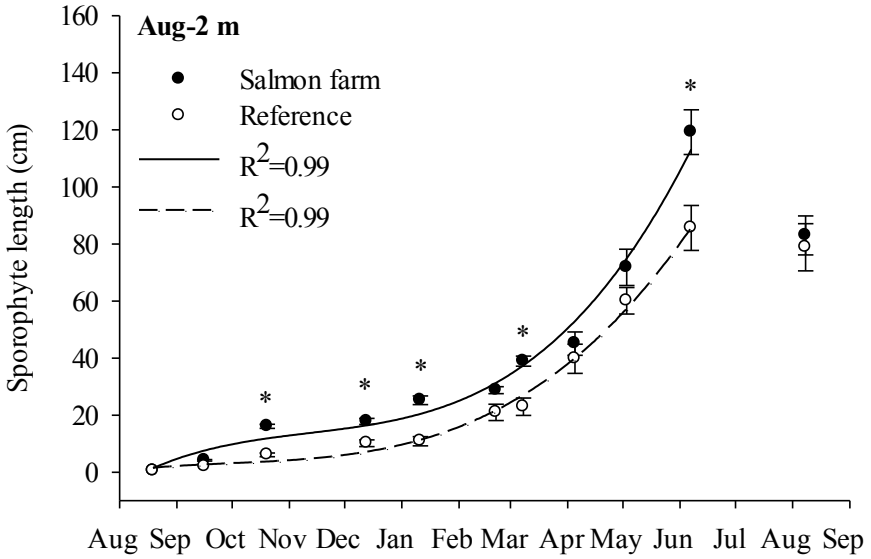
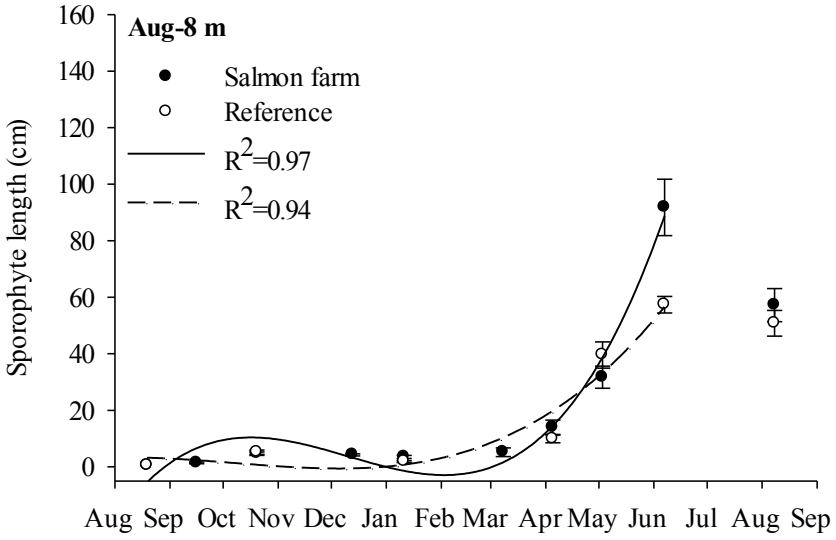
Growth in length of *Saccharina latissima* cultured together a salmon cage farm

2 m depth



8 m depth



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Other Norwegian IMTA projects

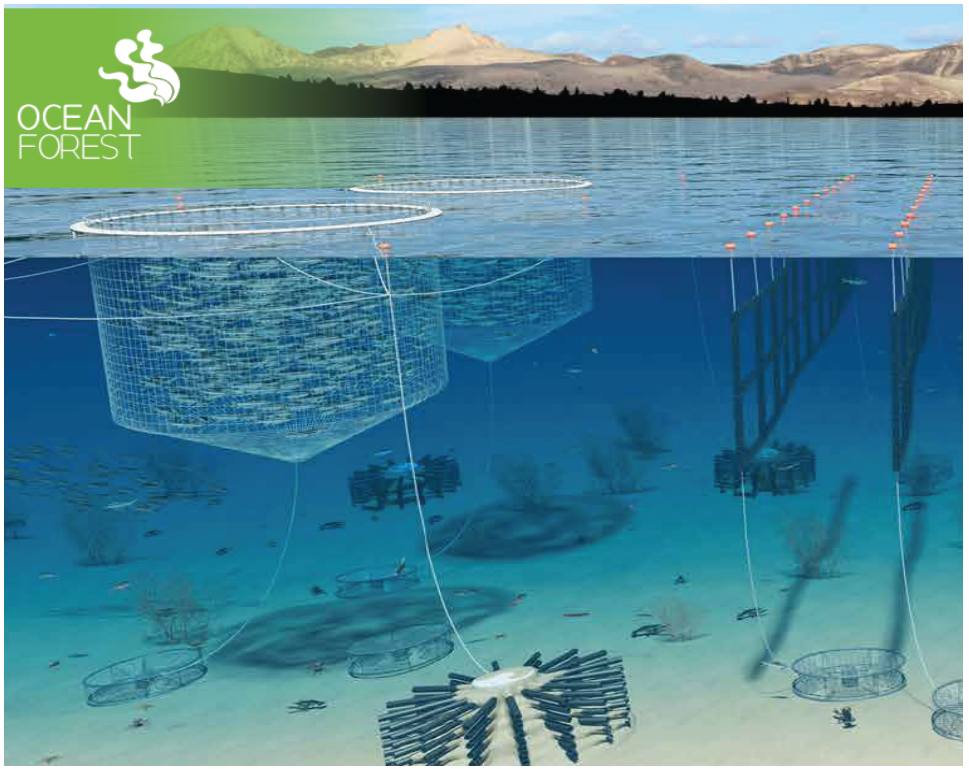
Project in Solund, Sogn og Sjordane:

- Salmon Group, Sulefisk, Hortimare and Inovasjon Norge

Aim: To cultivate seaweed (several species) in close location to a fish farm to assimilate nutrients from the fish farm

Ocean Forest Project – a Bellona initiative:

- Integrated Multitrophic Aquaculture
- Cultivation of seaweed for bioenergy, capture of nutrients and CO_2



The EXPLOIT Project

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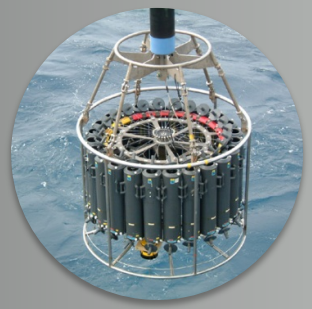
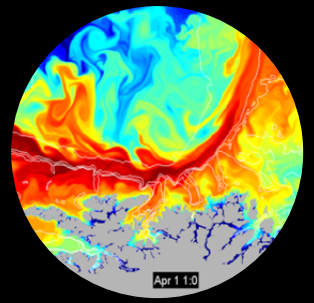


Environment

- Hydrography
- Temperature and salinity
- Nutrients
- Particles
- Chlorophyll a
- Biological tracers
- Sediment traps

Cultivation

- Atlantic salmon (*Salmo salar*)
- Suger kelp (*Saccharina latissima)*
- Blue mussel (*Mytilus edulis*)
- Great Scallop (*Pexten maximus*)



Modelling

- Hydrodynamic-biological model FLÅTEGRUNNEN
- Hydrodynamics (SINMOD)
- Ecosystem and nitrogen (SINMOD)
- Growth of sugar kelp (Broch)
- Growth of blue mussels (DEB)

Project"Exploitation of nutrients from salmon aquaculture - Exploit", funded by the Research Council of Norway

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Integrated Culture of Seaweed - Finfish
Some international examples

- Fish (+shellfi
  - → China: *Sac*
    Growth ra ultured with fish
    (Yang et a
  - → Chile: *Mac*
    Productio

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What is the potential for cultivation of seaweed based on nutrients emission from fish farms

Based on production data from Norway in 2009

Feed
1 172 584 tons
(100%)

Production unit

Particulated

N: 14 224 tons (~18%)

P: 6 957 tons

(52%)

Disolved

N: 36 327tons (45%)

P: 2 484 tons

(18%)

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Potential for cultivation of seaweed based on nutrient emission from fish farms in Norway

- based on production statistics from 2009, FHL

- ✓ Total emission of Dissolved Inorganic Nitrogen (DIN): 36 600 ton N
  - ✓ Basic information:
    - ✓ Nitrogen content of seaweed: 4.0 of DW
      - ✓ Yang et al., 2006: 4.2% of DW; Handå et al.,2013: 1.6-5.0 of DW
    - ✓ Dry matter content of fresh weight : 15% of FW
      - ✓ Wang et al., 2012: 15% of FW
    - ✓ Production yield per year: 72 ton fresh weight per ha
      - ✓ Yang et al., 2006: 70 ton ha^{-1}; Broch et al., 2013: 70-75 ton ha^{-1}
- ✓ Two different scenarios:
  1. Seaweed will assimilate 30% of the DIN from the fish farming:
     - ✓ Potential biomass of seaweed: **1 730 000 ton WW**
     - ✓ Area needed: **240 km^2**
  2. Seaweed will assimilate 10% of the DIN from the fish farming:
     - ✓ Potential biomass of seaweed: **577 000 ton WW**
     - ✓ Area needed: **80 km^2**

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