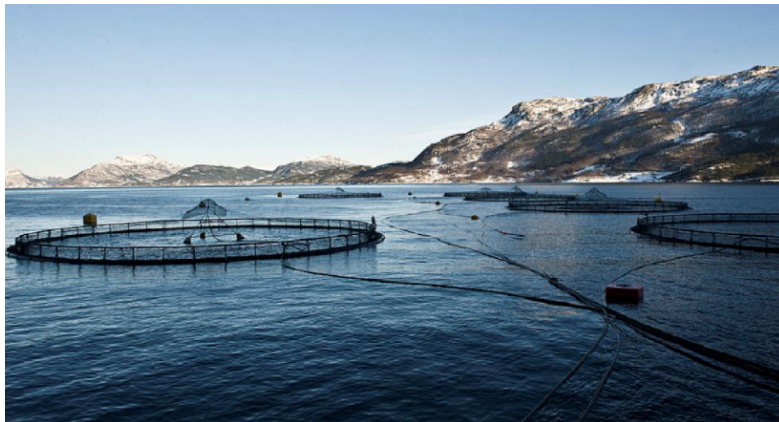




Seaweed farming: Fertilized by effluents from fish aquaculture

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SINTEF Fisheries and aquaculture

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



Aquaculture in Norway

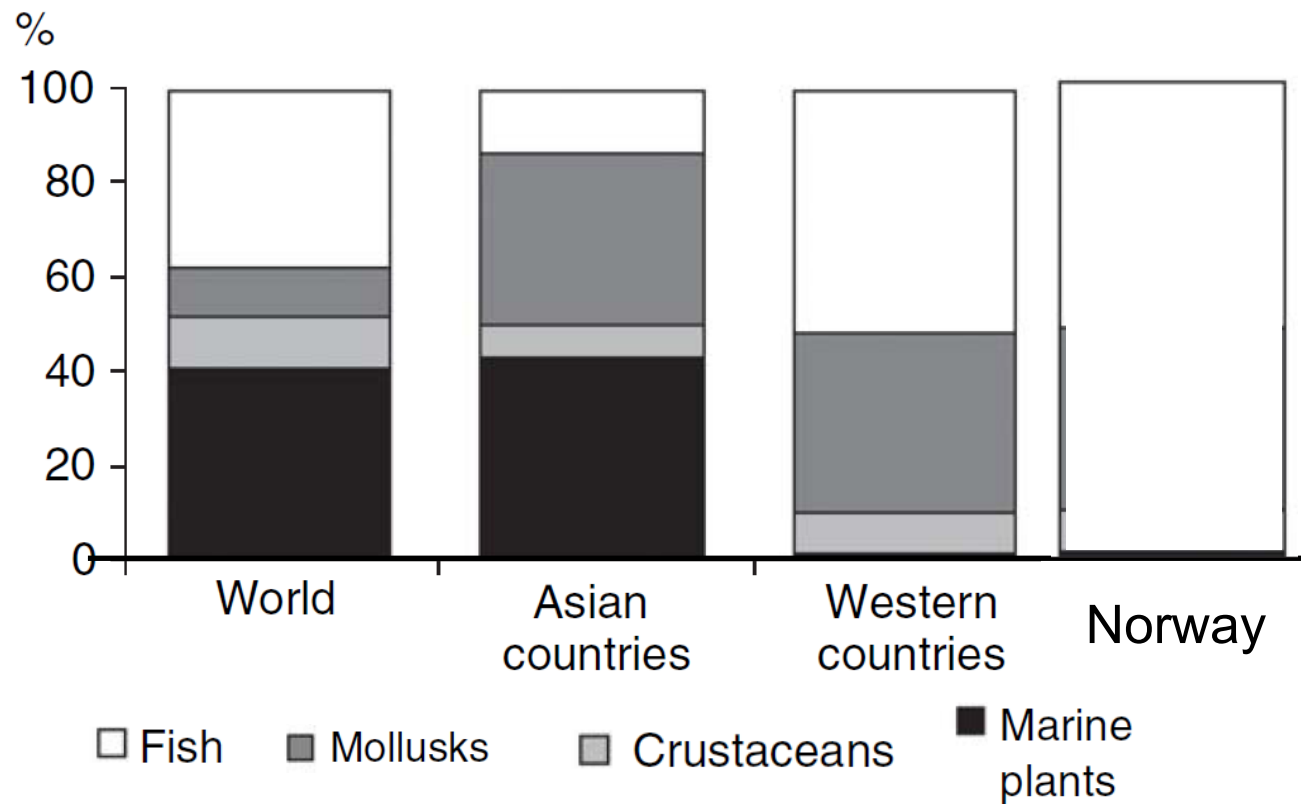
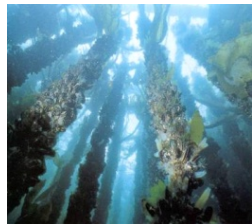
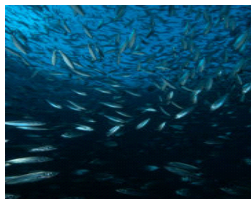


Statistics for aquaculture production in Norway in 2011

| 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



Development of fish farming sites: Bigger and more exposed



Large salmon farm at the coast of Norway

Aquaculture of salmon – Open ocean farming

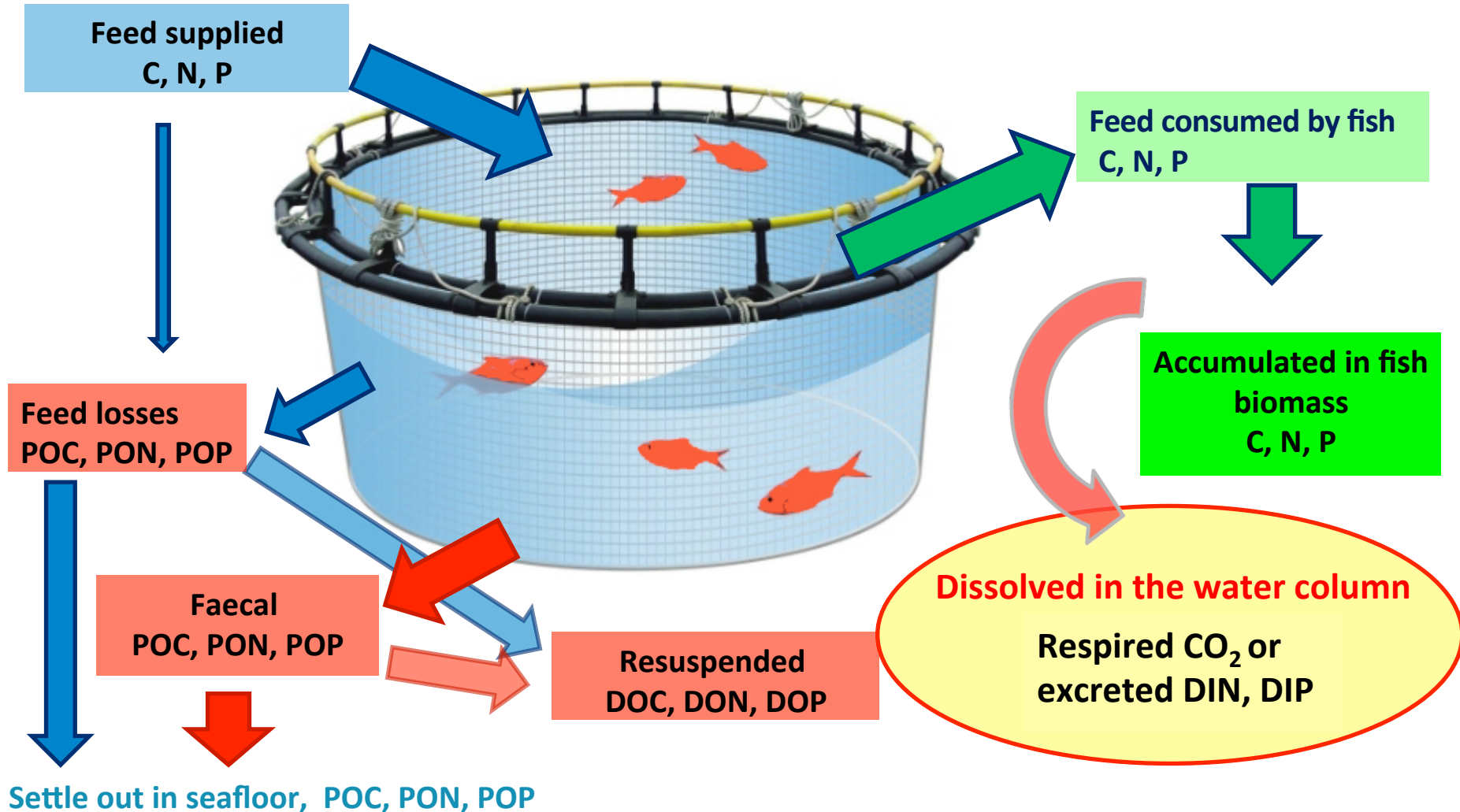
One example (Akvagroup AC 450):

- 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)

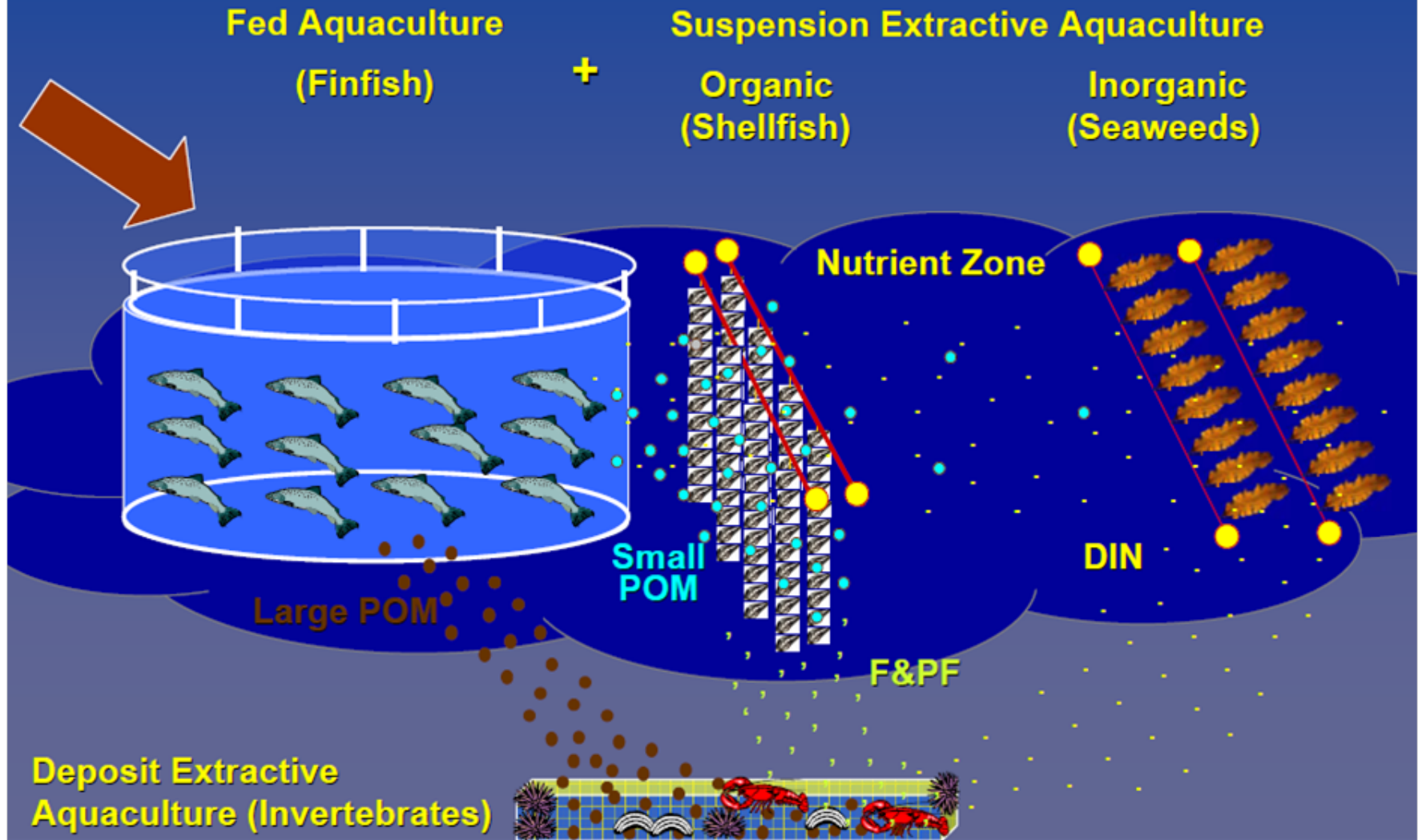


Wang, X., Olsen, L.M., Reitan, K.I., Olsen, Y., 2012. Discharge of nutrient wastes from salmon farms: environmental effects, and potential for integrated multi-trophic aquaculture. *Aquaculture Environment Interaction*. 2: 267-283

Can these resources be utilised??



How can the nutrients from fish farming be utilized?



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

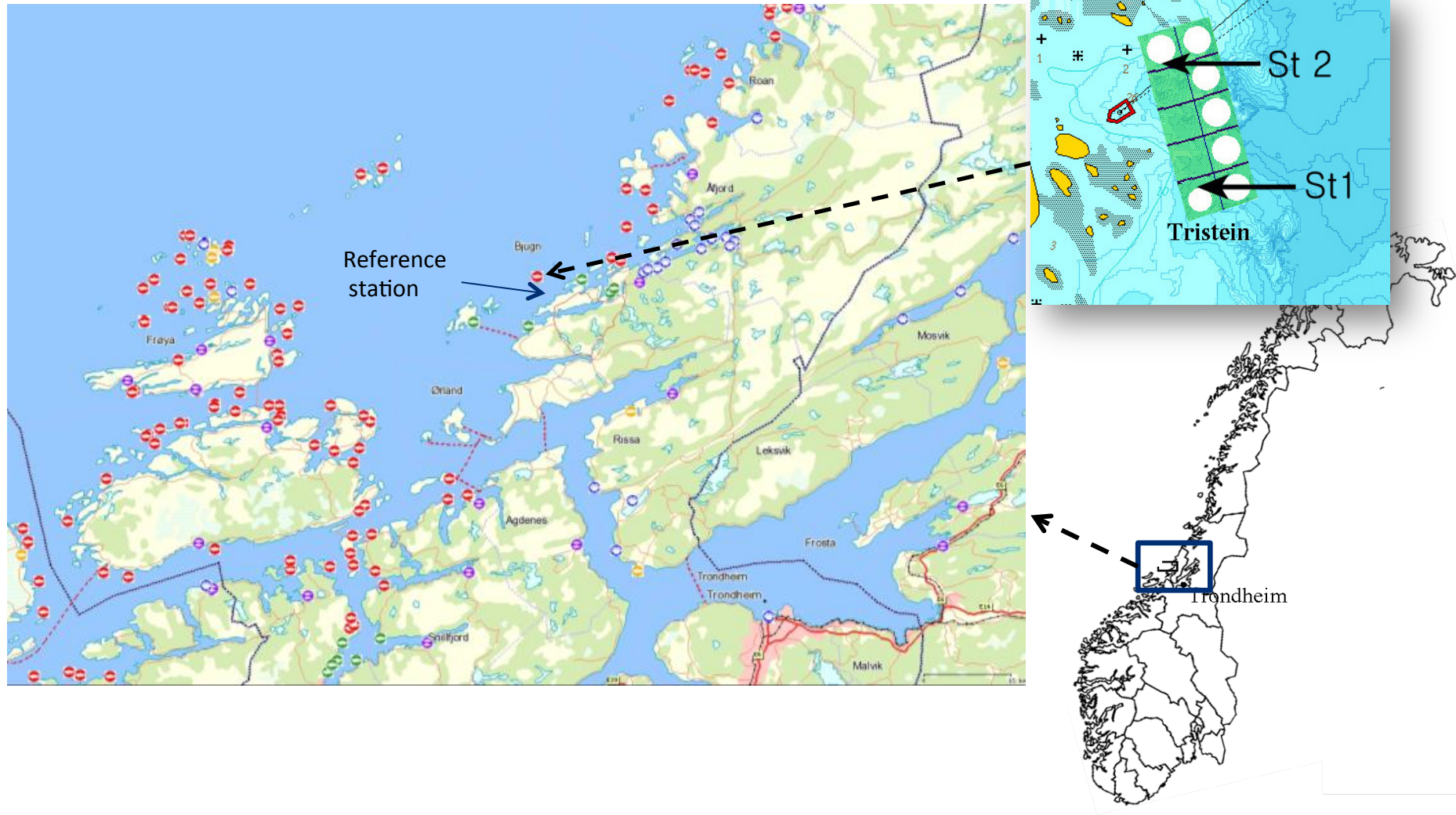
“The solution to pollution is not dilution”

- but extraction and conversion through diversification

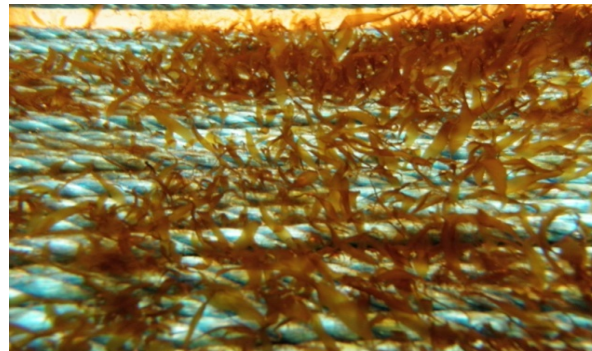
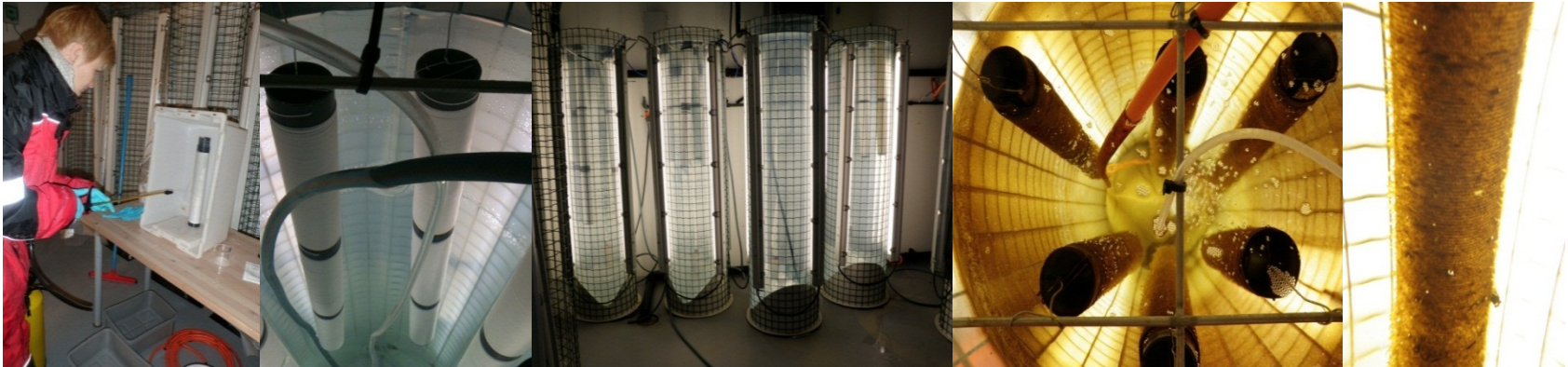
M Heide / SINTEF Fisker

Testing of seaweed growth at a salmon fish farm

ACE (Aquaculture Engineering)



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 Phycology*. 24: 393-399.

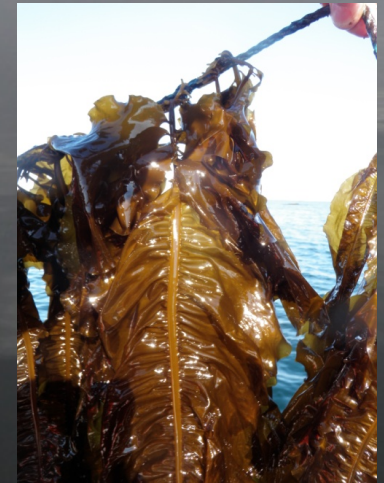
Cultivation of seaweed in open ocean location

- Integrated with salmon cage aquaculture

Saccharina latissima

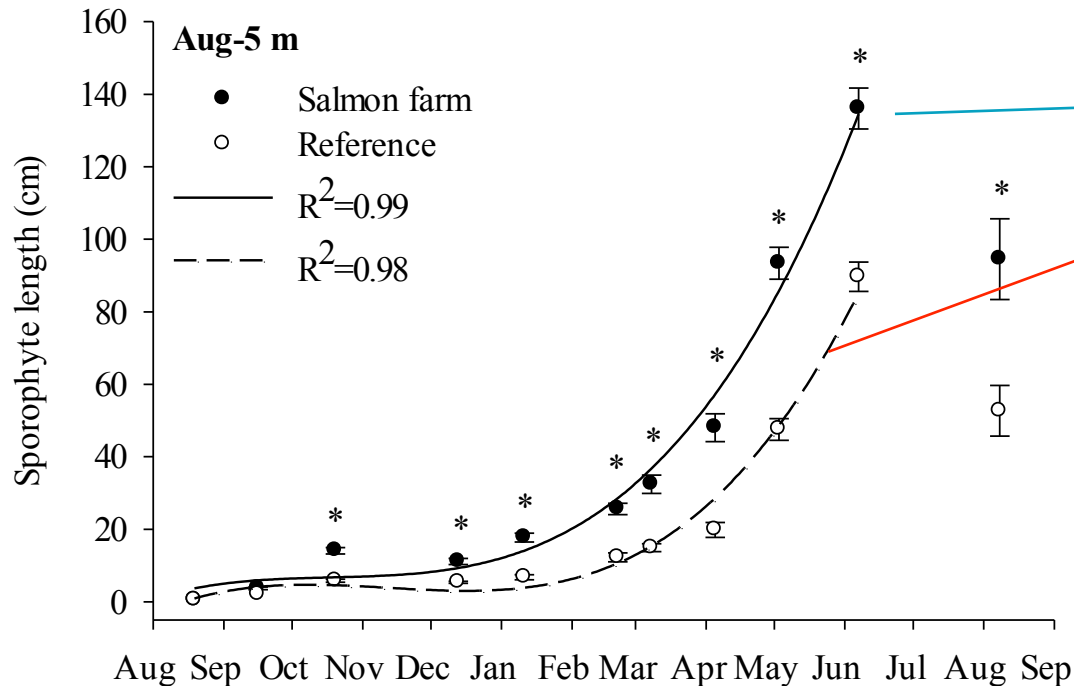


Alaria esculenta



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.

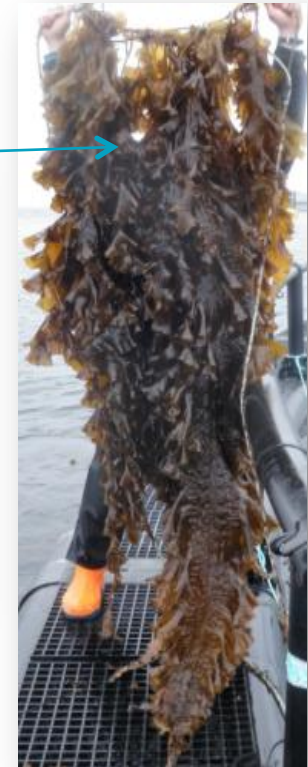
Growth in length of *Saccharina latissima* cultured together a salmon cage farm - 5 meters depth



Reference station



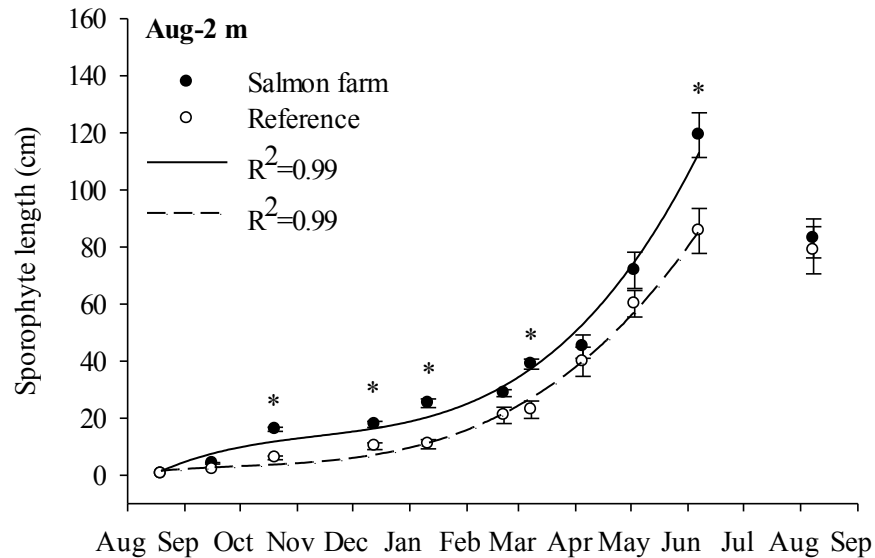
Salmon farm



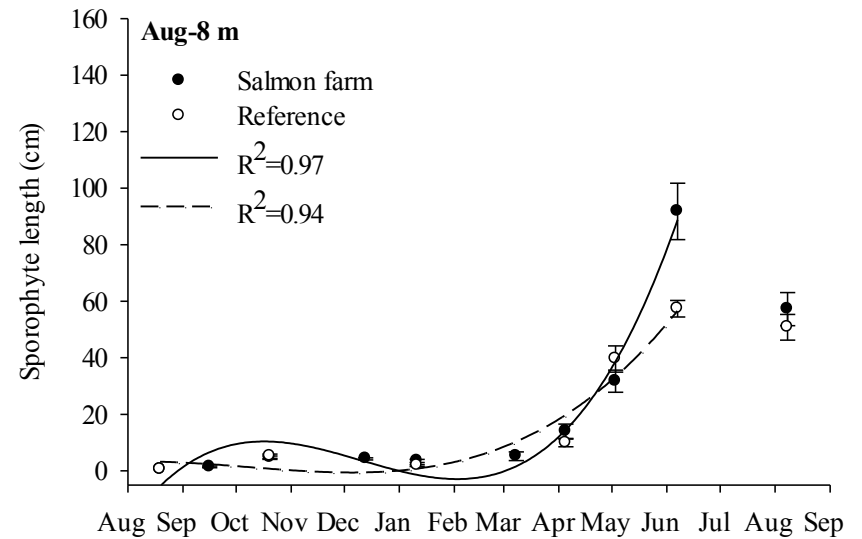
Handå, A., Forbord, S., Wang, X., Broch, O.J., Dahle, S.W., Størseth, T.R., Reitan, K.I., Olsen, Y., Skjermo, J. 2013. Seasonal- and depth-dependent growth of cultivated kelp (*Saccharina latissima*) in close proximity to salmon (*Salmo salar*) aquaculture: Implications for macroalgae cultivation in Norwegian coastal waters. *Aquaculture* 414-415: 191-201.

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

2 m depth



8 m depth



Handå, A., Forbord, S., Wang, X., Broch, O.J., Dahle, S.W., Størseth, T.R., Reitan, K.I., Olsen, Y., Skjeremo, 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.

Other Norwegian IMTA projects

Project in Solund, Sogn og Sjordane:

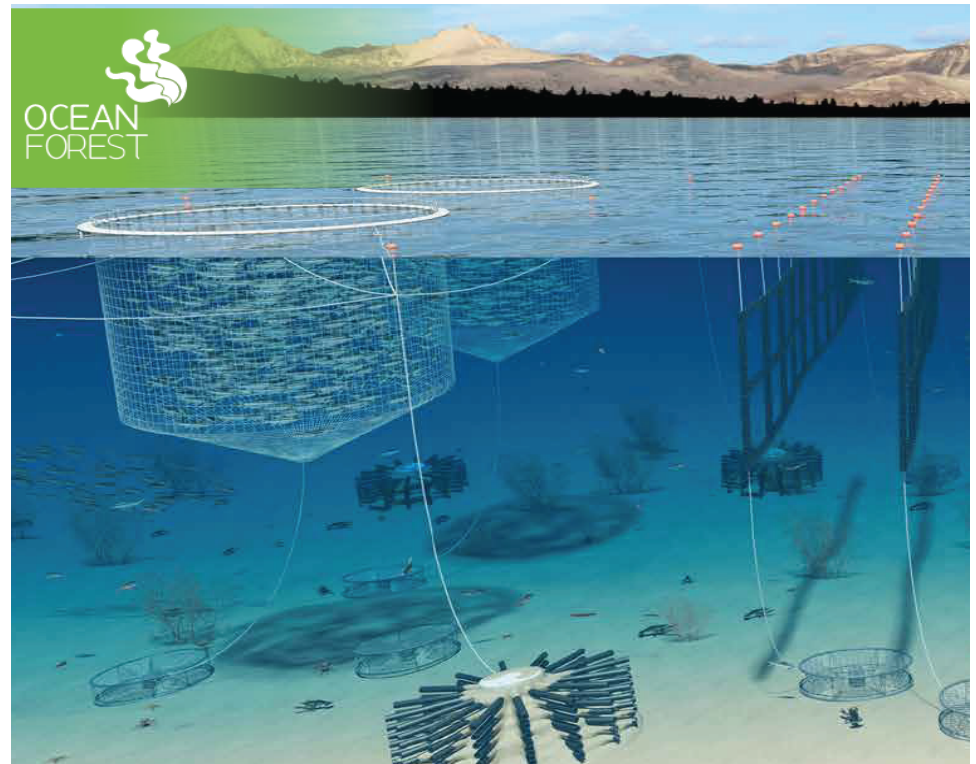
- Salmon Group, Sulefisk, Hortimare and Inovasjon Norge

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 CO₂



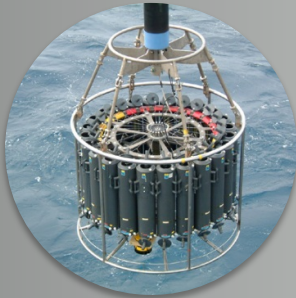
The EXPL^oIT Project



NTNU – Trondheim
Norwegian University of
Science and Technology



INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET



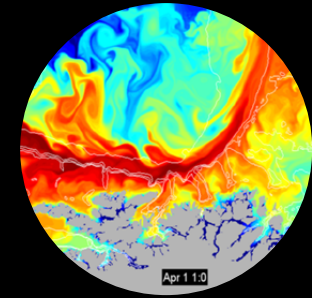
Environment

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



Cultivation

- Atlantic salmon (*Salmo salar*)
- Sugar kelp (*Saccharina latissima*)
- Blue mussel (*Mytilus edulis*)
- Great Scallop (*Pecten 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



Integrated Culture of Seaweed - Finfish

Some international examples

- Fish (+shellfish)
- China: *Sargassum*
Growth rate
(Yang et al)
- Chile: *Macrocystis*
Production

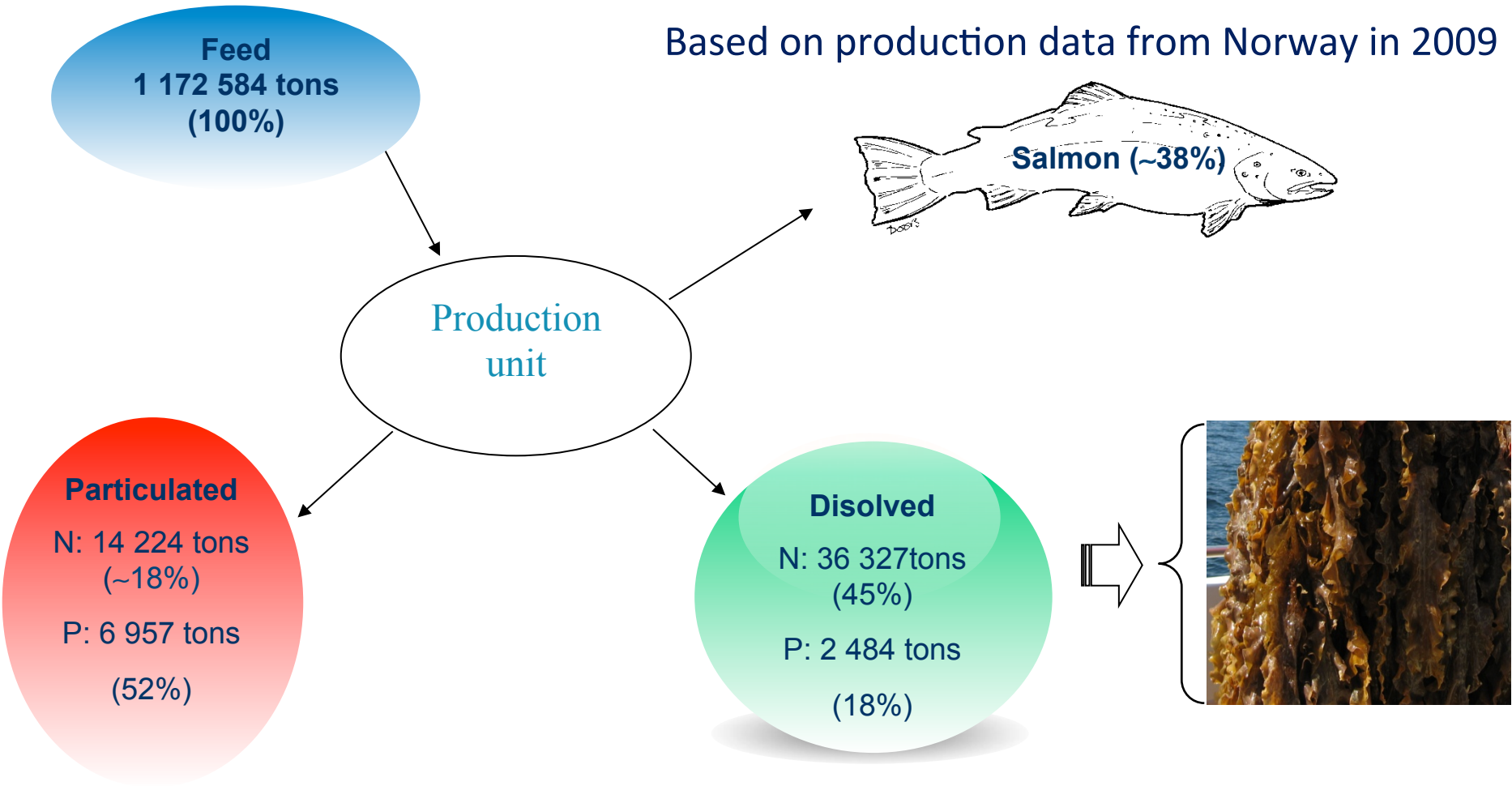


cultured with fish



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

Based on production data from Norway in 2009



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 Interaction*. 2: 267-283

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 km²**
 2. Seaweed will assimilate 10% of the DIN from the fish farming:
 - ✓ Potential biomass of seaweed: **577 000 ton WW**
 - ✓ Area needed: **80 km²**

A woman with blonde hair, wearing a red jacket, is smiling and holding a large, wet pile of brown seaweed. She is on a white boat, with a blue body of water and a clear blue sky in the background. The text "Thank you" is overlaid in a white box across the center of the image.

Thank you