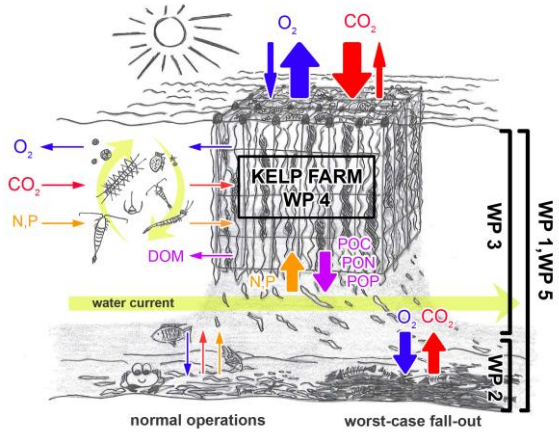
KELPPRO

Kelp industrial production: Potential impacts on coastal ecosystems

By Kasper Hancke, Ole Jacob Broch, Trine Bekkby, Hartvig Christie et. al.

Norwegian Institute for Water Research (NIVA)

PROMAC project meeting, NMBU, Oslo
26 October 2017



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KELPPRO

Kelp industrial production: Potential impacts on coastal ecosystems

- **Project lead**: Norwegian Institute for Water Research (NIVA, Kasper Hancke)

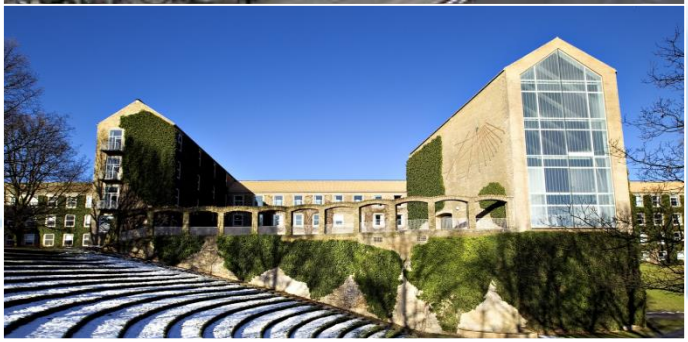
- **Scientific partners**: SINTEF, Norwegian University of Science and Technology (NTNU), Akvaplan NIVA, Institute of Marine Research, University of Southern Denmark (SDU)
- **Industrial partners**: Seaweed Energy Solutions (SES), Hortimare
- **Duration**: 2017-2020 (4 years)
- **Budget**: 8.5 MNOK in total

Kasper: Education and positions

- **2002 MSc in Aquatic Microbial Ecology**, Uni. of Copenhagen
- **2003-2007 PhD in Arctic Marine Ecology**, NTNU, Norway
- **2007-2010 Post doc on Ocean optics and bio-optics,** IMR, Norway
- **2010-2011 Research coordinator** at NTNU, Norway
- **2011-2014 Post doc Benthic & pelagic biogeochemistry,** Uni. of Southern Denmark (SDU)
- **2015-2016 Researcher in Sea ice ecology.** Aarhus Univ.
- **2016 – Researcher in coastal ecology.** NIVA

Scientific keywords

1) Biological Oceanography and Marine Biogeochemistry
2) Algae Ecology and Physiology
3) Photobiology and Bio-optics
4) Coastal ecosystems ecology and modelling



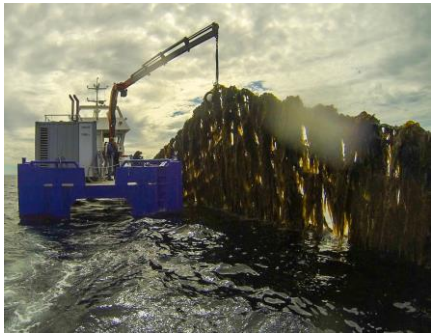
Kelp industrial production: Potential impacts on coastal ecosystems

Aim:

Provide an **integrated assessment of positive and negative impacts** of industrial-scaled kelp farming on the marine ecosystem of coastal Norway

Three main questions:

1) Will future industrial kelp farming impact open water and sea floor habitats and ecosystem functioning?
2) Will farmed kelp detritus provide valuable bio-resources or pose a threat to natural coastal ecosystems?
3) Will kelp farming facilities provide ecosystem functioning as 'artificial' forest habitats?



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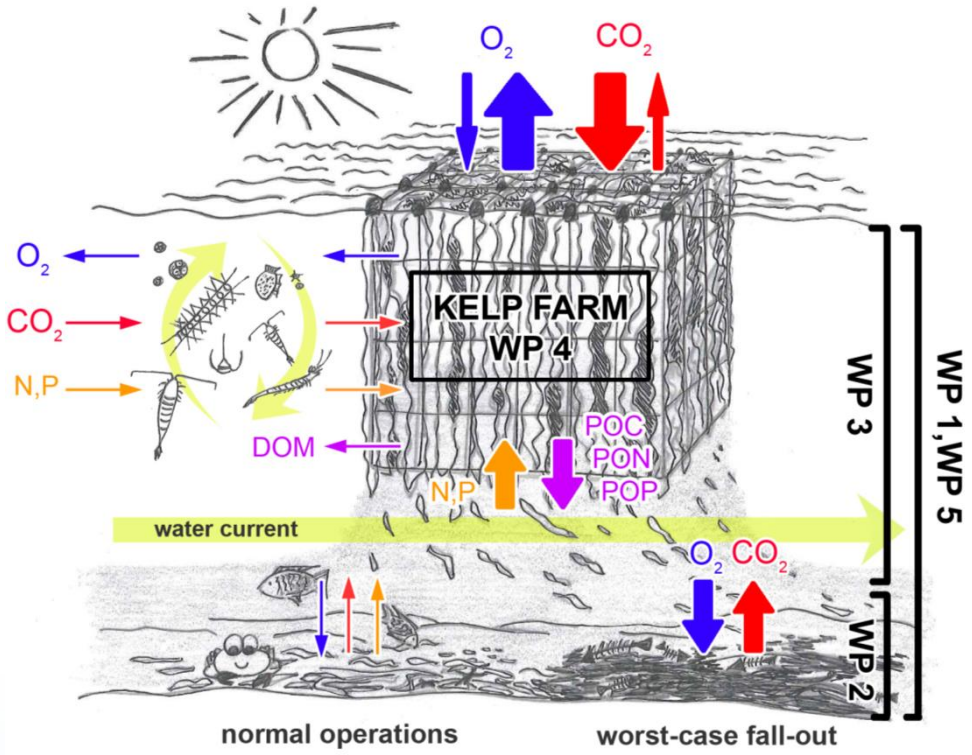
Potential environmental impacts of extensive seaweed cultivation



Positive impacts are

- **Nutrient uptake,** reducing marine eutrophication
- **CO2 uptake**, reducing ocean acidification
- **Increased primary production**
- Promote elevated **biodiversity**

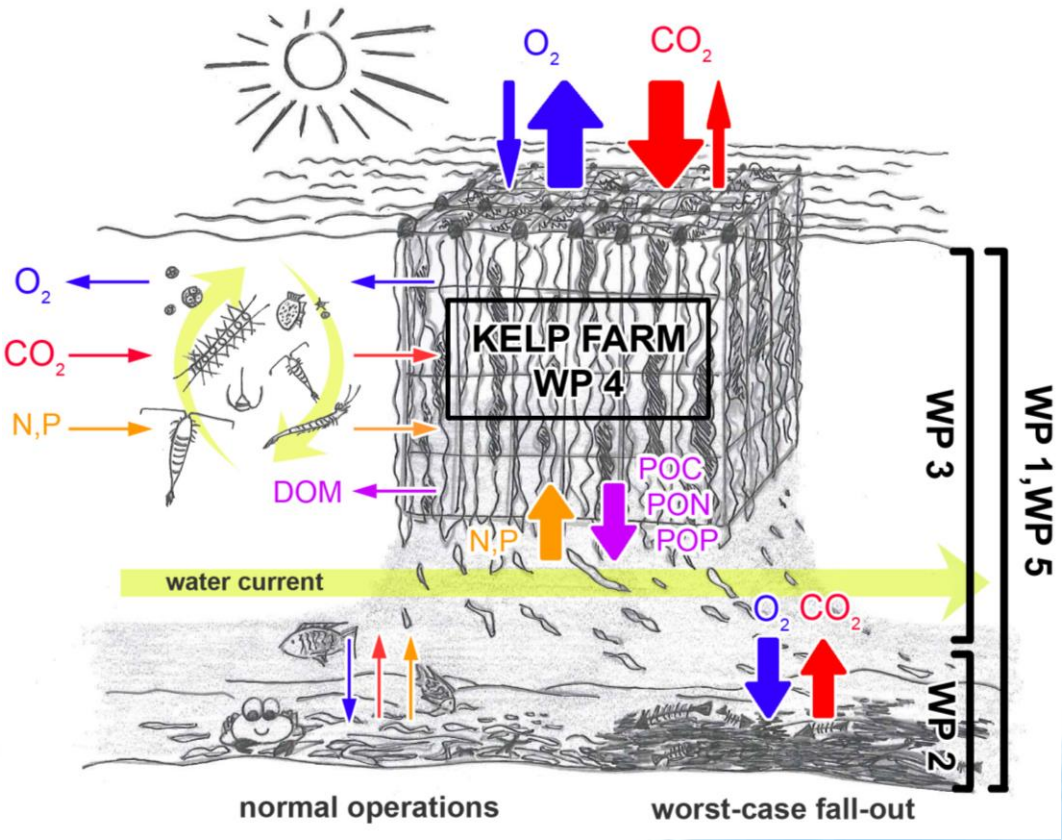
Negative impacts are

- **Depletion** of limited nutrients
- **Depositing** of large quantities of kelp biomass on the seafloor, leading to
- **poor environmental conditions**,
- **oxygen deficiency**,
- and change in natural **biodiversity**

Kelp industrial production: Potential impacts on coastal ecosystems

Research focus:

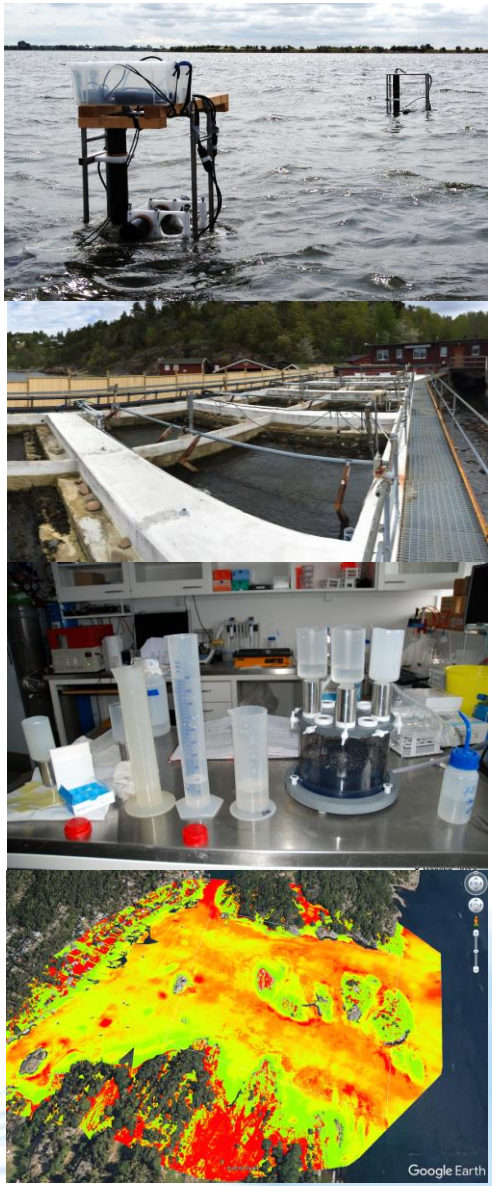
- **WP#1**: Industrial kelp cultivation scenarios
- **WP#2**: Effects of industrial kelp farming on sea floor ecosystems
- **WP#3**: Effects on open water ecosystems
- **WP#4**: Industrial kelp facilities as 'artificial kelp forests'
- **WP#5**: Integration and dissemination



Kelp industrial production: Potential impacts on coastal ecosystems

Experimental approach and team

- Field investigations (NIVA, NTNU, ApN, SDU)
  - Two industrial kelp production facilities (industry-partners), i.e. Seaweed Energy Solutions (SES, Trøndelagskysten) and Hortimare (Sognefjorden)
  - Impact studies on open water uptake and dynamics of nutrients, CO2, oxygen alongside effects on hydrological condition
  - Impact studies on sea floor ecosystems
  - Role as artificial 'kelp forests' habitats
- Mesocosms experiments (NIVA, ApN)
  - degradation and bioavailability of kelp detritus as function of detritus size and O2 availability.
- Numerical modelling (SINTEF, NIVA)
  - Assessment of regional and local areas for kelp farming
  - Regional and local effects of kelp production
  - Pathways, deposit areas and fate of kelp detritus



Images by NIVA (K Hancke)

Kelp industrial production: Potential impacts on coastal ecosystems

Key scientific personal

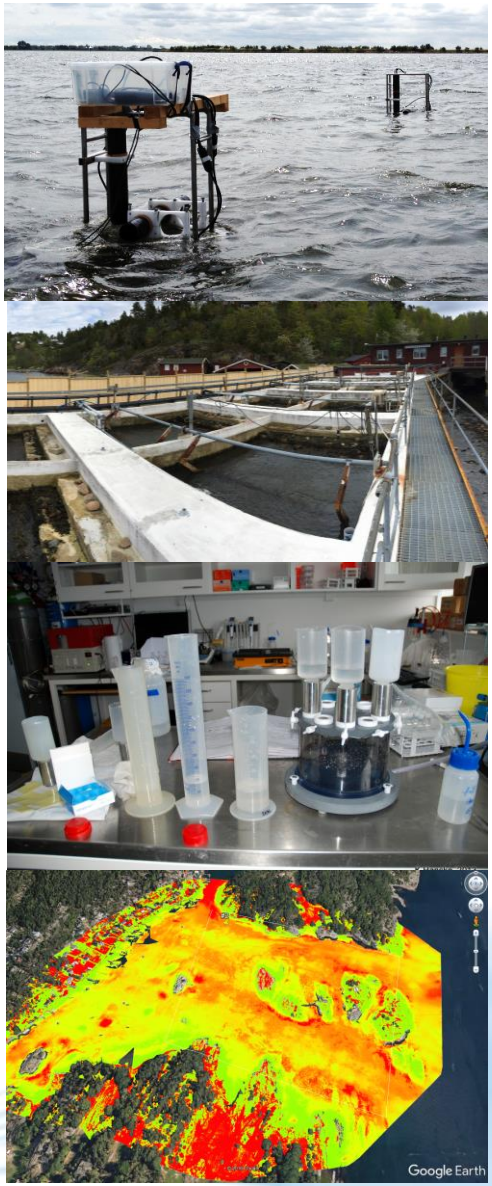
- **NIVA**: Kasper Hancke, Trine Bekkby, Hartvig Christie, Hege Gundersen, Eva Ramirez-Llodra, Gunhild Borgersen
- **SINTEF**: Ole Jacob Broch, Morten Alver, Aleksander Handå
- **NTNU**: Yngvar Olsen, Øystein Leiknes
- **ApN**: Reinhold Fieler
- **IMR**: Pia Kupka Hansen
- **SDU**: Ronnie N. Glud, NN post doc

Industry partners

- **SES**: Jon Funderud, Luiza Neves
- **Hortimare**: Job Schipper

Scientific Advisor Board

- Prof. Isabel Sousa Pinto, University of Porto, Portugal
- Dr. Dorte Krause-Jensen, Aarhus University, Denmark
- Prof. Alf Norkko, University of Helsinki, Finland



Images by NIVA (K Hancke)

Time plan / Gantt diagram

KELPPRO gantt diagram	2017				2018				2019				2020			
NFR HAVBRUK2, 2017-2020	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
T1.1 Areas for kelp production	x	x														
T1.2 Specification of cultivation scenarios	x	x	x													
T2.1 Estimate export of kelp detritus				x	x											
T2.2. Transport pathways and 'deposit areas' for exported kelp					x	x										
T2.3 Impact studies on sea floor biodiversity and function						x	x									
T2.4 Impact of kelp detritus; tipping point between food source or ecosystem threat						x	x									
T2.5 Fate and bio-availability of exported kelp									x	x	x					
T3.1. Quantification of nutrient (N, P) and C (CO_2) uptake and retention in kelp	x	x	x													
T3.2. The effect of kelp farming on the carrying capacity	x	x	x													
T3.3 The potential of bioremediation by kelp farming								x	x	x						
T4.1. Abundance, species composition and function										x	x					
T4.2. Distribution of unwanted and red-listed species										x	x					
T4.3. Genetic diversity in natural kelp											x	x	x			
T5.1. Synthesis an integrated assessment												x	x	x		
T5.2. Provide guidance													x	x	x	
T5.3 *Ensure efficient communication*		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kick-off workshop		x														
Concluding workshop															x	
Annual meetings		(x)			x				x						(x)	
post doc (SDU)									x	x	x	x			x	
post doc (NTNU)	x	x	x	x											x	
Scientic publication				x	x	x	x	x	x	x	x	x	x	x	x	x
End-user guidance and reporting				x				x				x	x	x	x	x
Conferance contributions							x								x	
Website and public outreach	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

WP1 – Industrial kelp cultivation scenarios

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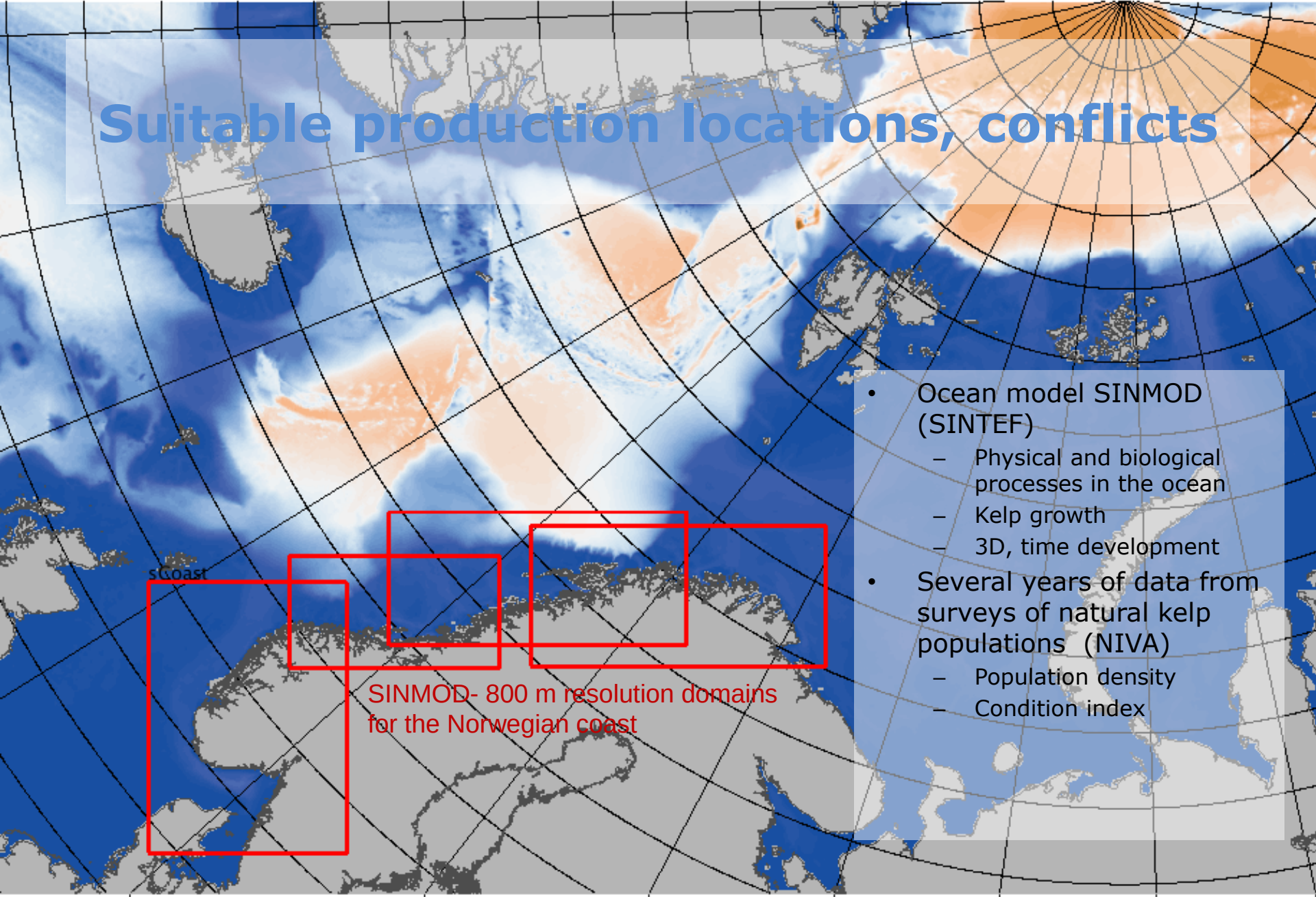
Main objectives

1. Identify key environmental variables for efficient kelp production
2. Identify suitable kelp production locations and potential conflicts with natural populations
3. Estimate future industrial cultivation scenarios ranging in volume from "probable" to "extreme"

Environmental variables for high production

Presently included in growth model	Further important variables
Temperature	Waves
Light intensity (PAR)	Phosphorous
Nutrient concentration (DIN)	Micronutrients (iron, iodine?)
Water current speed	Epiphytes
Salinity	
Latitude	

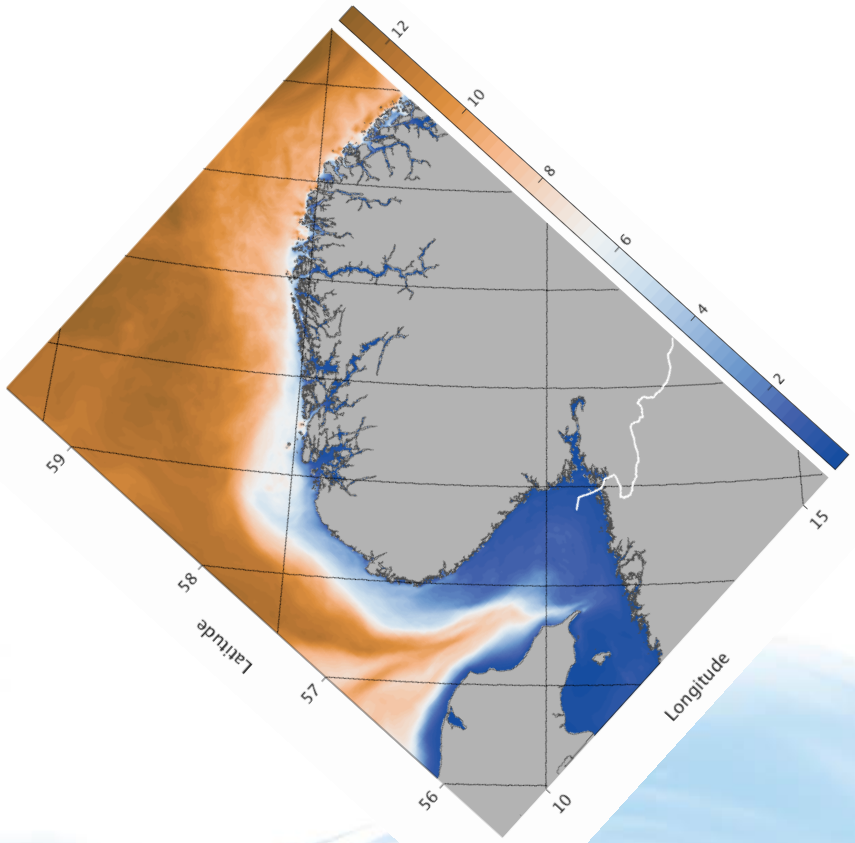
Suitable production locations, conflicts



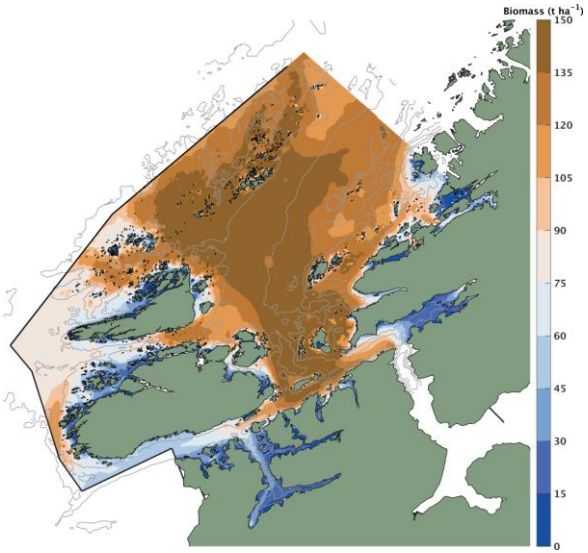
- Ocean model SINMOD (SINTEF)
  - Physical and biological processes in the ocean
  - Kelp growth
  - 3D, time development
- Several years of data from surveys of natural kelp populations (NIVA)
  - Population density
  - Condition index

The model results provide spatial information

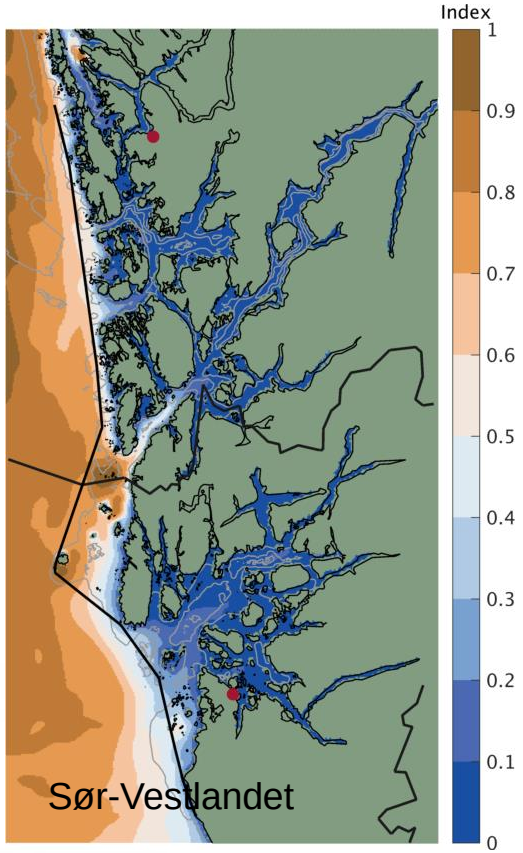
- Example of simulation results for Southern Norway
- The colours represent simulated frond area for sugar kelp (*Saccharina latissima*) cultivated from February to June (dm^2)
- Each pixel represents an 800 by 800 m square assumed to be containing one "model kelp individual"; all individuals everywhere had the same (0.2 cm^2) initial size
- The figure displays the surface layer; deeper layers may also be shown (e.g. 5m, 10 m depth)

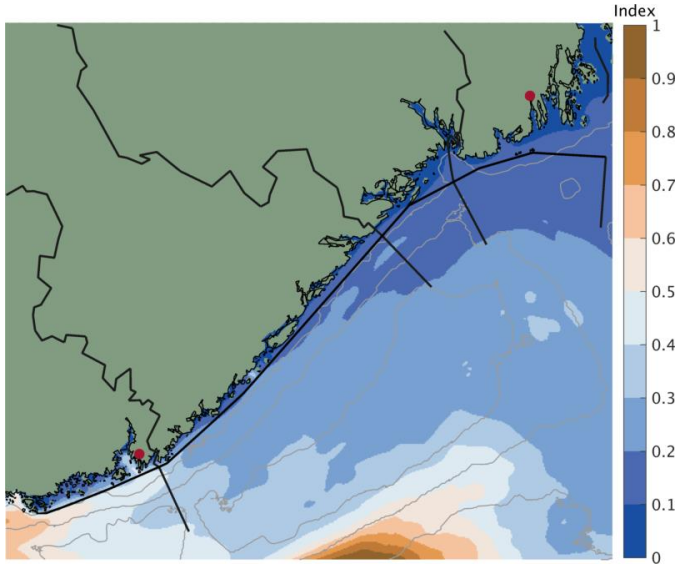


Examples (preliminary results)



Trøndelag, biomass



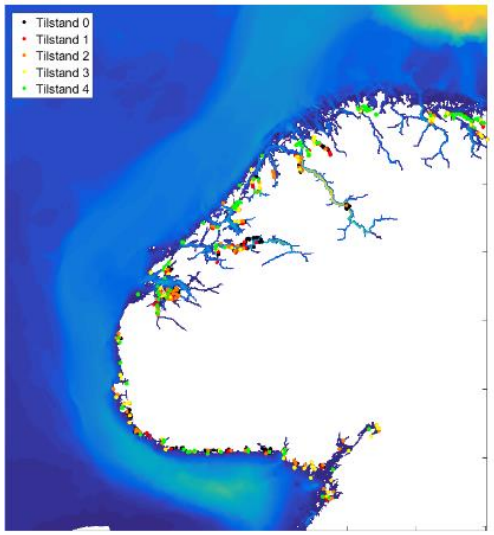


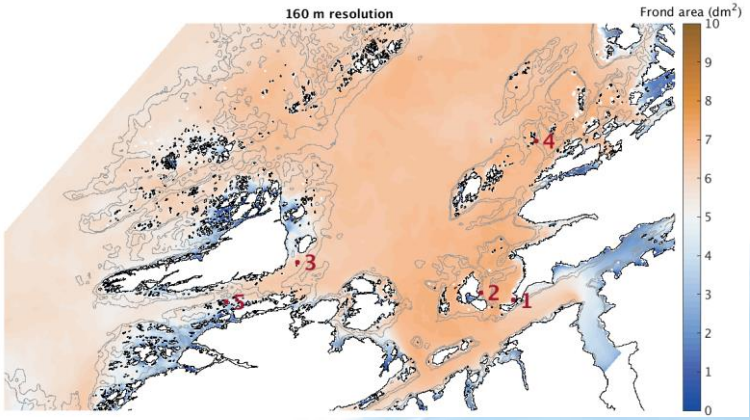
Sørlandet (Kristiansand to Sandefjord)

Model verification

- Effort put into understanding to what degree the model provides reasonable and realistic results

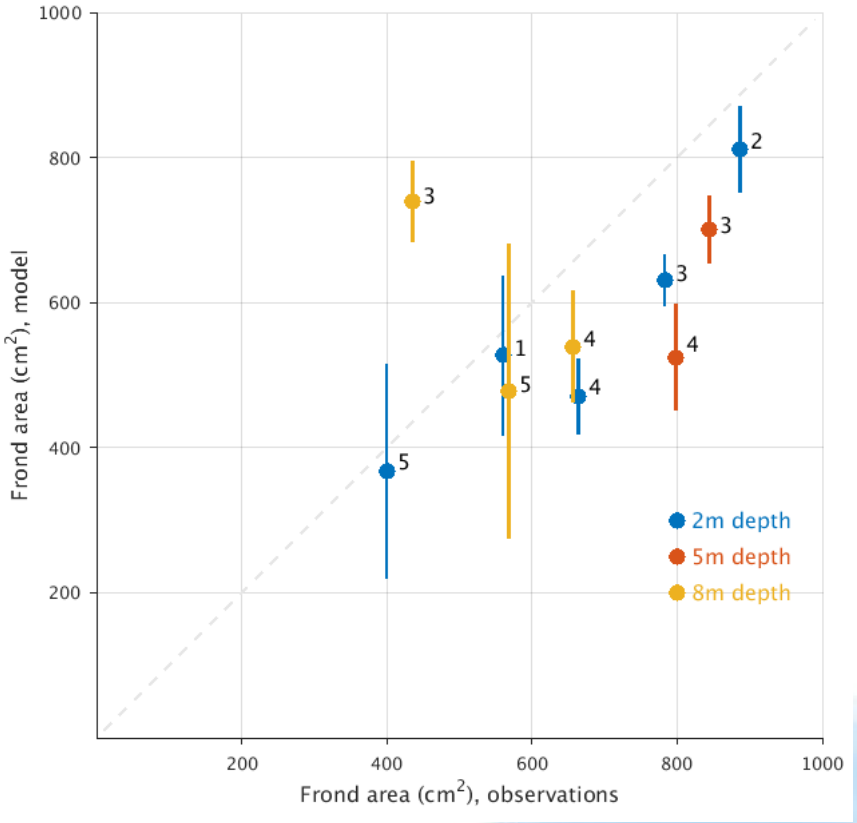
- We have compared simulation results with
  - **extensive field surveys** of sugar kelp populations (NIVA, top figure) and
  - cultivation trials in Trøndelag





Simulation results and cultivation results

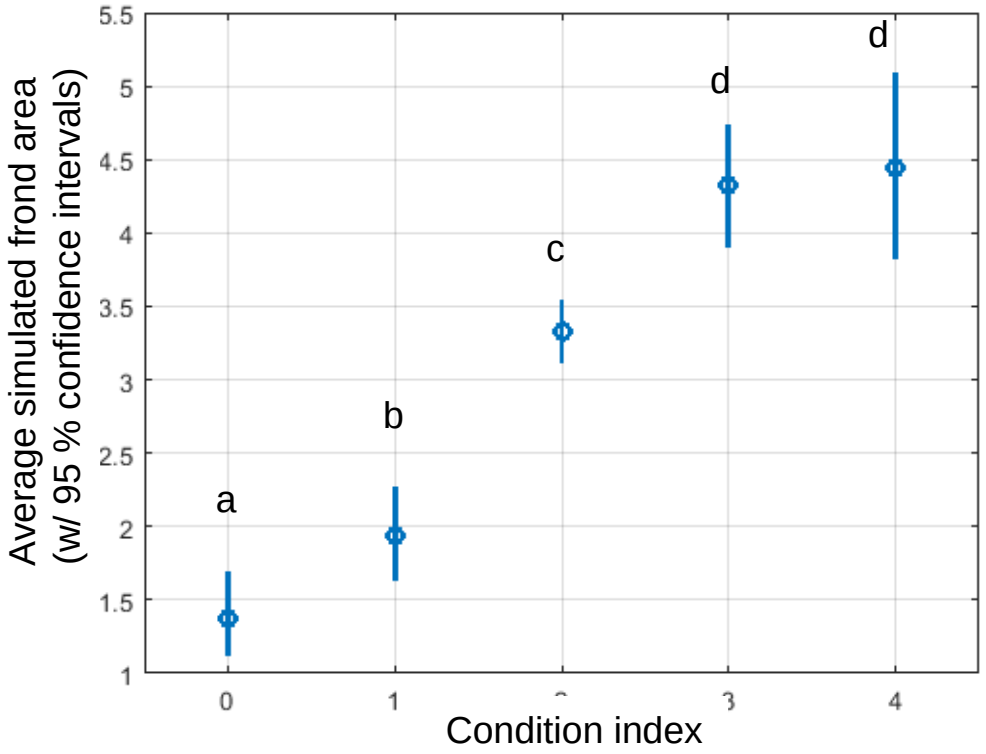
- The graph compares simulated frond area (vertical axis) with data from five cultivation experiments in Central Norway
- Bars represent spatial variation in the model results
- Of interest because
  1. The model provides realistic values
  2. The model is able to distiguish between cultivation locations



The cultivation experiments were conducted in the projects Macrobiomass (199391/I10) and PROMAC (244244) funded by the Research Council of Norway

Simulation results and kelp condition index

- The graph shows simulated kelp frond area plotted against the condition index for sugar kelp in Southern Norway (density of natural populations)
- The average simulated frond areas are all significantly different, except between conditons 3 and 4



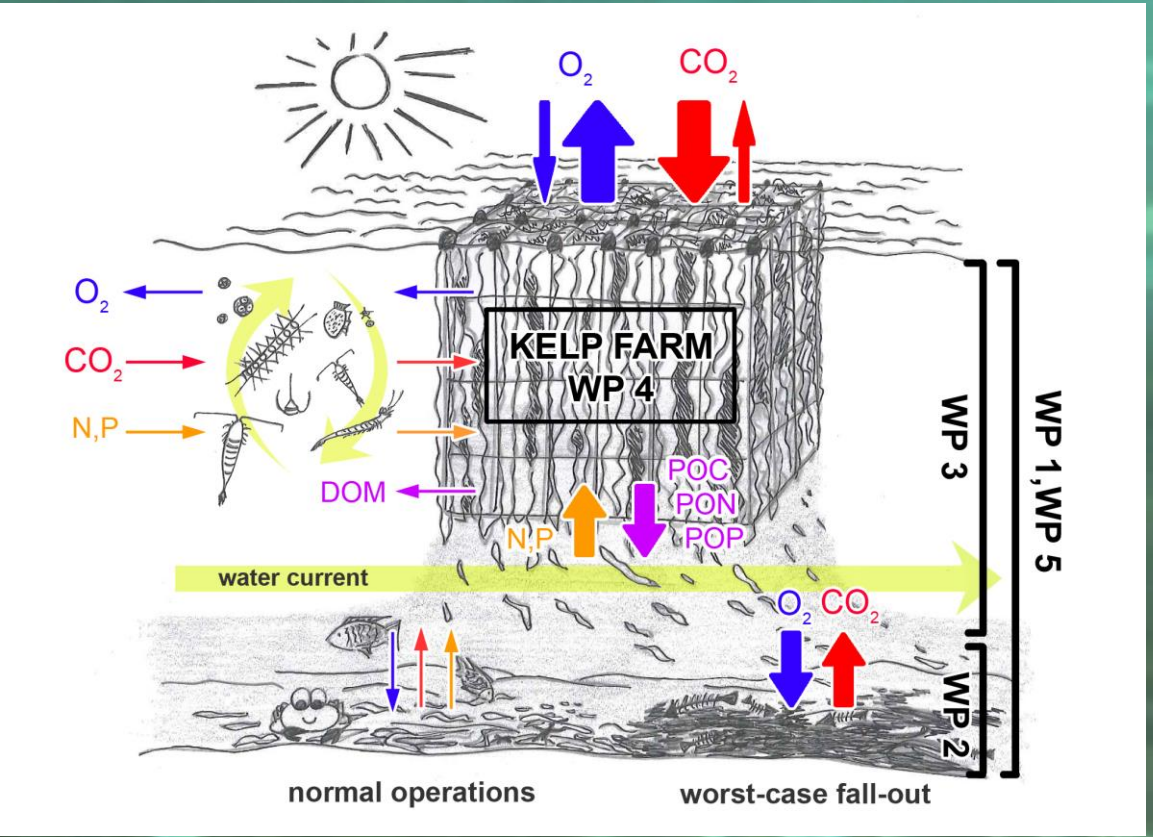
Conclusions on WP1 and further work

- The results are promising, the rationale being that the variables used in the dynamical growth model are also of (some) importance for development in natural populations

- **Further work**
  - Simulations in higher resolution (e.g. 160 m) –better match between model and field data
  - Use simualtion results to determine e.g. areal requirements for specified production volumes or production volumes for specified areas
  - Look into four types of scenarios linked to geographic regions

	Small area(s)	Large area(s)
Low total volume	Non-intensive, local	Extensive
High total volume (~ 10^6 tons)	Intensive	Intensive & extensive

Thank you
Any questions?



Konklusjon

- Industriell skala algedyrkning vil ha effekt på lokale og regionale økosystemer – Positive & negative
- Per i dag mangler vi datagrunnlag for å estimere mulige miljøkonsekvenser på en faglig ansvarlig måte
- Første forskningsprosjekt på miljøeffekter er satt i gang, KELLPRO 2017-2020

Take home message:
Kundskabsbasert drift og forskningsbasert overvåkning vil sikker en bæredyktig næring i fremtiden

Photographs: K. Filbee-Dexter, NIVA