KELPPRO annual meeting 2019 notes

Kelp industrial production: Potential impacts on coastal ecosystems (KELPPRO)

When & where: 18-19 November 2019, Oslo CIENS park, Oslo Norway
Agenda and participants: See below
By Kasper Hancke, Siri Moy, Marijana Brkljacic, and Lise Tveiten (NIVA)

Short summary:

- The KELPPRO 2019 annual meeting went well and as planned. Enjoyable discussions, enthusiastic participations, and fruitful outcome. **Thank you all for participating actively during the meeting!**
- Most WP leads and key scientific personal was present during the meeting including one industry partner (SES, Jon Funderud), with exception for Yngvar Olsen (WP3 lead). Unfortunately, this year the Scientific Advisory board and invited stakeholders were not able to participate.
- Lots of Interesting and well-prepared presentations. Thank you to all speakers for your contributions!
- WP and task leaders (or appointed) and students presented results from the 2018 and 2019 field seasons, achieved modelling efforts, current status of the various WP's and tasks, and further progress plans.
- So far KELPPRO publications include: **two primary peer-reviewed publications, two associated peer-reviewed publications, three ISBN-labelled reports, 36 national and international talks and posters, 22 popular science contributions, and 7 media (radio and TV) contributions**.
- The planned milestones and deliverables are being meet, and **under preparation are 9 scientific papers for peer-review, 3 MSc thesis, 2 reports and a policy brief publication.**
- Overall, the project is progressing well and has moved forward in good speed since last year (2018).
- REMEMBER to register your KELPPRO publications, presentations etc. in CRISTIN and tag with NFR project number #267536 (Cristin-prosjekt-ID: 622782)

KELPPRO 2019 annual meeting participants (18 Nov. 2019, Oslo)

Meeting agenda

Monday 18 November – in Meeting room: AQUA		
09:45-10:00	*Coffee and mingling*	
10:00-10:15	Welcome and introduction	Kasper Hancke (NIVA)
10:15-10:35	The KELPPRO project – overall aim and current status	Kasper
10:35-10:55	INDUSTRIAL KELP CULTIVATION SCENARIOS (WP1)	Ole Jacob Broch (SINTEF)
15 min	*Coffee break*	
11:10-11:45	EFFECTS OF INDUSTRIAL KELP PRODUCTION ON SEA FLOOR ECOSYSTEMS (WP2) T 2.1 Estimate export of kelp detritus T2.2. Transport pathways and "Deposit areas" for exported kelp T 2.3. Impact studies of sea floor biodiversity and function – status?	Reinhold Fieler (ApN) Ole Jacob Broch & Ingrid Ellingsen, (SINTEF) Gunhild Borgersen et al. (NIVA)
11:45-12:00	*Question & Discussion*	
12:00-12:50	*Lunch and group photo*	
12:50-13:30	*(WP2) continues* T 2.4. Impact of kelp detritus - Kelp degradation T2.5 Fate and bioavailability of exported kelp	Karl Attard, Ronnie Glud (SDU), Kasper (NIVA) Emma Hald Boldreel (SDU)
13:30-14:00 14:00-14:40	EFFECTS ON OPEN WATER ECOSYSTEMS (WP3) Nutrient uptake in S. latissima INDUSTRIAL KELP FACILIITES AS ARTIFICIAL KELP FOREST (WP4) Preliminary results from field and lab work - on communities in kelp farm versus natural kelp forests	Elin Bjørndal Njåstad & Yngvar Olsen (NTNU) Trine Bekkby (NIVA), Ragnhild Grimm Torstensen and Lars Andreas Grünfeld (NIVA/UiO)
14:40-15:00	*Coffee and refreshments*	
15:00-15:20	INTEGRATION AND DISSEMINATION (WP5) Presentation of publications, presentations and outreach Guidance to stakeholders and policy makers	 Kasper + Pia Kupka Hansen (HI)
15:20-16:00	Plenum discussions and wrapping up the day	All
19:00	*Dinner at Arakataka, Mariboesgate 2, Oslo*	
Tuesday 19 November in Meeting room: AQUA		
09:00-09:15	Picking up from and summing up yesterday	Kasper, all
09:15-10:15	Each WP presents a specific plan for publication, open for discussions, including publications across WPs	
10:15-10:45	*Coffee and refreshments*	
10:45-12:15	Working groups on publications and dissemination	All
12:15-12:30	Wrap up and conclusions. Outlook to the final year, 2020	Kasper
13:00 -	Simple lunch for those who wish	All

PS. The Integration and Dissimination session was moved to the morning of Day2.

Participant list

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Planned publications – an output of Day 2 discussions and summery

1) **Broch OJ, Alver MO, Bekkby T, Gundersen H,** Forbord S, Handå A, Skjermo J and **Hancke K** (2019) The Kelp Cultivation Potential in Coastal and Offshore Regions of Norway. *Front. Mar. Sci. 5:529. doi: 10.3389/fmars.2018.00529* - published

2) ***Reinhold****, M Greenacre, Sanna M, Elin, Luiza, (Yngvar), Kasper (in prep).* **Kelp biomass export from farms** (C, N, P). *Journal?*
Subm: Draft in March 2020, submitted June 2020

3) **Gunhild**, Hilde, Hege, (Ole Jacob), (Karl), Kasper (*in prep*). **Fate, and impact on sea floor biodiversity and ecosystem functioning of kelp detritus.** *Journal?*
Data analysis completed: Jan 2020
Subm: June2020

4) **Karl/Kasper**, Ronnie, Pippa, xxx?, (Gunhild), et al. (*in prep*) **Kelp detritus being a food source or ecosystem threat: an in situ Eddy Covariance study.** *J. Aquacult. Environ. interact.*
Data analysis completed: March/April 2020
Subm: Sep2020

5) Emma Boldreel (*in prep*). **Degradation and bioavailability of kelp detritus as function of detritus size and O2 availability: a mesocosms study**. *MSc thesis, SDU*
Data analysis completed: Aug2020
Subm: MSc thesis Sep2020
Possible publication hereafter with Karl, Ronnie, Kasper co-authoring

6) Elin, Luiza, Yngvar, (Kasper) et al. (*in prep*). **Kelp carbon and nutrient uptake stoichiometry at future industrial-scaled facilities.** *Journal?*
Data analysis completed: Nov2019
Subm: Dec2019

7) Yngvar, Elin, Luiza, (Kasper), et al. (*in prep*). **Carrying capacity of the coastal pelagic ecosystem in light of industrial-scaled kelp farming.** *Journal?*
Data analysis completed: Dec 2019
Subm: xxxxxx? (Yngvar)

8) *Kasper/Yngvar, Elin, Luiza et al….. Maybe include social science (under consideration).* **Potential for bioremediation and CO2 mitigation by kelp farming.** *Journal?*
Maybe combine with 6?

9) **Ragnhild** *(in prep)***. Abundance, biodiversity, and function of species associated with kelp farming compared to natural kelp forests_part I**. *MSc thesis UiO*
Data analysis completed: Jan 2020
Subm: MSc thesis July2020

10) **Lars** *(in prep)***. Abundance, biodiversity, and function of species associated with kelp farming compared to natural kelp forests_part II**. *MSc thesis UiO*

Data analysis completed: Jan 2020
Subm: MSc thesis July2020

11) Trine/Ragnhild/Lars, Hartvig, Eli, Luiza, (Guri), (Hege), Kasper (*in prep*) **Abundance, biodiversity, and function of species associated with kelp farming compared to natural kelp forests.** *Front Mar Sci – Topic issue Marine Aqua impact on marine biodiv.*
Subm: Sep 2020? (Trine)

12) Trine, Ragnhild, Lars, Hartvig, Luiza, Eli (Guri, Hege, Mats, Harry, Kasper) (*under consideration*) **Stepping stones for trouple paper: Caprella abundance in kelp farms.** *Front Mar Sci – Topic issue Marine Aqua impact on marine biodiv.*
Data analysis completed: Jan 2020
Subm: Sep 2020

13) Kasper, Trine, Ole Jacob, Yngvar, Reinhold, Hartvig, +(entire kelppro group). (*planned*) **Synthesis on positive and negative impacts of industrial kelp production on coastal ecosystems.** *Journal?*
Setting the scene (WP1), sum up impacts on benthic (WP2) and pelagic (WP3) environments, and assess the impact of farms as artificial habitats (WP4). Conclude with recormendations (WP5)
Analysis done: Sep2020
Subm. Dec2020

14) Pia/Reinhold, Kasper, people from MDIR/FDIR/management, et.al (planned) **Policy maker paper aimed for Norwegian decision makers and managing agencies providing basic knowledge and future guidelines on environmental impact of large-scale kelp production.** *Journal/format?*
Management guidelines/Policy brief
Reinhold on parallel to fish farm and management (either here or in 13))
Do we have the tools for envir. Impact from kelp cultivation?
Subm: Dec2020

Planned reports for internal use, to managers and end users

1) **Broch OJ** et al (**2019**). Report from WP1 including **specification of large- scale cultivation scenarios** to be used in WP#2 and #3 and recommendations for WP#5. COMPLETED

2) Reinhold et al. (*in prep*) Report **on up-to-date knowledge of genetic variation in kelp** and assessment of potential risks of natural kelp populations.
Subm. June 2020?

3) A baseline description of the **current knowledge and gaps** with a perspective for future studies – this report will be replaced by a policy brief paper (#14, see above)

4) Pia, Kasper, Reinhold, et al (*in prep*). **Report targeted towards Norwegian decision makers and managing agencies** providing basic knowledge and **future guidelines** on environmental impact of large-scale kelp production.
Subm. Sep 2020?

Meeting notes

10:00-10:15 Welcome and introduction. Kasper Hancke (NIVA)

- Overview of the KELPPRO organization
- Second annual meeting.
- 2020, last year of KELPPRO

Introduction round

10:15-10:30 The KELPPRO project – overall aim and current status. Kasper

- Why spend time on environmental impacts
    - Today Norway is producing 150 tons (2018) and increasing
    - Future prospect is 20 mill ton by 2050, which require an area of 2000-3000 km^2.
- Increased market potential
- Overview of the Seaweed industry in Norway.
- Aim
    - Provide an integrated assessment of positive and negative impacts of industrial-scaled kelp farming on the marine ecosystem of coastal Norway
- Main questions:
    - Will large scale kelp farming impact the coastal ecosystems – open water and sea floor habitats and functioning?
    - Will farmed kelp detritus provide valuable bio-resources or pose a threat to natural coastal ecosystems?
    - Will kelp farming facilities provide ecosystem functioning as 'artificial' forest habitats?
- Experimental approach and team
    - Field investigations (NIVA, NTNU, ApN, SDU)
    - Mesocosms experiments (NIVA, SDU, ApN)
    - Numerical modelling (SINTEF, NIVA)
- Potential environmental impacts of extensive seaweed cultivation.
    - Positive: nutrient uptake, CO2 uptake, increased primary production, promote elevated biodiversity.
    - Negative impacts: Depletion, depositing large quantities of kelp biomass. Other not included in this project: spreading of genetic material and spreading of diseases.
- Overview of the work packages.
- Current status, and a look at the time plan
    - WP1: completed
    - WP2: ongoing
    - WP3: ongoing
    - WP4: ongoing
    - WP5: ongoing
- Conclusion
    - There is a large potential for growing industrial-scale volumes of seaweed biomass to supply the global market with food and resources
    - Industrial-scaled kelp farming will inevitably impact local, regional and global ecosystems and productivity – positively and/or negatively
    - As of today, we have limited knowledge on ecosystem consequences, and potential positive and negative impacts are largely unmeasured
    - KELPPRO is well in progress and in 2019 intensive field and laboratory investigations have been accomplished
    -
- *During this meeting, have in mind.*

    - *How do we bring all this data into a finishing format?*
- *Discussion tomorrow.*
    - *Publications across WP*
    - *What after KELPPRO? Should we continue KELPPRO 2? Possible themes for further work: Negative impacts such as spreading of genetic material and spreading of diseases.*

10:30-11:00. INDUSTRIAL KELP CULTIVATION SCENARIOS (WP1). Ole Jacob Broch (SINTEF) 10 min

- WP1 – Industrial kelp cultivation scenarios.

Theme in Arendals uka (Arendals week). Politicians involved. Potential for conflicts in the costal zone. Using former fish farming areas – easier to get a permit, not necessarily the most suitable area for kelp farm.

- Main objectives
    - Identify key environmental variables for efficient kelp production
    - Identify suitable locations and potential conflicts with natural populations
    - Estimate future industrial cultivation scenarios ranging in volume from "probable" to "extreme"
- Deliverables
    - Report: “Industrial kelp cultivation scenarios”
    - Paper: "Kelp cultivation potential in coastal and offshore regions" (**published**)
    - Activities in WP1 is finished
- Key variables of kelp growth.
- SINMOD – dynamical coupled physical-biological model system, which is the ecosystem model behind kelp model. Food web model: zooplankton, phytoplankton, nutrients, forcing (climate?), and hydrodynamic model (currents temp, salinity).
- Potential for kelp cultivation in Norway.
    - Potential increases out from the coast in deeper areas. Offshore is better than coastal because of the mixing, temperature and light
- Index translated into biomass
    - 20 million tons require 2,700 – 3,000 km^2
- Timing of growth:
    - specific growth rate (Feb-Mar) and absolute growth rate (May-Jun). Simulations along the whole coast. Mapped against latitude
- The potential for kelp cultivation in Norway
- Assessment of production potential
    - By weight (14 locations sum: 27.7 kilotons) and area (37 locations, sum 12.0 kilotons).
- Discussion
    - What do we think about these estimates?
    - Use some of this to assess large scale effects (up-scale from experiments using models)?
    - Effects – to be discussed in other WPs?
    - Relevant to run simulations including effects and feedback – large scale farms (se e.g. WP2 later)

Q: what is needed to upscale seaweed farming in Norway?
In Norway the marked for kelp is limited.
How to use more of the kelp biomass.

EFFECTS OF INDUSTRIAL KELP PRODUCTION ON SEA FLOOR ECOSYSTEMS (WP2)

T2.1. Estimate export of kelp detritus. Reinhold Fieler (ApN) et al

- Capture kelp from standard rigs.
    - Locations: Frøya and Tromsø
    - 16000 measurements from Frøya and Tromsø
    - 50 plants

- Measure erosion of sugar kelp – method.
    - Measure length with punch hole technique. Measure the distance between hole (can distinguish between growth or stretch).
    - Repeated measurements through the season.
    - Out every 2nd week – huge work.
- All shedding and comparison
    - Natural shedding 19,52 cm, 15,1% of theoretical growth
    - All shedding 40,73 cm, 31,5% of theoretical growth
- Area-length relationship - Solveig Fodal.
- Kelp – erosion.
    - Different shapes
    - Loss of kelp tissue
    - Length and weight changes over time.
    - Difficult to predict dry weight.
    - Length is a poor estimate for erosion, divide each plant into 4 sections.
- Most erosion from small fractions from the tip
- Kelp plants divided into sections (S1 – S4)
    - Section 1 – tip: 5% of blade length measured from the tip;
    - Section 2 – next to tip: an additional 5% of blade length measured from the cutting edge for the tip;
    - Section 3 – mid section: an additional 40% of length measured from the cutting edge for section 2;
    - Section 4 – base section: resting 50% of blade length
    - Calculated the dry weight of different parts/sections.
- Section regression model
    - Used to calculate the loss of kelp material (dry weight)
- Section loss dynamics Tromsø and Frøya 2018 deployment.
    - Graphs showing loss of sections throughout the season.
    - Tromsø April 2018 – no loss of whole plants compared to February
    - Frøya January 2018 – almost no loss until approx. in June. In June, loss of a great amount of biomass. Biofouling might be a reason. Harvest plants before this point.
- Linking length loss to biomass loss
    - 125 kelp divided into 500 sections. Calculated loss in dry weight for each piece.
      Regression best for smaller weights.
- Simulation study
    - Graph showing the result of 1000 simulations of weight loss. Estimated mean weight loss plotted against actual mean weight loss.
    - 1000 simulations of losing about 13% of the length, due to break offs of section 3, 2 or 1.
- Kelp dynamics: Dry weight length – region
    - Dry weight. Tromsø vs Frøya – absolute values (stacked) and relative values (stacked).
    - Ideal plant length in Tromsø 90 cm. 125 days to reach this size. Frøya only need 110 days to reach 90 cm (grows faster, but they are lighter).
    - The weight of section 4 is about 63% of the kelps weight. Section 1 is 5% or less of the total weight. The dry weight of the different sections is relative constant across the locations and the kelp sections.
- Growth and erosion
    - Growth: Gram dry weight plotted against time. The curve straightens out around July. Not because it stops growing, but because it loses material, erosion (orange line).
    - Erosion: until approx. June there are no loss due to erosion.
      august, Frøya loses almost 900g per 50 plants.
- Biomass and erosion

- Graph showing dry weight – standing population against time.
    - Graph showing percent of biomass against time.
      Tromsø 30% loss in august
      Frøya 25% loss
      Information useful for kelp farms – shows when the kelp should be harvested.
- Erosion rate in Tromsø and Frøya
    - Graph: percent erosion per day for the period

  Erosion rate is 1% per day
- Erosion rate
    - Formula
    - Due to growth, erosion has no fixed base, because the base for erosion is changing every day.
- Example
    - A one ha farm (10 000 sqm) produces 10 kg wet weight per sqm / year. Observed biomass is 100 tons.
    - Out of this we get a DW biomass of 13,6 % = 13,6 tons
    - Produced DW biomass was (1+0,42) times observed DW biomass = 19,4 tons.
    - 5,8 tons DW biomass are lost into the environment from such a standard aquaculture kelp farm.
    - These values can now be used to calculate the P, N and C flow to the environment.
    - BUT!! If a farmer in Frøya is harvesting too late (august), the erosion is twice the observed biomass.
    - Erosion is 13,6 tons X (1 + 1.86) = 38,9 tons minus 13,6 tons = 25,3 tons
- Important message to the industry. If the harvesting is performed at the right time, you can reduce the loss of biomass. You also reduce the impact biomass loss have on the ecosystem.
- Summary
    - Length measurements used as starting point for DW regressions of erosion.
    - Model for erosion dynamics in aquaculture is established (sectional loss) and studied through seasons/ years and across regions.
    - Model for estimation of DW from "lost length/sections" is established from a "learning set" of data and tested with a bootstrapping re-computing method.
    - Erosion estimated and described for Troms and Frøya through 2018 season.
    - Left: Finalize Tromsø 2017 and Troms 2018 April deployment data sets.
    - Quality assurance and paper.

T2.2. Transport pathways and “Deposit areas” for exported kelp Ole Jacob Broch & Ingrid Ellingsen, **(SINTEF)., Kasper (NIVA)**

- Dispersal of detritus from natural and farmed seaweed (last year)
    - Simulation study using SINMOD to estimate the dispersal of detritus over a growth season for: 1. Natural seaweed growing at depths 0-30m. 2. Farmed seaweed at SES location near Frøya.
    - *Learned from last year, its sensitive to sinking rates.*
- Transport and sedimentation model
    - Physical-biological ocean model SINMOD
      See any recent paper for details regarding setup, nesting, forcing etc.
    - Eulerian approach
    - Used 4 detritus and sedimentation compartments

What is the relation between types of materials? The type of material is important, big fast sinking or small slow sinking.
Including resuspension, important because: resusp. can lead to aggregation

Figure of sedimentation model including sedimentation, resuspension, sinking speed, water currents, diffusion and horizontal transport. Detritus, 3D variable. Sediment 2D variable.

- Sinking rates of kelp detritus?
    - Where does the excess kelp go, where does it aggregate?
    - Wernberg & Filbee-Dexter (2018) *Scientic Reports* 8:17180
    - Figure 2. Sinking speeds of different kelp detrital particles against a) area and b) biomass
    - Table of simulation assumptions (detritus compartment and rate (m s^{-1})
    - *NB! No degradation – or predation rates in these models.*
- Sinking rates of S. latissimi detritus?
    - Results indicate that (cultivated) *S. latissima* may have lower sinking rates
    - Lower sinking rates - longer transportation.
- Simulation scenarios
    - April to June
    - Daily release rate constant within each month
    - No degradation
    - Thee release scenarios
        - SES permit 33 ha ("near shore")
        - "Froan" farm 125ha (exposed)
        - "offshore" farm 125 ha (offshore)
    - Table with month, start biomass, net production, detritus release, DW fraction, C fraction of DW and C release.
    - *fixed daily release rate. Calculated back into carbon release.*
- Model domain and release sites.
    - Map of release sites.
- Overview of dispersal results on June 30.
    - *concentration of deposit matter. Log scale. Where does it goes? Accumulated over a season. First pic: SES-farm. Red dot source/ release point, blue dot central mass.*
- Dispersal results from
    - Sheltered location (approx. dispersal under 1 km from farm). *Most is concentrated around the farm.*
    - Exposed location (approx. dispersal 1,5 km from farm). *High weight transported further. Lighter particles show a tendency to be transported further.*
    - Full offshore location (approx. dispersal 4 km from farm). Results that we would expect.

  Integrated results, including resuspension.
- Dispersal distance of detritus until "sedimentation"
    - Figures showing sedimentation for SES, Froan and offshore. Sedimentation from approx. 4 km from farm. More matter dispersed far away.
- Sinking rates, location and average transport distance of detrital biomass (m)
    - The differences between release sites reflect the differences in topography, bathymetry, and water currents of 3 months

What happens to the ("break offs") kelp fractions? Where do they go?

- Further work and plans
    - Store (e.g. daily) sedimentation and resuspension rates (easy, but need to rerun) – provided more insight into "dynamics"
    - More realistic release connected with currents, etc., partition between compartments
    - Reinhold's work – we may have overestimated results in terms of biomass released; results on distances etc. remain valid (only relates to fraction of total mass)
    - Couple kelp model, biology and physics in this setting – include degradation results.
    - Publishing?
    - Potential for paper focusing on this (not a promised deliverable?) or joint with other efforts –important to relate to the field data

- Accepted oral presentation at AGU Ocean Sciences Conference, San Diego February 2020

T2.3. Impact studies of sea floor biodiversity and function – status? Gunhild Borgersen et al. (NIVA)

- Focus: Benthic macrofauna.
    - Impact studies on seafloor biodiversity and function

Benthic macrofauna in a kelp density gradient in Frøya.

- Sampling in June and October 2018
    - "soft" bottom samples from 12 sites
    - One grab sample (0,05m^2) from each site. 60- 220 m depth.
- Sediment characteristics
    - Coarse sediments
        - *usually, more fine sediments are used in this type of analysis.*
    - High TOC content 41.3 – 111 mg/g
    - "normalized" TOC: 56.6 – 126.9 mg/g. Status for organic content classified av very bad.
- Species diversity and ecological status
    - High number of species
    - Higher number of species in October than June.
    - Index classification based on species data.
        - All sites classified as very good based on the fauna.
        - Coarse sediments are more species rich than fine sediments.
- Species composition
    - MDS – plot showing how similar or different the sites are based on species composition.
    - Results from June (green dots) and October (blue dots)
    - Pattern in the results matches the sample sites.
- Next
    - Look at the variables in relation to the results from the species analysis
        - Grain size
        - TOC
        - Kelp residue
        - Chl A
    - Trait analysis

T2.4. Impact of kelp detritus - Kelp degradation. Karl Attard, Ronnie Glud (SDU), Kasper

- Overall Concept
    - Figure: Remineralization rates (eddy fluxes) Organic carbon -> CO_2. Biomass export (standing biomass). C burial (sedimentation C content).
    - Look at the effect in a worst-case scenario.
    - How kelp degrades *in situ*.
- Finding a study site
    - Site: Solbergstrand.
    - Depth 12m (chosen of practical reasons)
    - May
- Net setup and deployment.
    - Large 6,6 m * 9,3m mesh net «sandwich" filled with 530 kg of freshly harvested *Saccharina latissima* from SES (8,63kg FW m^{-2})
    - Kelp biomass: three pillows of 0,6m * 0,9 m filled with same density. The pillows could be lifted up to look at degradation trough out the summer.
    - 10 cm layer of kelp
- Eddy covariance fluxes (figure). Compute oxygen fluxes.
- Two instruments deployed. One on the net, and one at a control site.

    - Large footprint area (typically 10-50 m^2)
    - Non-invasive measurements
    - High temporal resolution (typically 15 min)
    - Peter Berg et al. 2017 L&O e-Lectures

  Can assume that it is little primary production from the kelp blanket. (important because we want to look at degradation).
- Suitable for eddy covariance measurements?
  Need good enough hydrodynamics (turbulence) to use this equipment. Tested in January 2019.
  In addition to measure oxy – fluxes. CTD measurements was also taken.
  Looked at sediment characteristics + core samples.
- Eddy covariance fluxes.
    - Carbon turnover calculated from oxy – flux. Assume equal activity.
    - Accumulated carbon turnover 40g carbon/m^2 (in the net, over a period of 4 months)
    - 260 g C/m^2 is the calculated amount the experiment started with in the net.
        - Assuming DW = 10% WW, and C content =30% of DW, net C content = approx. 260 g C m-2
        - Therefor local remineralization represents approx. 15% of local C flow pathway.
    - The sediment underneath the net became anoxic
    - Biomass export is a major C flow pathway
    - C burial – working on it
- Picture of biomass nets, kelp fronds and sediments after two months of deployment.
- O2 dynamics within kelp net (figures)
    - Well-oxygenated conditions above net
    - Net biomass frequently experienced hypoxia
    - Similar conditions observed in macroalgal deposits in the Baltic Sea
- Complementary laboratory studies- Emma's MSc project
    - Some open questions:
    - How does the seafloor respond under a range of kelp deposition concentrations?
    - What is the anaerobic C turnover rate?
    - At what point is harmful free sulfide (H2S) produced- and what biogeochemical factors control this?
    - Any differences between A. esculenta and S. latissima?
    - Many of these will be tackled in Emma's MSc project

T2.5 Fate and bioavailability of exported kelp. Emma Hald Boldreel (SDU) et al.

Microbial degradation dynamics of two kelp species: sugar kelp (*Saccharina latissima*) & dabberlocks (*Alaria esculenta*) and the impact exerted on the benthic community.

- Aim of the master thesis – to investigate the dynamics of microbial driven degradation.
    - microbial degradation under oxic conditions – frozen algae material.
        - Method: Total incubation.
        - Parameters: O2, dissolved inorganic carbon (DIC), NO3- and NH4+.
        - microbial degradation under anoxic conditions – frozen algae material
        - Method: Wurgler bags.
        - Parameters: DIC, NO3-, NH4+ and H2S, iron content.
    - microbial degradation under oxic conditions – fresh algae material.
        - Method: Total incubation
        - Parameters: O2, dissolved inorganic carbon (DIC), NO3- and NH4+
    - microbial degradation in water – frozen algae material
        - Method: Winkler bottles
        - Parameters: O2
- Experiment 1

- Adding the seaweed
    - Size and amount from literature. 1*1 cm pieces.
  - Pilot experiment
    - 8 doses from 0,3 – 2g wet weight
    - Sufficient amount of algae to get a response?
    - 1,1g WW as a pilot dose.
  - Table from Wernberg & Filbee-Dexter, 2018. With particle type, area, biomass and sinking speeds.
- The net – to prevent the tissue from floating
- Results from experiment 1
  - Saccharina and alaria doses
    - Figures: O_2 uptake against days relative to the day of seaweed addition
  - Difference among species oxygen (*S. latissima* and *A. esculenta*).
    - Figure: oxygen uptake against days relative to seaweed addition.
  - Difference among species carbon (*S. latissima* and *A. esculenta*).
    - % C turnover against doses
- Sum up
  - The net keeps the seaweed in place. The net does not create a barrier and does not exert an effect on the degradation dynamics (quite stable controls)
  - The O2 consumption changes with seaweed dose – up to fivefold from the starting point for the highest concentration.
  - There seem to be a difference in the degradation dynamics of the two species. Saccharina has a much more rapid turnover of carbon, almost twice as high as Alaria.
- Further work.
  - Complete experiment 1
  - Begin experiment 2 and 3.

13:30-14:00 EFFECTS ON OPEN WATER ECOSYSTEMS (WP3) Nutrient uptake in S. latissimi. Elin Bjørndal **<u>Njåstad</u> & Yngvar Olsen (NTNU)**

Paper in prep from last year's work

This year cultivated *A. esculenta* and *S. latissima*. Deployed in January and sampled in June. Last year, only outflow water, this year both inflow and outflow.

- Content
- Physical environment
- Temp outflow and inflow
  - As exp. Increasing temp with the season
- Salinity
  - Effect caused by mixing of the water column
- Dissolved inorganic nutrients (Phosphate, Nitrate and ammonium)
  - Normal values during the whole period.
  - High P and N – normal for this site during this period.
  - Ammonium relatively low.
    The dots are snap-shots from sampling.
- Seaweed
  - Deployed in January 2019
  - 6 samplings between 23rd of March and 11th of June
  - 3 replicate ropes
  - Each sampling:
    - 10 individuals for chemical analysis
    - Kg/m, n = 3
    - Length and width, n = 30/15

- Seaweed growth
    - *S. latissima* showed a higher max growth. Max sporophyte area for S. latissima around 2200 cm^2.
    - *S. latissima* max weight: 7 kg in June. *A. esculenta* max weight 4 kg in May.
- Growth rate
    - A. esculenta has the highest growth rate. Mean: 0,05.
    - *S. latissima* mean growth rate: 0,03
- Phosphorus, Nitrogen and Carbon content
    - Follows same pattern with a decrease towards the summer.
    - *A. esculenta* has a higher content of P, C and N at the end of the season.
    - Ended the experiment earlier in 2019 because of epiphytes (bryozoans), affected the content of P, N.
- Net uptake
    - Highest net uptake of P and N in *A. esculenta*
    - From May, net uptake is close to zero.
- CNP ratio
    - Same pattern in both species.
    - End of May, epiphytes observed – this is not visible in the results.
- Water column
    - 10 sampling between 31st of Jan and 1st of July
    - Two locations: Inflow and Outflow
    - 2 samplings before March
    - 2 samplings after harvest in May
    - Water sampled from 0-10 m depth
- Particulate organic nutrients
    - POP /PON– normal concentrations for phytoplankton
- Phytoplankton biomass
    - CHL A – indicates phytoplankton biomass. Within the normal.
    - POC – Question: second peak, what can it indicate? - unsure… May be bacteria or zooplankton? Sampled <200µm fraction. Indicates a biomass of organisms that is <200µm
- N:C ratio in plankton
    - Indicates which elements that limits phytoplankton growth. (Reference line 0,16)
    - Well balanced PON:POC
- P:C ratio in plankton
    - (Reference line 0,025). Under the line indicates P limitation. At the end of the season, more P. P:C balance.
- N:P ratio in plankton
    - (Reference line 7,2). Ecosystem in a balanced condition. No P or N limitation.

Q: infow /outflow – follow current directions
It doesn't look like the kelp farms compete with phytoplankton. Seaweed not able to compete with phytoplankton at a point. N and P uptake in kelp is low after May.

14:00-14:40 INDUSTRIAL KELP FACILIITES AS ARTIFICIAL KELP FOREST (WP4) Preliminary results from field and lab work - on communities in kelp farm versus natural kelp forests. Trine Bekkby (NIVA), Ragnhild Grimm Torstensen and Lars Andreas Grünfeld (NIVA/UiO), Kasper et al.

How is the ecosystem connected to the kelp farm? Comparing the fauna in kelp farms with natural kelp forests
Further work: genetics in kelp farms compared to natural kelp forests.

- Location – Frøya.

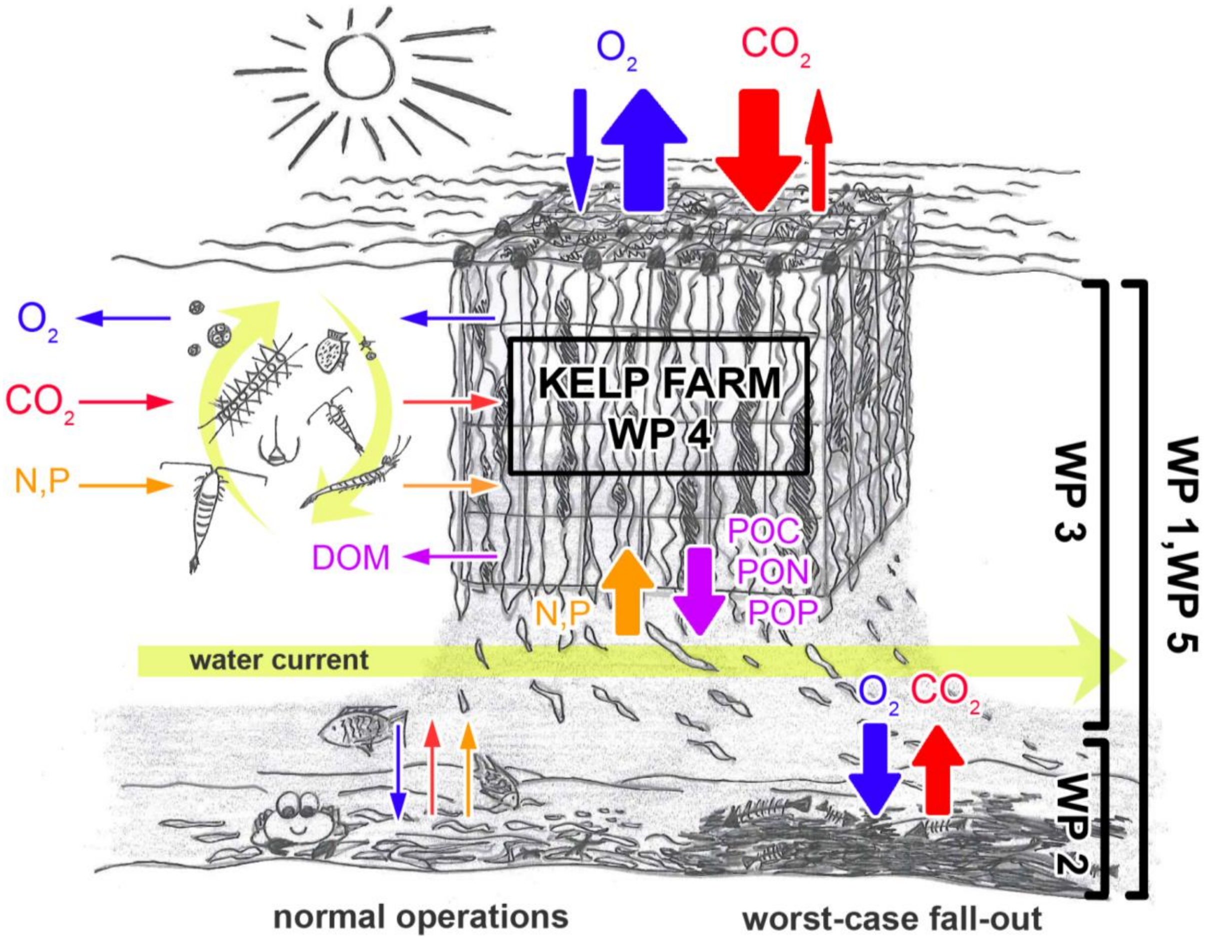
- Map of where the field work was carried out. Two farms: SES concession (not in use) and SES farm (in operation)
- April 2019
  - Hypothesis: Does the farm represent its own community, or does it hold the same community as the *Saccharina latissima* forest or the *Alaria esculenta* forest, or is the community in the farm similar to the surrounding *Laminaria hyperborea* forest? Or is the fauna community in the farm similar to the water mass control, being just an effect of structure introduced?
  - Ragnhild: *Saccharina latissima*
  - Lars: *Alaria esculenta*
- The SES- kelp farm
  - Picture that represents the farm from above showing the S. latissimi part, A. esculenta part and one area with no cultivation.
  - Markings that show the placements of fauna traps, bottom traps and fish net.
  - Fauna traps in *S. latissimia* part placed both in January and September.
  - Fish net in area with no cultivation.
- Pictures from field work.
- All the samples were brought back to (NIVA) Oslo for analyzing. Species identification (with help from Hartvig, Marijana and Gunhild). Weight of samples in December.
- Pictures representing the common species found in the samples.
- Results – spring
  - Haven't done much analysis. Graph showing number of species. Big difference between the kelp farm and natural forest. More fauna in the natural kelp forest. Especially on the kelp plants. Expected since the farm does not want epiphytes, and the kelp is in the habitat for a shorter time period.
- Fish
  - Less fish than expected
  - No fish in the kelp farm
  - Placements of fish nets?
- September 2019
  - Farm is now empty of kelp
  - Are the community only a result of the farms substrate?
- Caprella mutica picture
- Caprella mutica – dominating the farm
  - Hardly any other species, registered some Jassa falcata and shrimps
- Fish
  - Only one fish in the kelp farm
  - But many observations
  - Look at data from the blue eye?
- Species composition spring vs fall
  - In total, more individuals and more species in the fall field work.
  - Expected – there are less animals abundant in the spring
  - Would be interesting to see a kelp farm in the fall and compare to a natural kelp forest.
- November 2019
  - New field work
  - Do we find Caprella mutica in other artificial substrates?
    - Salmon farms
    - Docks
- Methods
  - Scrape off all the animals/epiphytes. Fixated in ethanol and brought back to the lab.

    - Haven't analyzed the samples yet, but during field work Caprella mutica was observed in many of the samples.
- Whats next?
    - Is the community in the Alaria esculenta part of the kelp farm similar to the community in the natural Alaria esculenta forests?
    - The same goes for Saccharina latissimi. In addition, is there any difference in growth period in the farm? Difference in September plants and January plants?
    - Multivariate analysis
    - Diversity indexes
    - Difference in total biomass
- Thanks to supervisors and everyone at NIVA for great help!

Next presentation postponed until Day02 (19.11.19)

15:00-15:15 INTEGRATION AND DISSEMINATION (WP5). Kasper (NIVA) and Pia Kupka Hansen (HI)

Presentation of publications, presentations and outreach
Guidance to stakeholders and policy makers.
Postponed to 19.11.19
15:30-16:00 Plenum discussions and wrapping up the day All



The KELPPRO concept figure and work package overview.

Involved Institutions

NIVA – Norwegian Institute for Water Research, Section for Marine Biology (www.niva.no/en/forskning)
SINTEF – SINTEF Ocean AS (www.sintef.no/ocean)
NTNU – Norwegian University of Science and Technology, Dept. of Biology (www.ntnu.edu/biology)
ApN – Akvaplan-niva AS (www.akvaplan.niva.no/en)
IMR – Institute of Marine Research (www.imr.no)
SDU – University of Southern Denmark, Dept. of Biology (www.sdu.dk/biology)
SES – Seaweed Energy Solution (industry partner, www.seaweedenergysolutions.com/en)
HORTIMARE – Hortimare (industry partner, www.hortimare.com)

www.kelppro.net