Exploration of the environmental mitigation potential by farming blue mussels in connection commercial to fish farms

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Fiskaaling

DTU

SAMS
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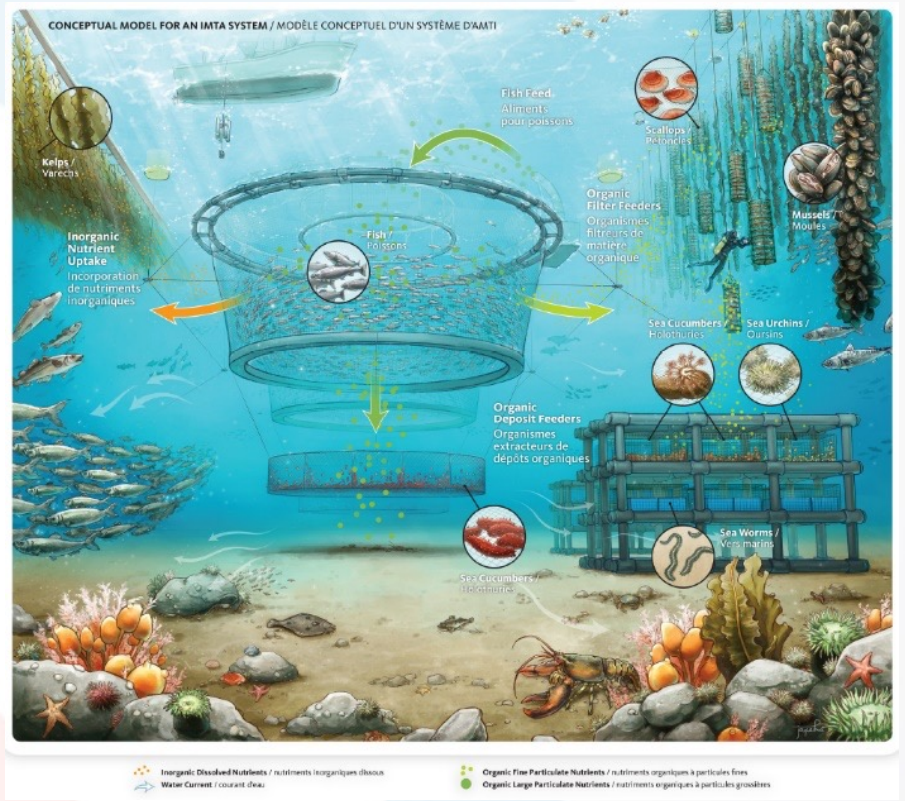
IMTA Integrated MultiTrophic Aquaculture



- Aquaculture >40% of the export value
- Aquaculture dominated by Salmon farming
- Limited sheltered areas

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Objectives

- Best practice to utilise blue mussels to mitigate the environmental impact from salmon farming
  - Case: A specific fish farm

- Method

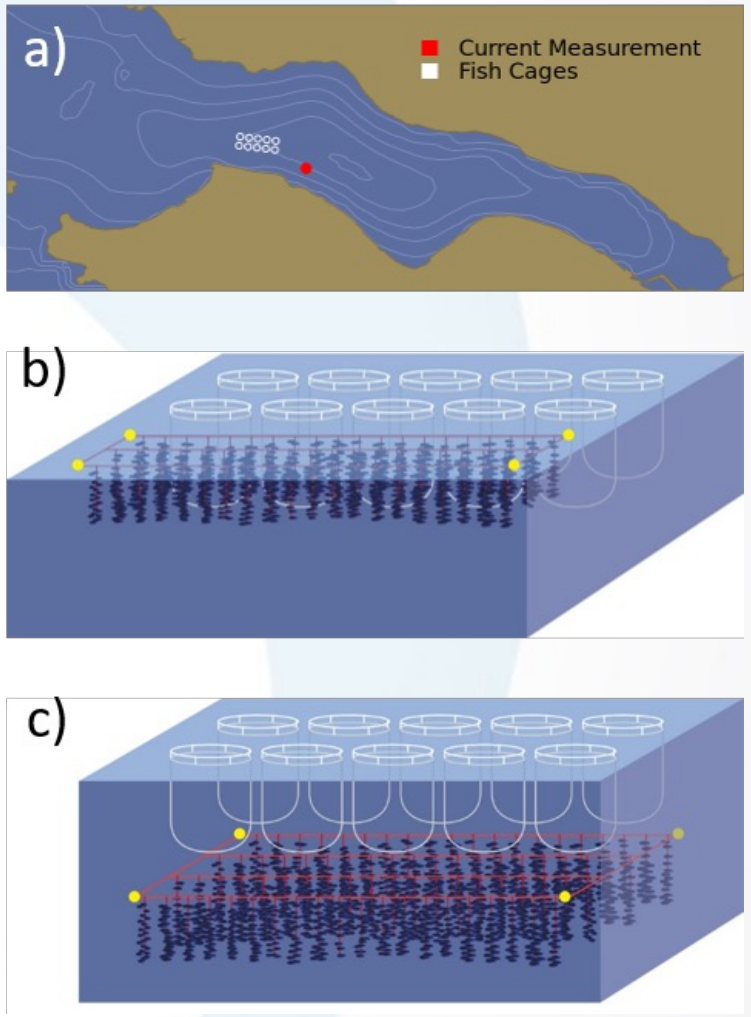
  Overview of the fjord ecology

  Amount of particulate and dissolved waste from farm

  Growth potential of blue mussels

- Model the best mitigation practice

Blue mussel/Salmon IMTA



- Model the uptake of particulate waste within the constraints of a commercial fish farm
- Fish farm
  - 10 net pens
  - Total area 350 x 140 m
- Surface blue mussel farm
  - 350 m X 20 m X 10 m
- Submerged blue mussel farm
  - 350 m X 140 m X 10 m

https://doi.org/10.3389/fmars.2023.1236294

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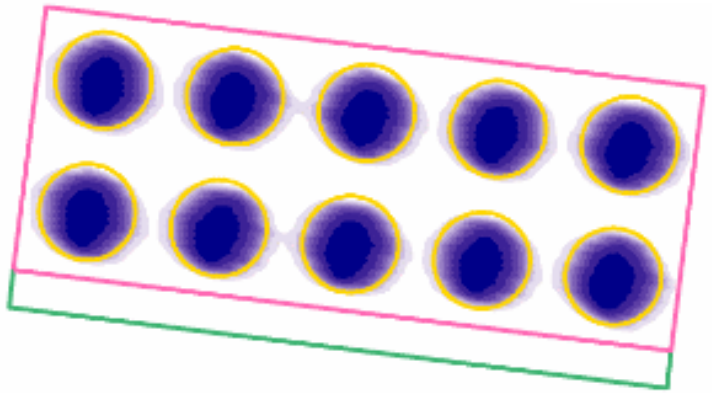
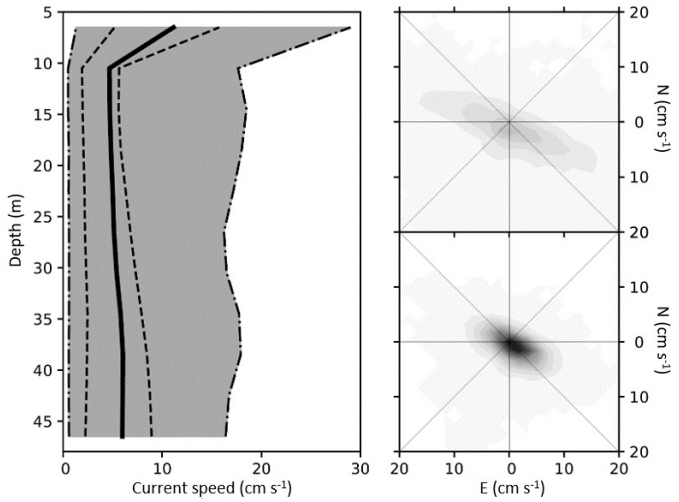
Waste dispersion

- Waste production:
  - Feed use and biomass increase
  - Feed analysis of commercial feed
  - Spatial arrangement of net pens



- Dispersion:
  - Local hydrodynamics (current measurement)
  - 4 different settling velocities
    - 7.5 cm/s (65%)
    - 3.2 cm/s (20%)
    - 1.5 cm/s (10%)
    - 0.1 cm/s (5%)

Bannister et al. (2016)



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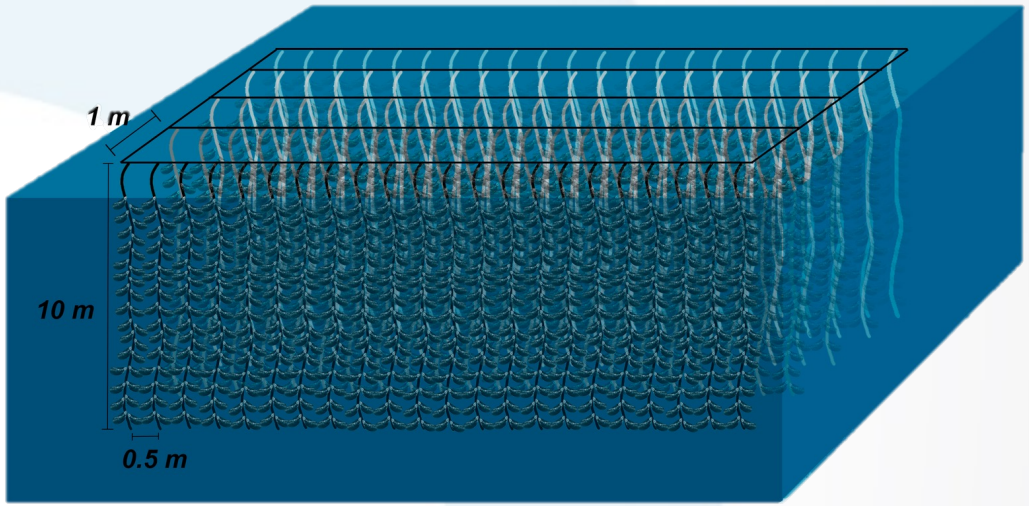
Blue mussel farm



Blue mussel density: 600 per m
from test blue mussel farm in the fjord

Passive spat collection
No restocking

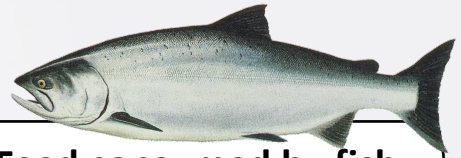
Danielsen and á Norði 2021
https://zenodo.org/record/6563040

Assumption: All fecal particles from the fish farm can be assimilated by the mussels

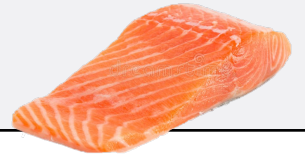
https://doi.org/10.3389/fmars.2023.1236294

Total nutrient load to the ecosystem during one production cycle

Feed
4599 t feed
- 273 t N
- 41 t P



Feed consumed by fish
4461 t feed
- 265 t N (97%)
- 39 t P (97%)



Incorporated in biomass
4400 t fish
- 130 t N (48%)
- 18 t P (45%)

Feed loss
138 t feed
- 8 t N (3%)
- 1 t P (3%)

Particulate waste (faeces):
- 19 t N (7%)
- 14 t P (35%)

Dissolved waste:
- 116 t N (42%)
- 7 t P (18%)

Total to environment:
143 t N → ~52%
22 t P → ~55%

Duration 18 months
Weight at deployment 360 g
Weight at harvest 6.7 kg
FCRbio 1.05

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Integrated Multi-Trophic Aquaculture (IMTA)

Feed
4599 t feed
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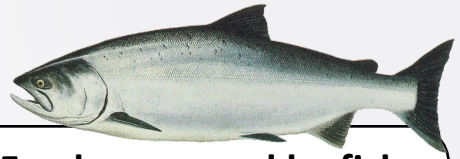
- 41 t P



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Dissolved waste:
- 116 t N (42%)
- 7 t P (18%)

Settled

Suspension

Microalgae

Macroalgae

Deposit feeders

Bivalves Mussels

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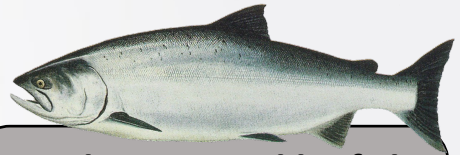
Blue mussels: Assimilation of particulate fish farm waste

Feed
4599 t feed
- 273 t N
- 41 t P



Feed consumed by fish
4461 t feed
- 265 t N (97%)
- 39 t P (97%)

Incorporated in biomass
4400 t fish
- 132 t N (48%)
- 18 t P (44%)

Feed loss
138 t feed
- 8.2 t N (3%)
- 1.2 t P (3%)

Particulate waste (faeces):
- 19 t N (7%)
- 14 t P (35%)

Dissolved inorganic waste:
- 114 t N (42%)
- 7 t P (17%)

Settable

Suspended

Microalgae

Macroalgae

Deposit feeders

Bivalves
Mussels

13% of total N waste

63% total P waste

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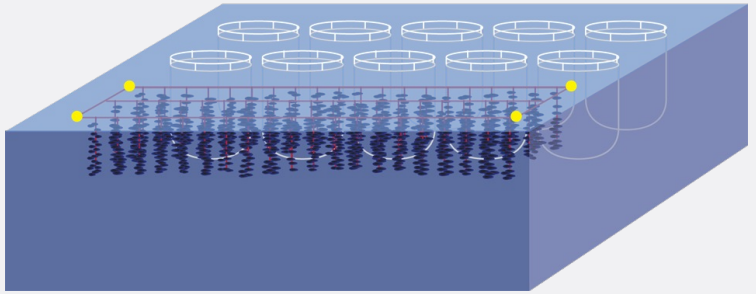
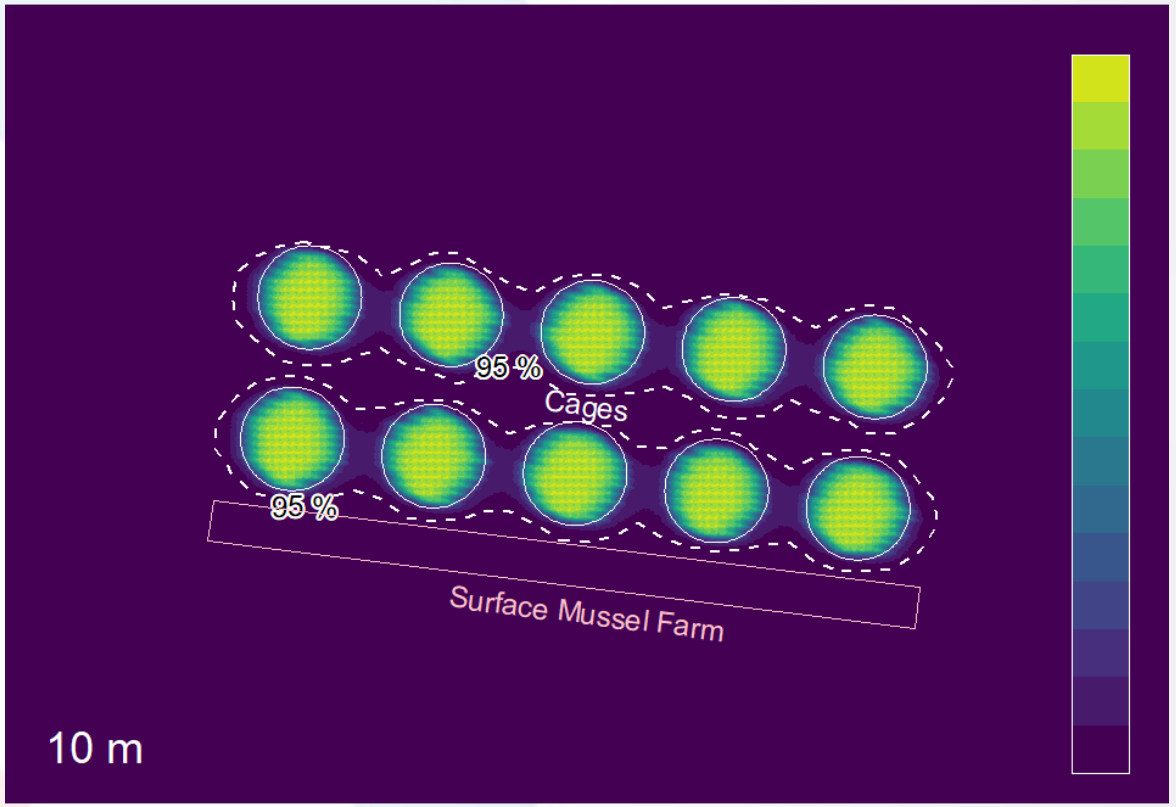
Blue mussels next to fish farm





PW From fish farm
- 19 t N
- 14 t P

Enters mussel farm
- 3.1 %
- 0.58 t N
- 0.44 t P

Assimilated
- 13% of particles that enter
- 0.08 t N
- 0.06 t P

0.4% of faecal particles assimilated in mussel farm

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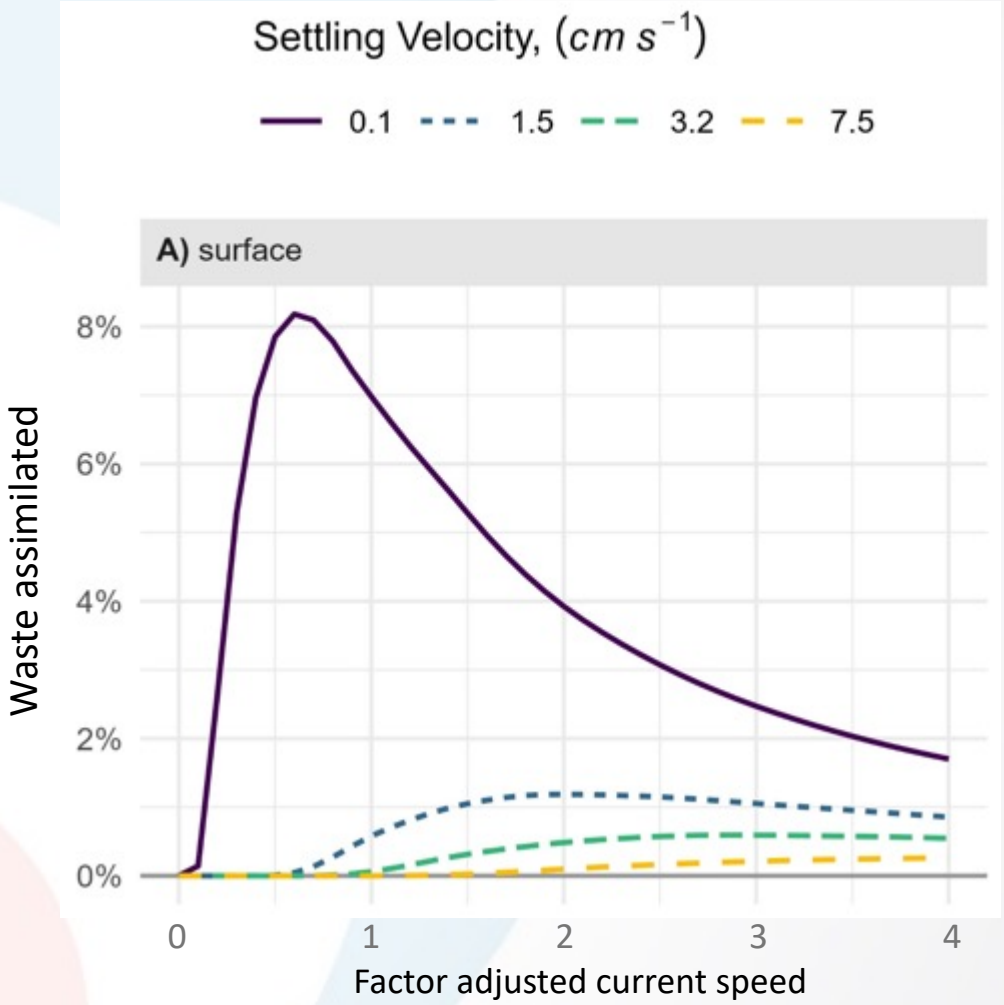
Influence of current speed on waste removal



Limitations for assimilation

Waste dispersion to blue mussel farm
Residence time in the blue mussel farm

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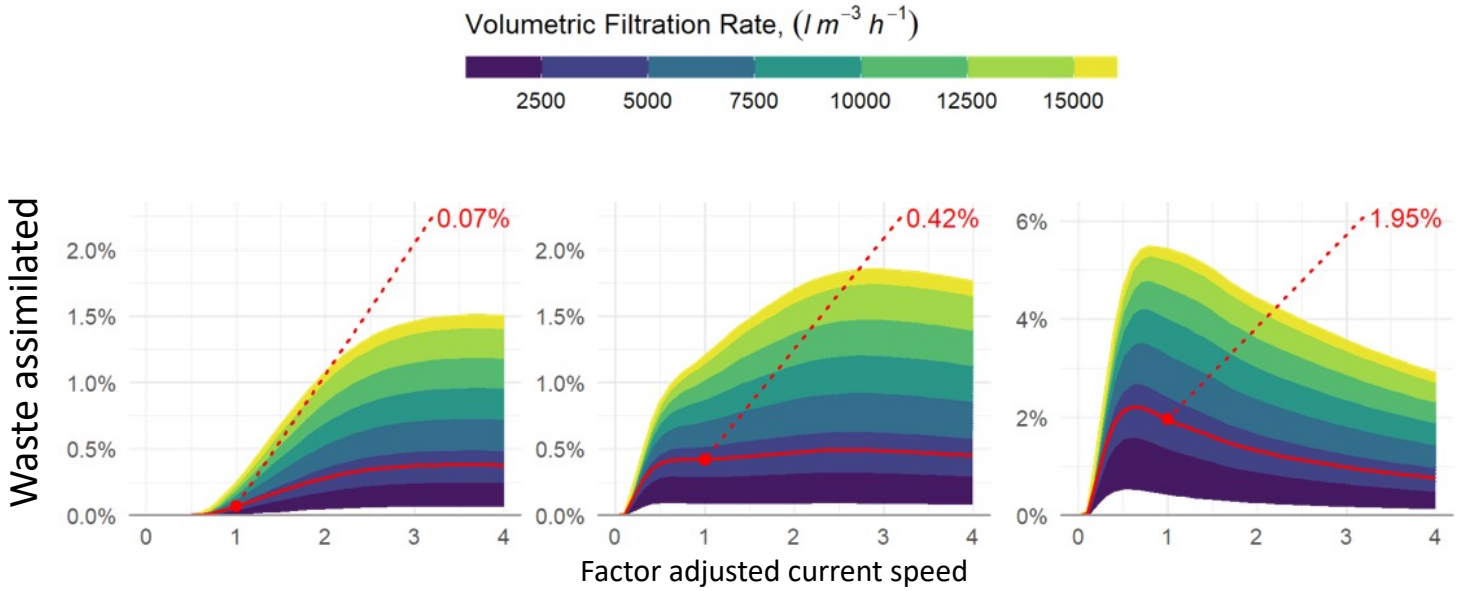
Sensitivity analysis



0% at 1mm s^{-1}	5 % at 1mm s^{-1}	27 % at 1mm s^{-1}
• 10 % at 1.5 cm s^{-1} • 20 % at 3.2 cm s^{-1} • 70 % at 7.5 cm s^{-1}	• 10% at 1.5 cm s^{-1} • 20% at 3.2 cm s^{-1} • 65% at 7.5 cm s^{-1}	• 10 % at 1.5 cm s^{-1} • 20 % at 3.2 cm s^{-1} • 43 % at 7.5 cm s^{-1}

Waste composition with multiple settling velocities

Volumetric filtration rate
max: 16000 l m^{-3} h^{-1}

Current speed
1=measured currents
Median speed 9.4 cm s^{-1}

Portion of slowly settling waste
Max 27% Wong and Piedrahita (2000)

Slowly settling waste highest impact on waste assimilation

Highest obtainable assimilation:
5.5% of the faecal waste

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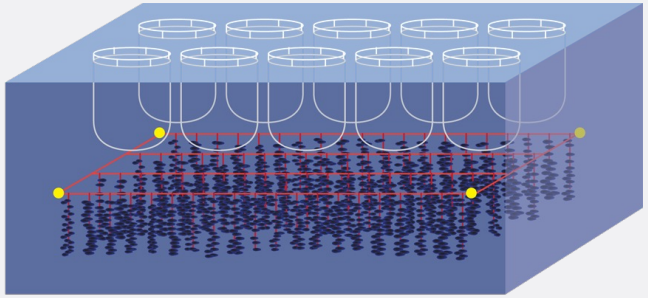
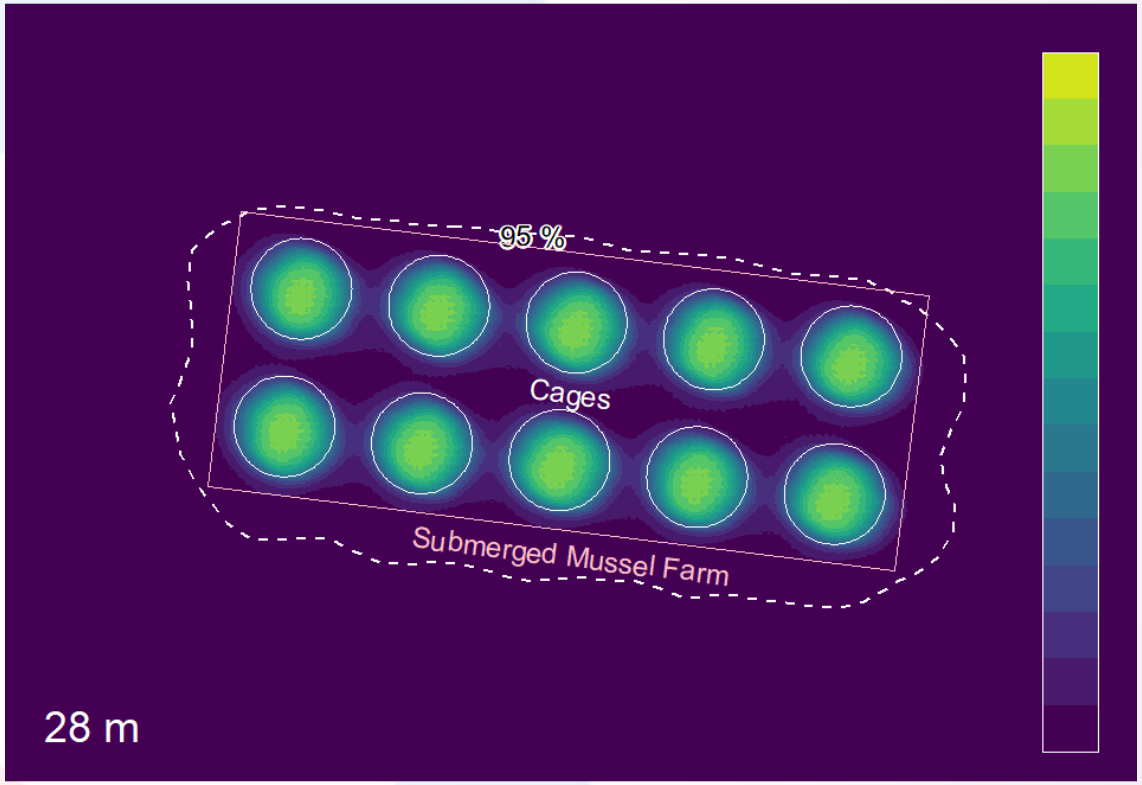
Blue mussels below fish farm





PW
From fish farm
- 19 t N
- 14 t P

Enters mussel farm
- 92.5 %
- 17 t N
- 13 t P

Assimilated
- 16% of particles that enter
- 2.7 t N
- 2.1 t P

15 % of faecal particles assimilated in mussel farm

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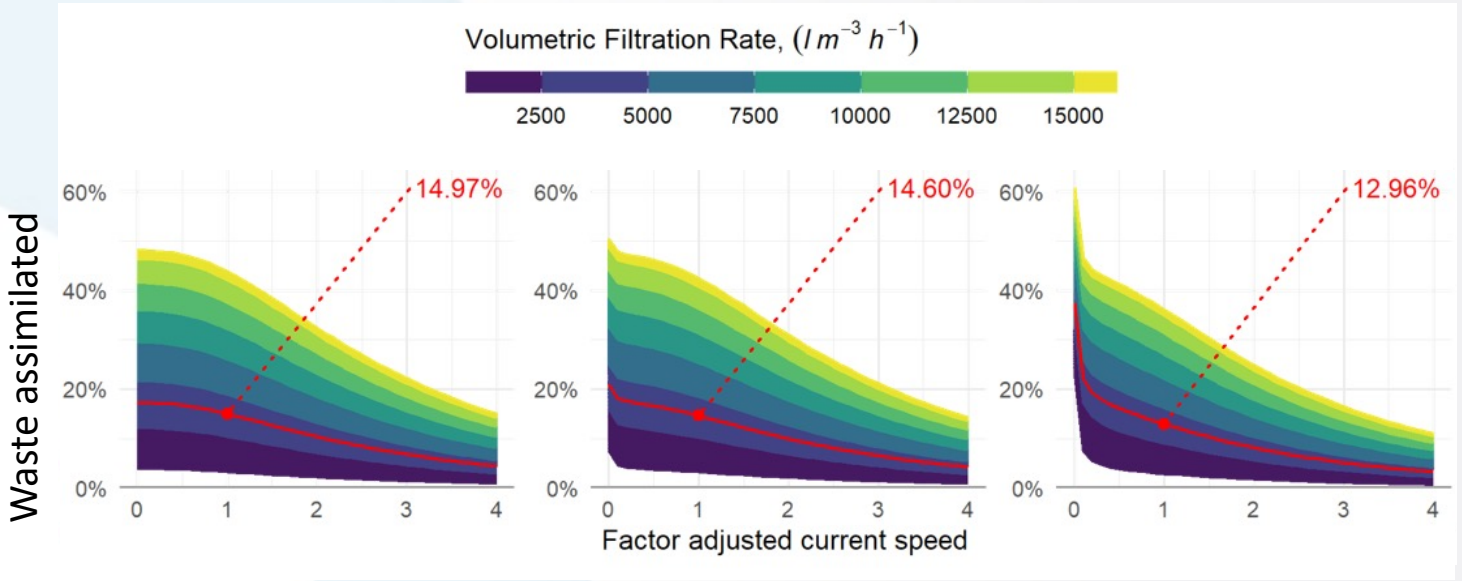
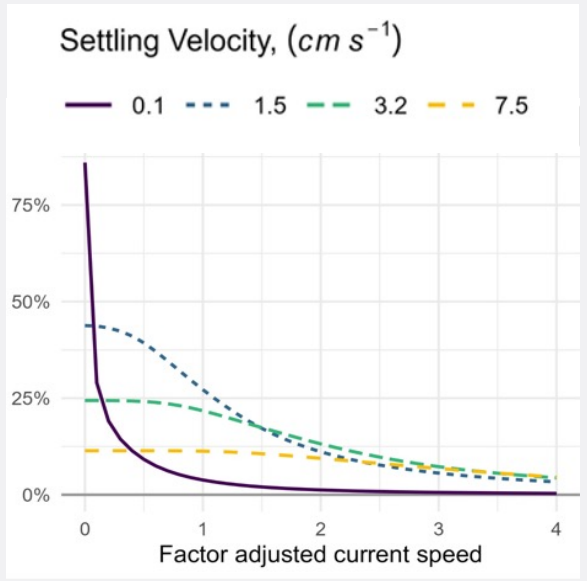
Sensitivity analysis





0% at 1mm s^{-1}	5% at 1mm s^{-1}	27 % at 1mm s^{-1}
• 10 % at 1.5 cm s^{-1} • 20 % at 3.2 cm s^{-1} • 70 % at 7.5 cm s^{-1}	• 10 % at 1.5 cm s^{-1} • 20 % at 3.2 cm s^{-1} • 65 % at 7.5 cm s^{-1}	• 10 % at 1.5 cm s^{-1} • 20 % at 3.2 cm s^{-1} • 43 % at 7.5 cm s^{-1}

Waste composition with multiple settling velocities

Overestimated:
Limitations due to particle size not accounted for

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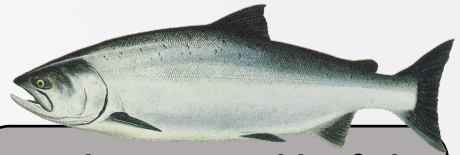
Ecosystem approach to Multi-Trophic Aquaculture

Feed
4599 t feed
- 273 t N
- 41 t P



Feed consumed by fish
4461 t feed
- 265 t N (97%)
- 39.3 t P (97%)

Incorporated in biomass
4400 t fish
- 132 t N (48%)
- 18 t P (44%)

Feed loss
138 t feed
- 8.2 t N (3%)
- 1.2 t P (3%)

Particulate organic waste (faeces):
- 18.5 t N (7%)
- 14 t P (35%)

Dissolved waste:
- 116 t N (42%)
- 7 t P (17%)

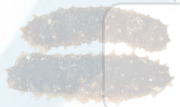
81% of total N waste
33% total P waste

Settable

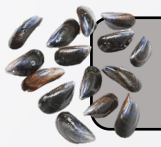
Suspended

Microalgae

Macroalgae



Deposit feeders



Bivalves
Mussels

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- Advantages
  - Better access to fish farm
  - Distance requirements due to disease prevention can be met
- Best location for blue mussels
  - Benthic impact
  - Microalgae availability

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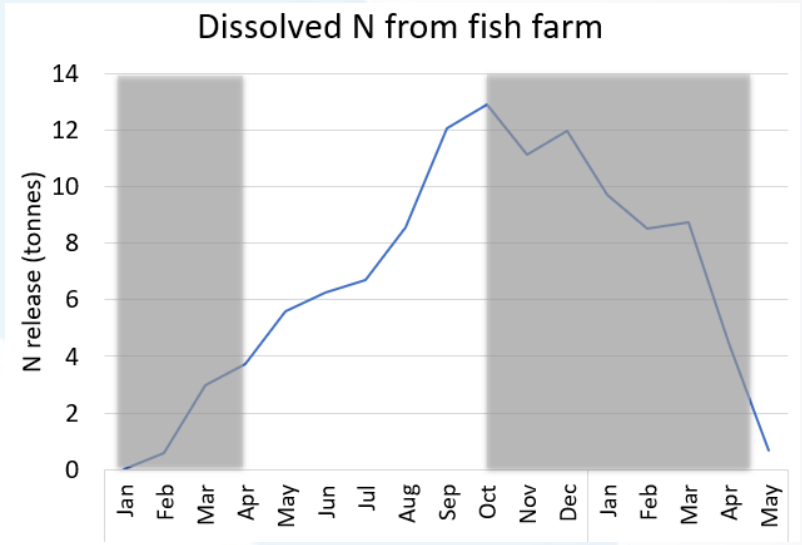

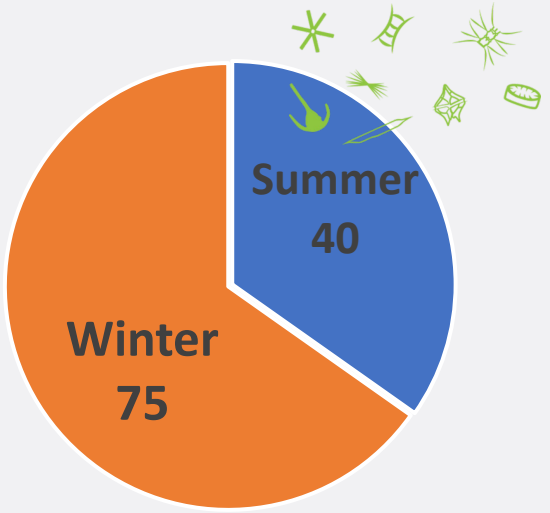

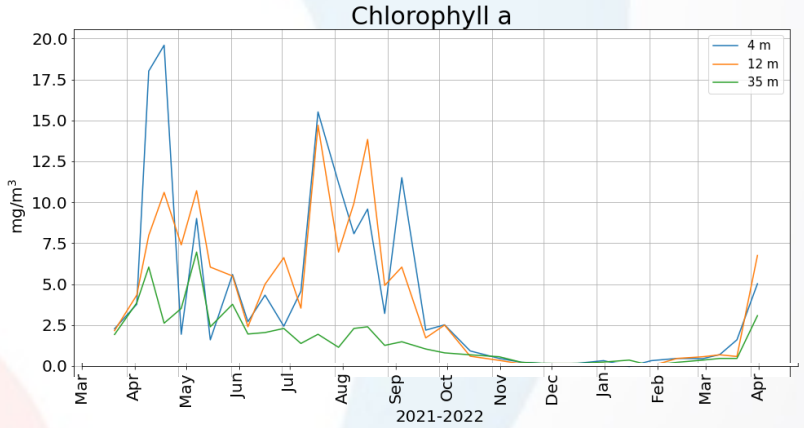

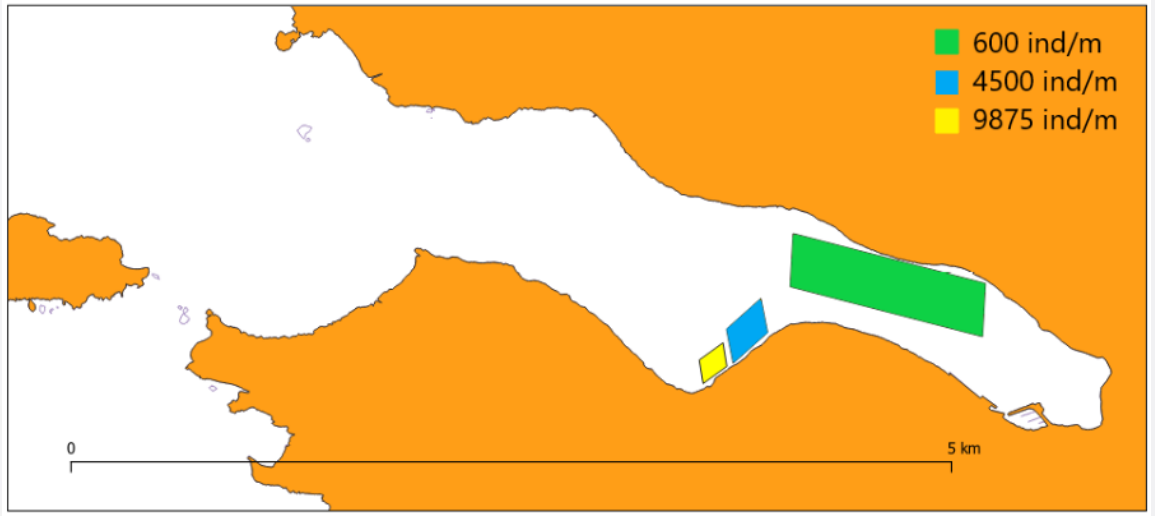

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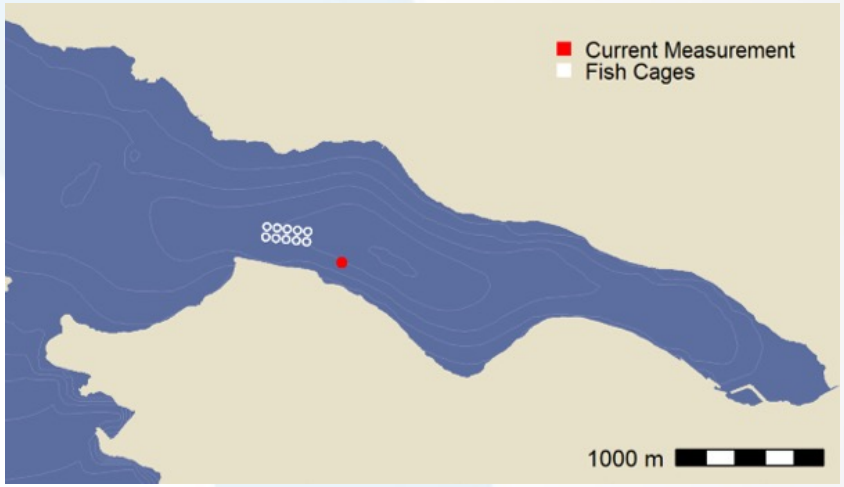
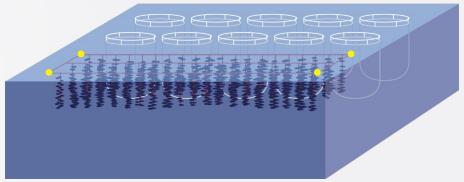
Østerø and á Norði 2022 https://zenodo.org/record/7515449

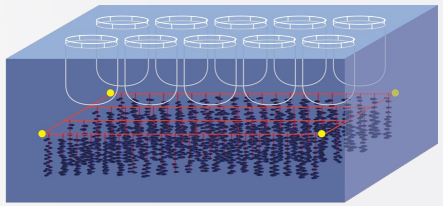
SUREAQUA

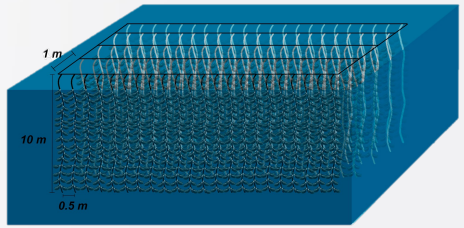
Best practice assessment grounded in the local environment to mitigate the impact from salmon farming by blue mussels



>50% of nitrogen added to a fish farm is lost to the environment as dissolved (>80%) or particulate (<20%)







Waste assimilation

0.4% of PN
<0.0% of TN

14.6% of PN
1.9% of TN

35% of DN
28% of TN

- *Modelling study*: Particulate waste settles too fast for mussels to have a considerable mitigation
- *Best practice*: Target dissolved nutrients incorporated in phytoplankton
  Limitation: season for primary production
- DN released during winter is diluted out of the area and not contributing to the primary production.
  - Spatial need to assimilate equal amounts of nutrients as released during summer dependent on blue mussel settlement rate and farming method

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