SustainAqua:
Sustainable aquaculture in the North – identifying thresholds, indicators and tools for future growth

Picture: Nigel Keeley

The budget

4 year project (Feb 2017 – Jan 2021) Forskningsrådet

Overall budget: 10 MNOK
              8.6 MNOK NFR
              1.4 MNOK HI (Research vessels)

The team

Norway

Nigel Keeley (Project & WP2 leader)
Lars Asplin (WP3 co-leader)
Pia Kupka Hansen (WP4 co-leader)
Olivier Laroche (Postdoc / forsker)
Sonnich Meier
(Raymond Bannister, Former project leader)

Astrid Harendza (WP1 leader)
Reinhold Fieler (WP4 co-leader)
Frank Gaardsted (WP3 co-leader)

Reidulv Bøe
Liv Plassen

International

CAWTHRON INSTITUTE

Xavier Pochon
Susie Wood

Fisheries and Oceans Canada

Dounia Hamoutene
Flora Salvo

The problem

- Aquaculture industry in the North is growing and further expansion is expected

- Increased number of large farms (>3600 MTB)

- Raising concern about environmental impacts

→ Excess feed & faeces, nutrients, therapeutic chemicals

Total number of active licenses (salmon & trout) per year

www.ssb.no

Nordland — Troms — Finnmark
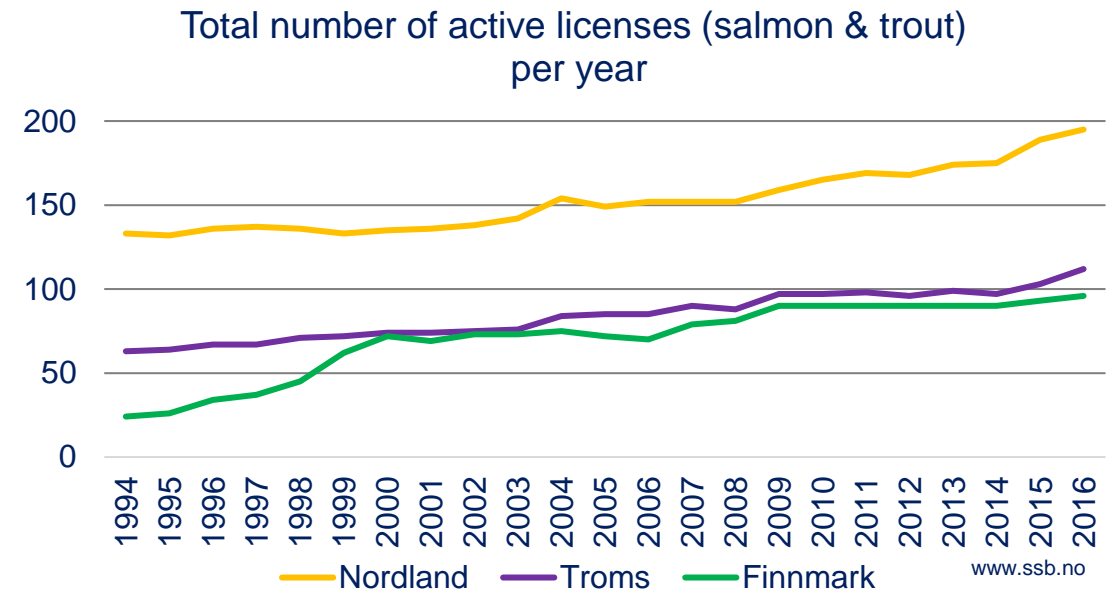
The problem

To allow for a *sustainable growth* of the aquaculture industry…

"The environmental impact of aquaculture must be kept at an exceptable level"

Environmental monitoring in Norway – Standard NS 9410
- Analysis of chemical and biological parameters from sediment and infauna samples

Picture: Raymond Bannister

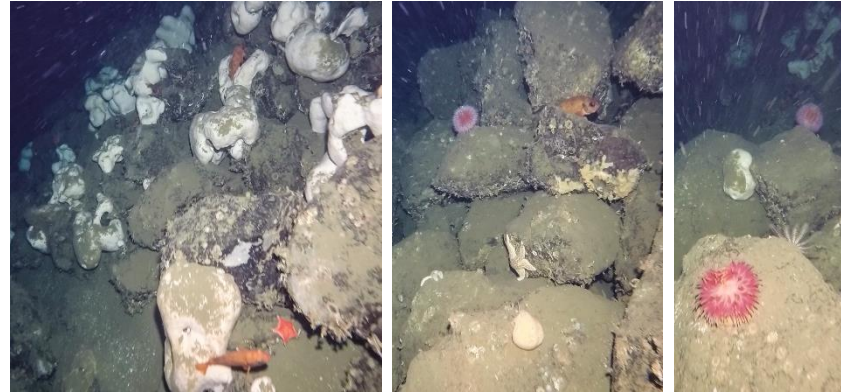Picture: Raymond Bannister

The problem

Favored physically dynamic water bodies are often associated with hard and mixed bottom substrates with diverse epibenthic assemblages
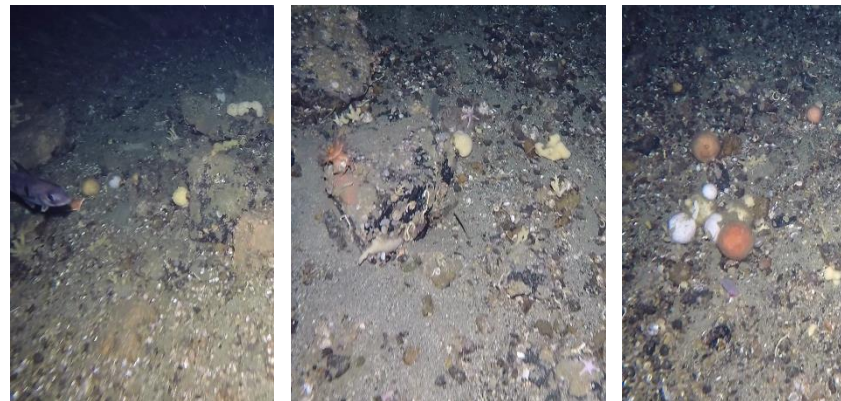
Bedrock

Boulder

Broken rocks, gravel & cobbles on sediment

Gravel & cobbles, medium sand

Coarse sand

What if fauna are not present?

Soft sediment

Rock - diverse

Rock – sparse / bare

Natural
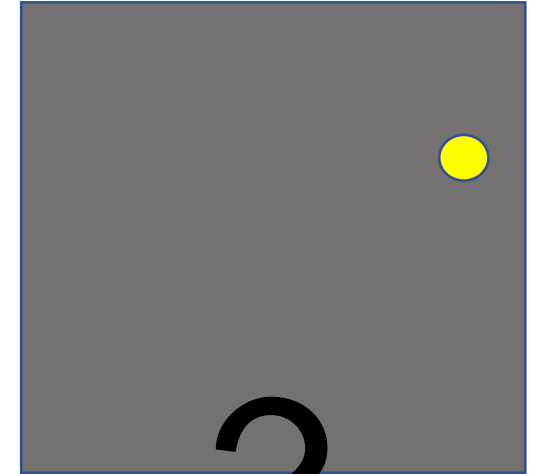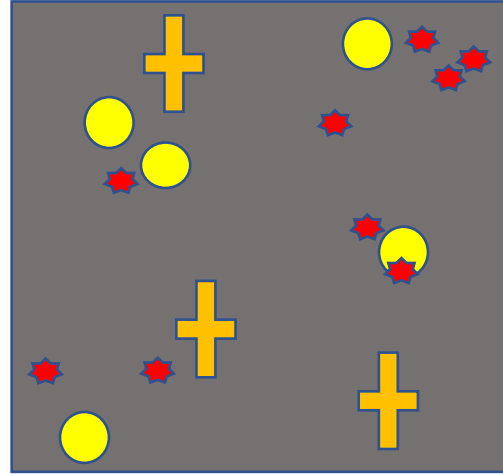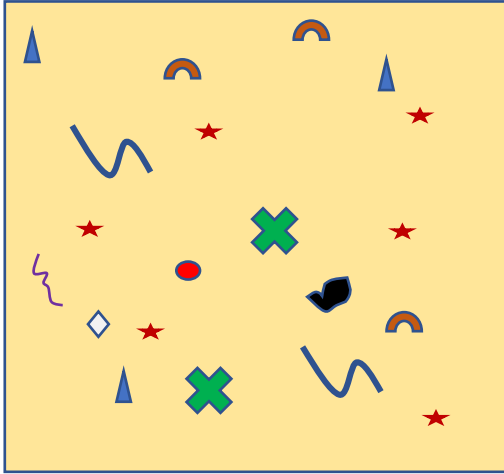
Enriched
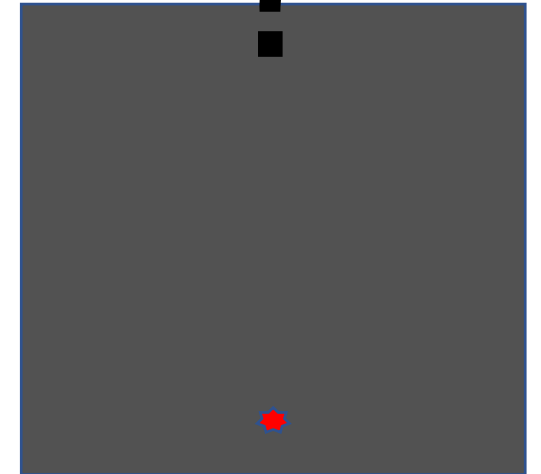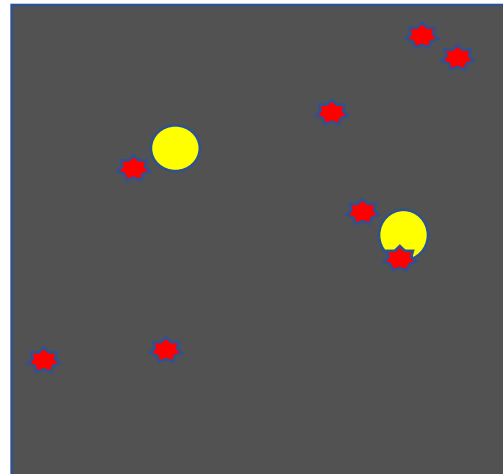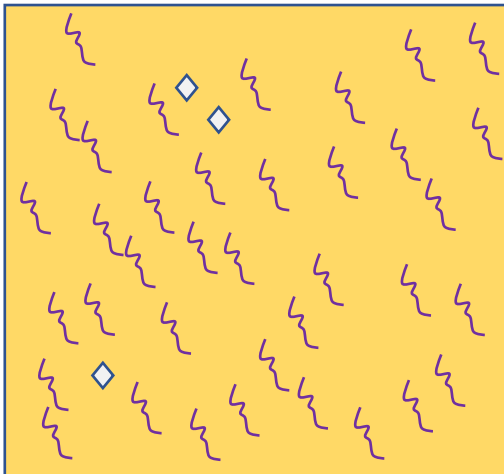
The problems, in short:

1. Lack of knowlegde on effects of organic enrichment on epi-benthic assemblages & no threshold levels or indicators

2. Subtidal hard bottom habitats are difficult to sample (depth, patchiness) - no standardised method

3. Information about subtidal epi-benthic habitats in Northern Norway is very limited

Primary objective of SustainAqua

To understand the relationship between ecosystem change and organic enrichment for hard and mixed bottom ecosystems

Sub-objectives:

→ Identification of potential biological indicators and enrichment threshold values.

→ Provide data input for the development of future monitoring tools

Work packages overview

Baseline data

Validation

Results

WP1
Broad scale video surveys and environmental mapping

WP2
Ecological interactions & potential biological indicators

WP3
Modelling the spatial distribution of particulate organic matter

WP4
Stakeholder engagement

Science, NGO's, regulating authorities, industry

Baseline - species & habitats

*Threshold levels
Indicators
Sampling methods*

Monitoring tool local & regional

Discussion, development, implementation

Development of new monitoring tools for hard & mixed bottom habitats

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Work Package 1

Broad-scale surveys and environmental mapping of salmon farms in Northern Norway

WP leader: Astrid Harendza (APN)

Objective

- Increase knowledge on the structure of hard and mixed bottom habitats and diversity of associated epibenthic assemblages in Northern Norway

- Focus: Under and adjacent to existing aquaculture locations

Work packages overview
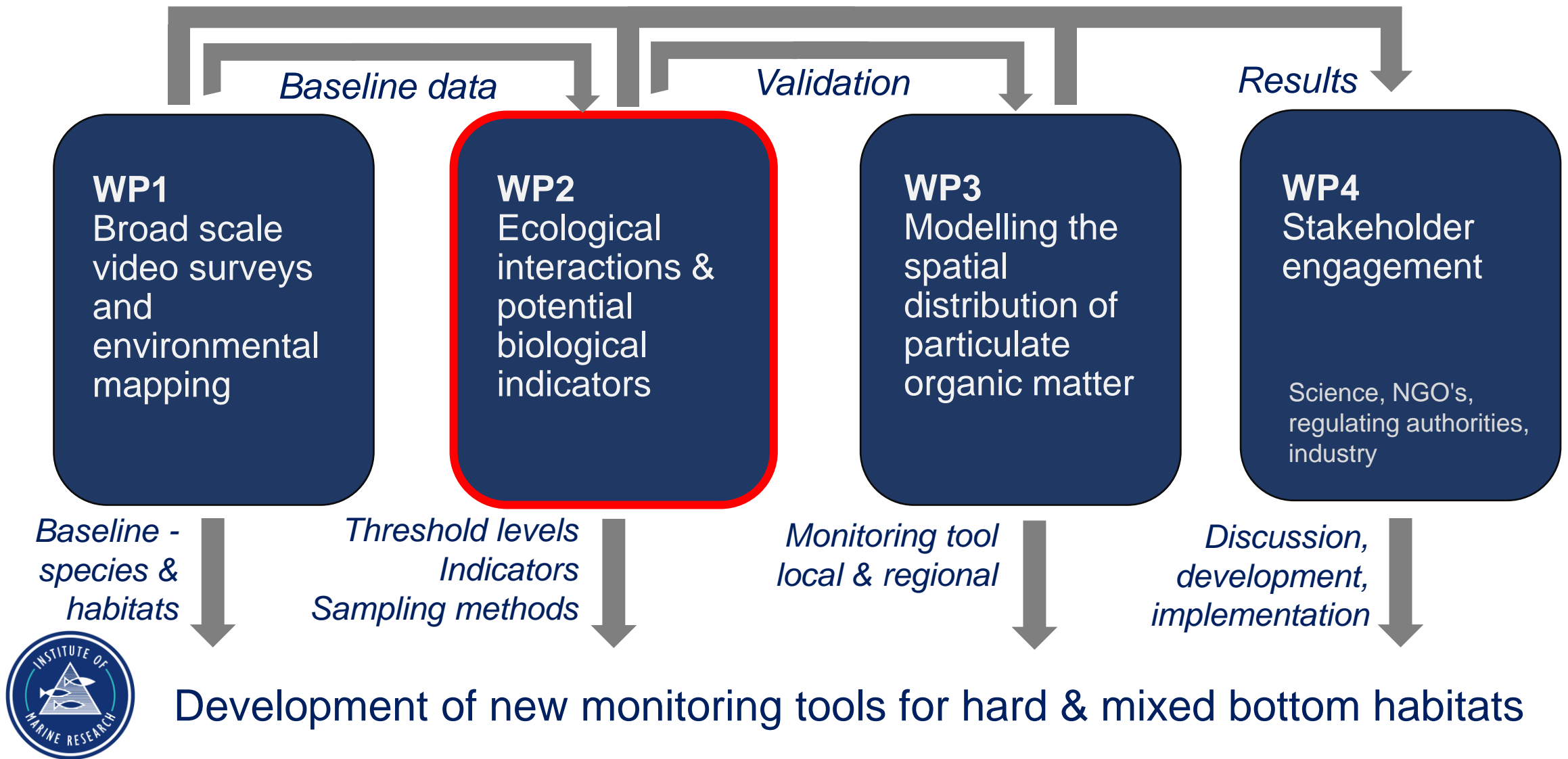

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Baseline - species & habitats

Threshold levels Indicators Sampling methods

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Work Package 2

Ecological interactions of organic effluents from fish farming on hard and mixed bottom habitats and the identification of potential biological indicators
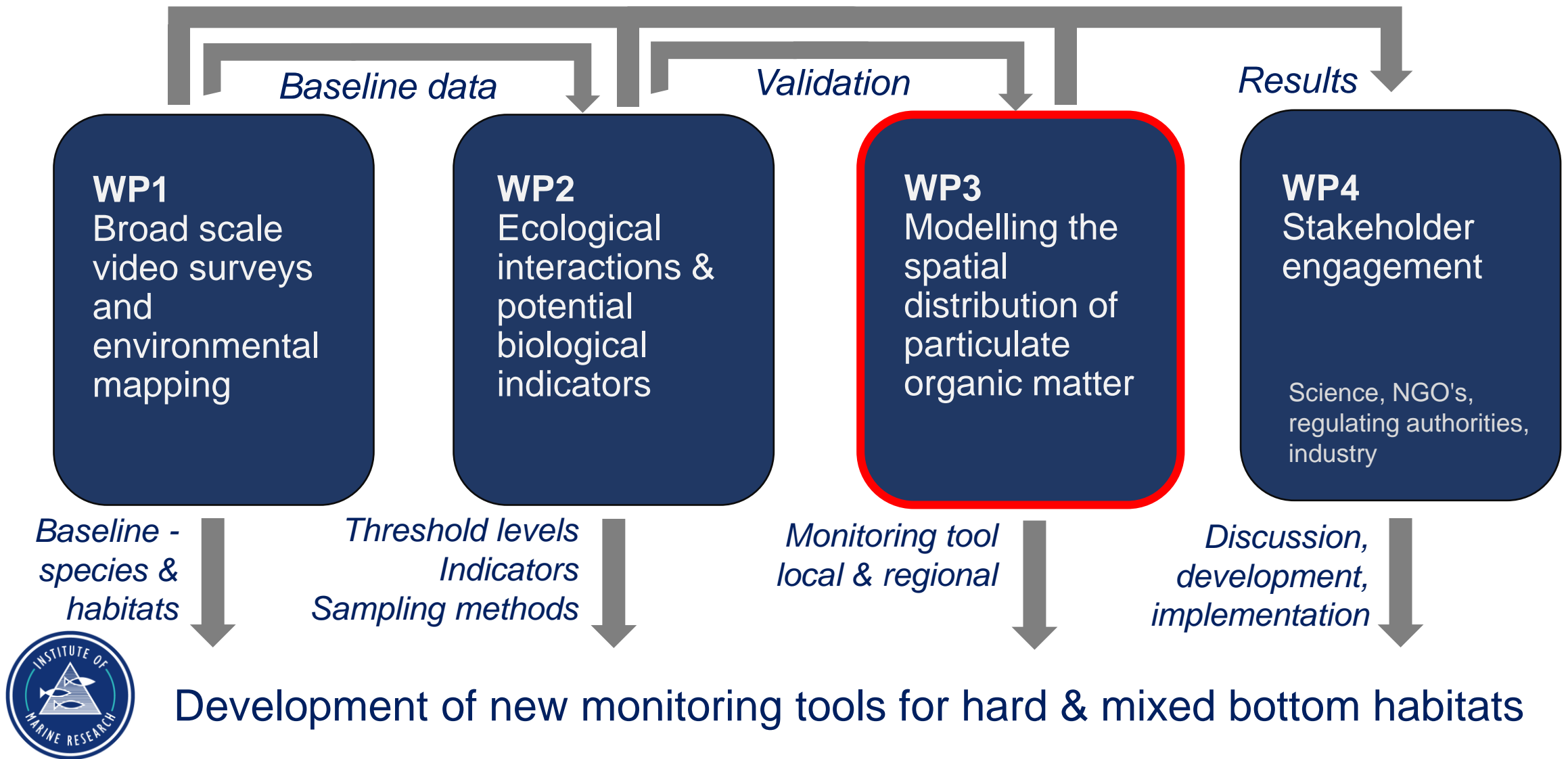
WP leader: Nigel Keeley (IMR)

Objective

- Elucidate interactions of organic enrichment with hard and mixed bottom habitats in Northern Norway

- Identify potential novel biological indicators for these habitats

- Udentify three focus sites

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Work Package 3

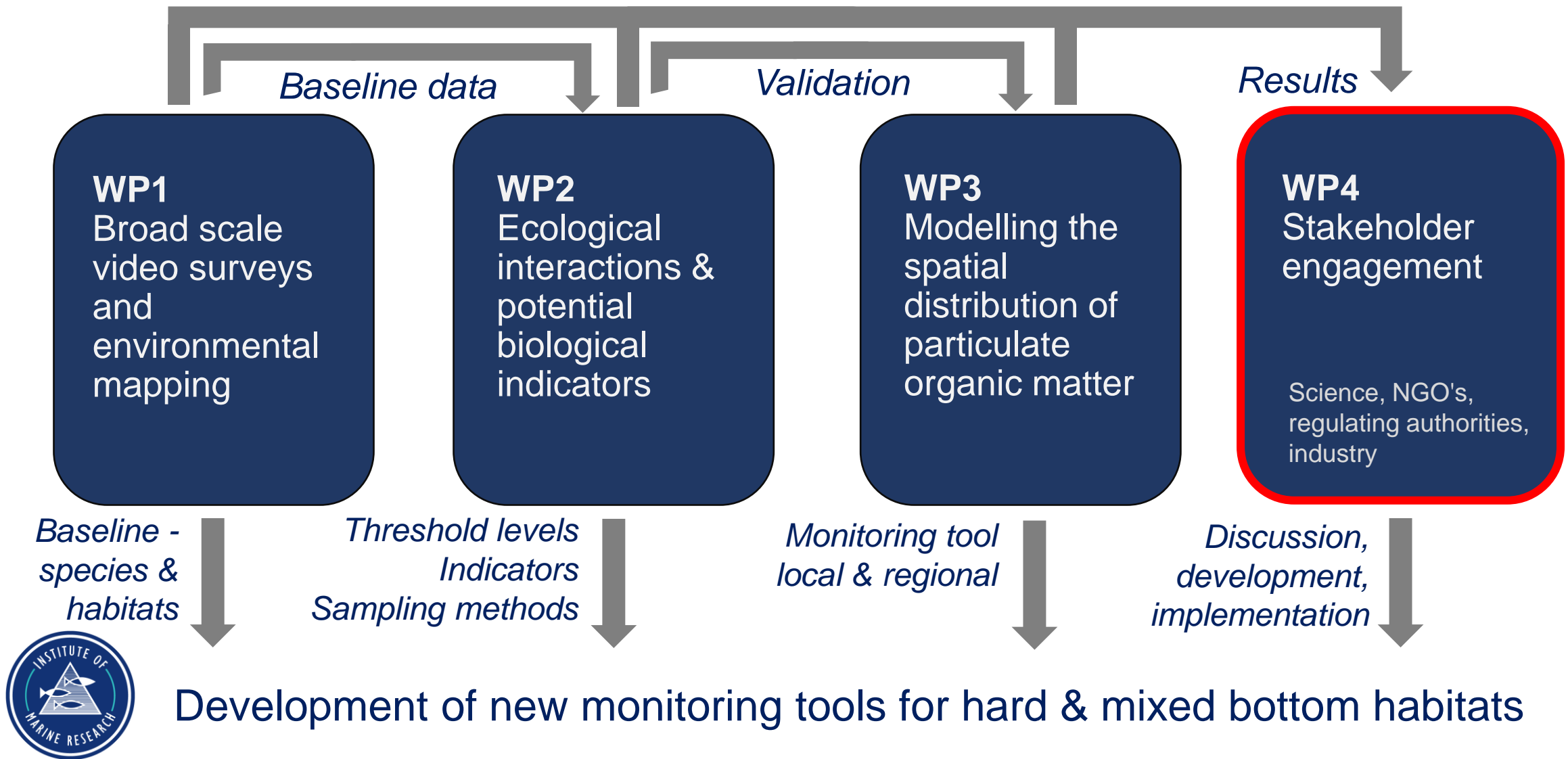*Modelling the spatial distribution of particulate organic matter in a dynamic environment*

WP leader: Frank Gaardsted (APN) and Lars Asplin (IMR)

Objective

- Develop key input parameters (resuspension and decay rates) – lab experiments
- → Improve depositional modelling tools to reliably predict local footprints and regional spatial extent of organic effluents in Norwegian fjord and coastal ecosystems

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Science, NGO's, regulating authorities, industry

Baseline - species & habitats

Threshold levels Indicators Sampling methods

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Work Package 4

Stakeholder engagement

WP leader: Pia Kupka-Hansen (IMR) and Reinhold Fieler (APN)

Objective

- Promote project outcomes to wider scientific community, regulating authorities, aquaculture industry and NGO's – publications, presentations and workshops

- Provide input data for development of suitable environmental monitoring and management tools for hard & mixed bottom habitats within national and potentially international monitoring frameworks

This meeting…

SustainAqua results dissemination. 22-23 October 2020

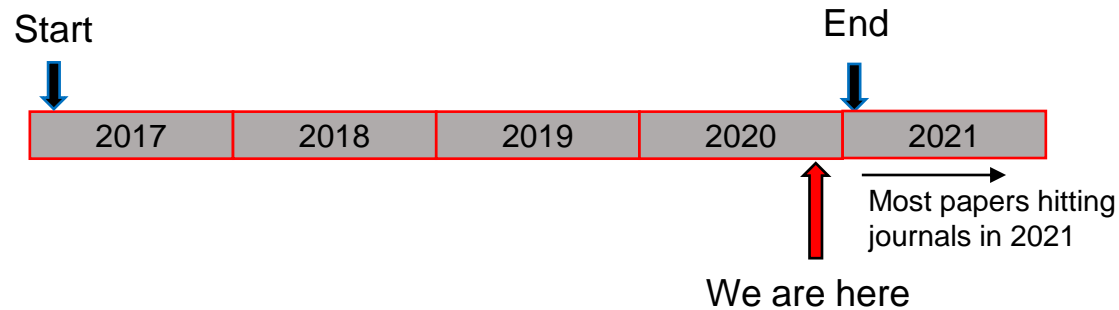|		DAY 1 (22 October)	
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		Questions	
	1530	**DAY 1 ENDS**	

This meeting…

Day 2

Stage	Time	Topic	Presenter
DAY 2 (23 October)			
Session 1	09:00	Welcome and technical information	Reinhold Fieler
		Introduction	Pia K. Hansen
	09:10	Setting the scene	
		Summary of results from research in SustainAqua, part I	
		(e.g. Epifauna in the North; Visual indicators)	Nigel Keeley,
		Questions	Kathy Dunlop,
	10:00	**COFFEE BREAK**	Astrid Harendza,
Session 2	10:10	Summary of results from research in SustainAqua, part II	Lars Asplin,
		(e.g. New bioindicators; Stress indicators; Modelling)	Pia K. Hansen
		Questions	
	11:30	Approach for hard bottom monitoring around fish farms	
		(equivalent of C-investigation)	
		Practical approach for hard bottom monitoring now	
		Approach for hard bottom monitoring in the future	
		Questions, comments & future challenges	
	12:00	**DAY 2 ENDS**	

This meeting…

Start   End

| 2017 | 2018 | 2019 | 2020 | 2021 |

We are here

Most papers hitting journals in 2021

This is still a work in progress…

https://www.hi.no/hi/forskning/prosjeker/sustain-aqua

Manuscript pipeline

1. Carvajalino-Fernández MA, Sævik PN, Johnsen IA, Albretsen J, Keeley NB. 2020. Simulating particle organic matter dispersal beneath Atlantic salmon fish farms using different resuspension approaches. MPB 161, 111685.

2. "Epifaunal habitat associations of sessile epifauna on mixed and hard bottom substrates in northern Norwegian fjords" (Dunlop et al. Accepted Oct 2020)

3. "Beyond taxonomy: Validating functional inference approaches based on eDNA metabarcoding data in the context of fish-farm impact assessments" (Laroche et al. In Review)

4. "Sustainable Aquaculture in the North; Spatial response of hard bottom epifauna in relation to enrichment from salmon aquaculture in northern Norway" (Dunlop et al. Ready for submission)

5. "Substrate Independent Benthic Sampler (SIBS) for hard & mixed-bottom habitats: a proof of concept study" (Keeley et al. Ready for submission)

6. "Effects of fish farm activities on sessile benthic taxa and their associated microbiota: A case study with Polymastia spp." (Laroche et al. In Prep: 95% complete)

7. "Benthic species' microbiomes and their response to fish farm activities and associated environmental changes." (Laroche et al. In Prep: 80% complete)

8. "Bioindicators of benthic health: What functional and genetic profiles tell us that community structure doesn't." (Laroche et al. 60% complete)

9. "Breakdown rates and microbial inoculation of natural sediments by salmon feces: an inconvenient truth for waste dispersal modellers" (Keeley et al. In Prep, Study complete)

10. "Specificity of main-stream biodepositional models and review of procedures and parameters for modelling waste dispersion" (In Prep. TBA)

Session 1: Characterising epifauna in the north (WP2)

SustainAqua results dissemination. 22-23 October 2020

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		Questions	
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Session 2: Stress indicators in epifauna –
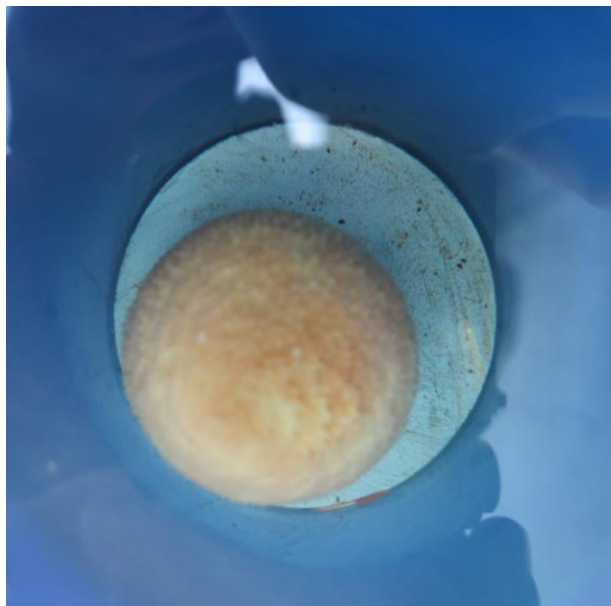## Introducing the fauna translocation study (WP2)

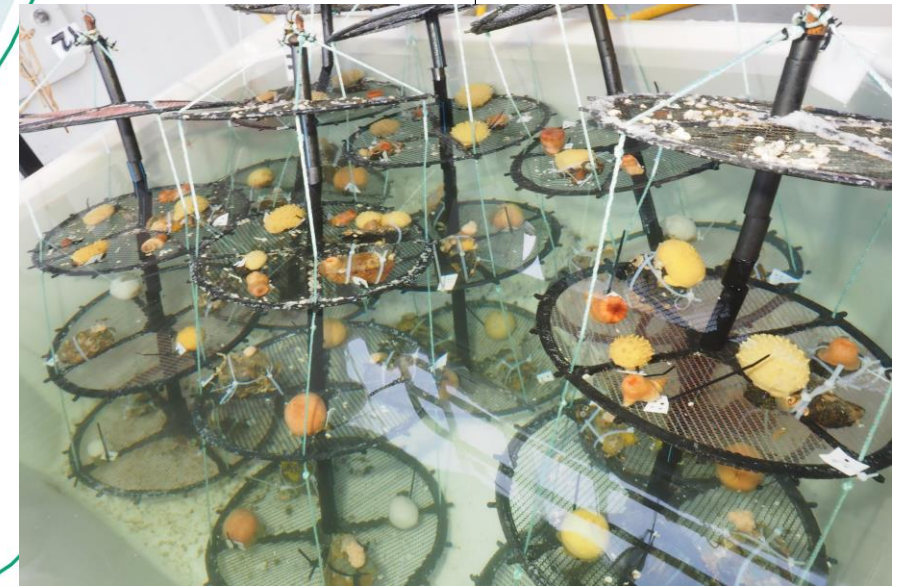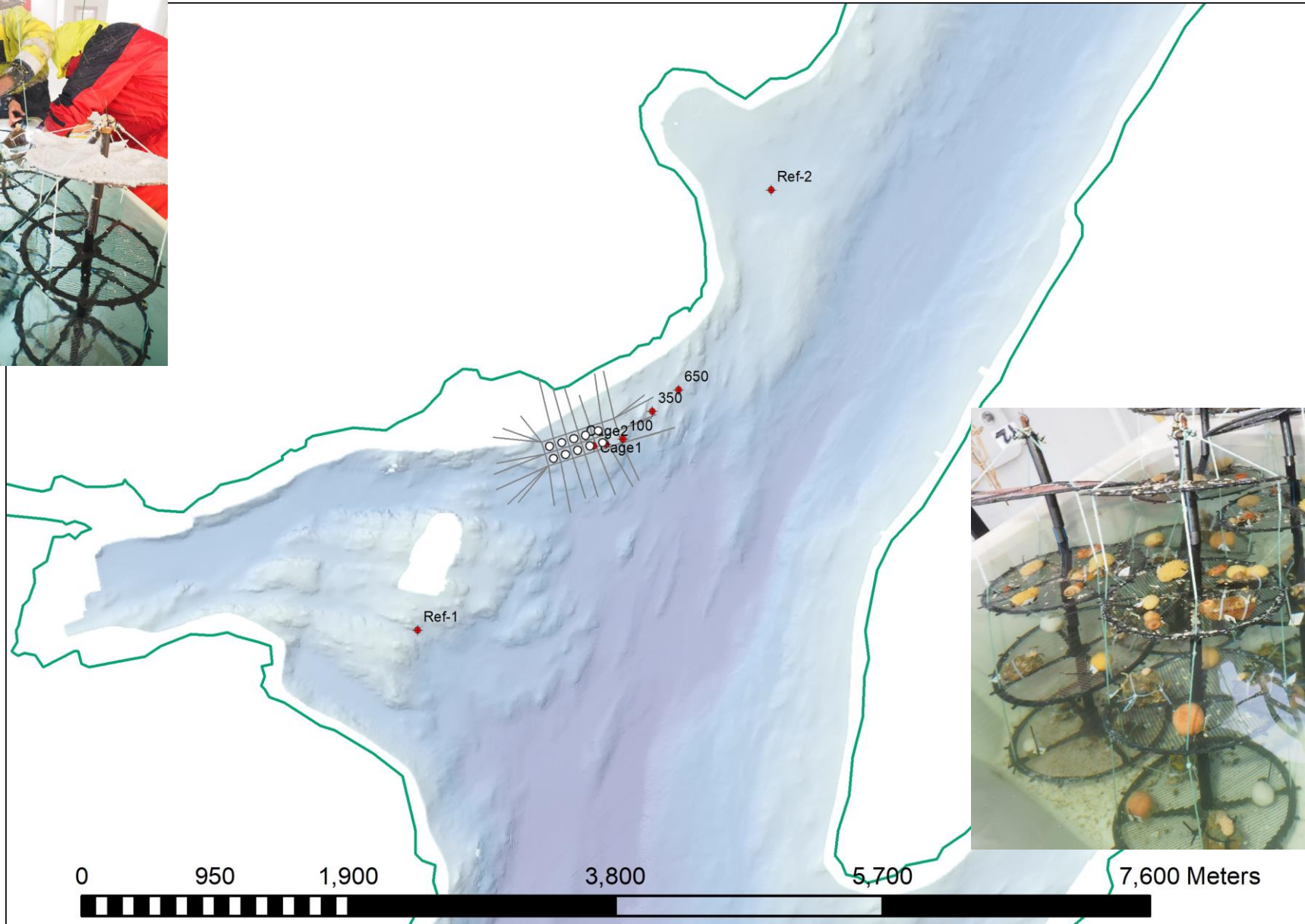# On 'the hit list'

Polymastia sp.

Craniella sp. (cranium)

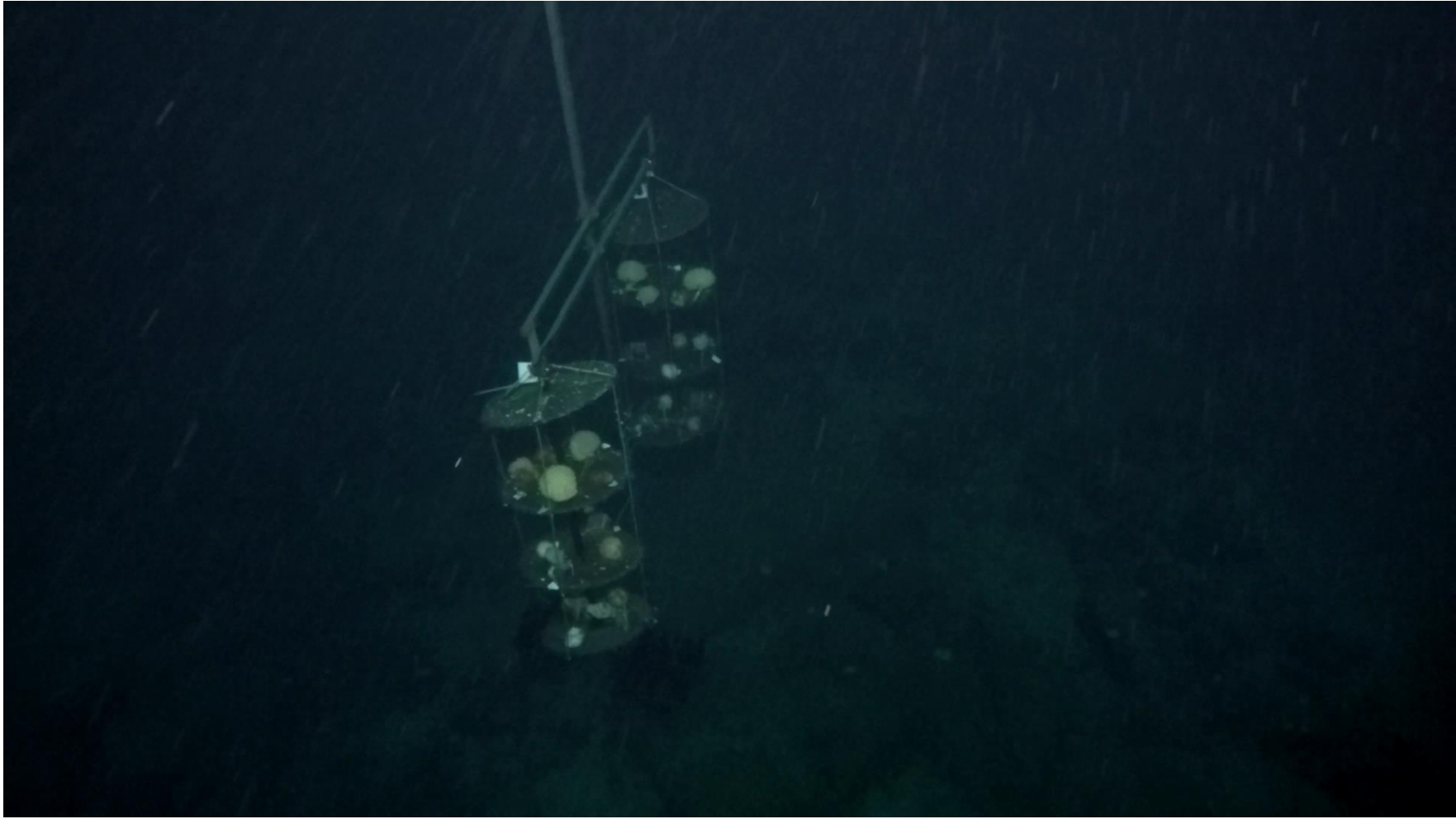*Hormathia digitata*

Drifa florida

650

350

Cage2 100

Cage1

Ref-2

Ref-1
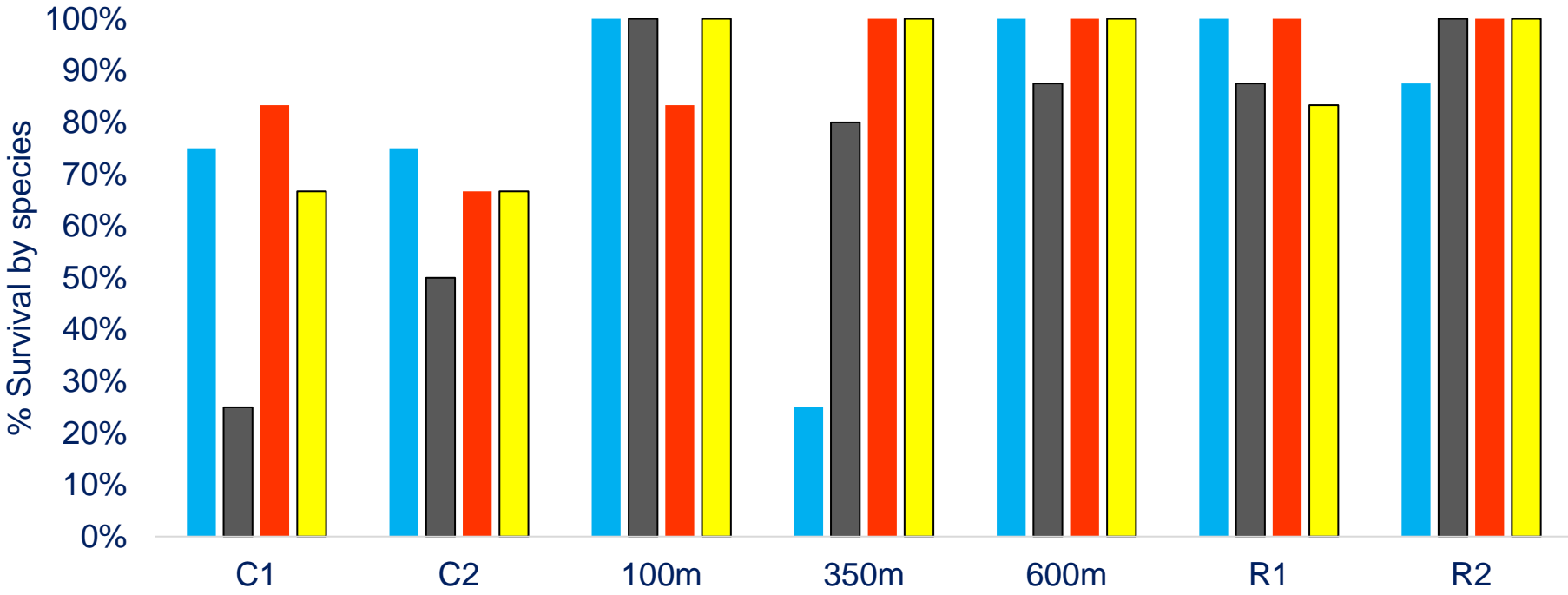
0   950   1,900   3,800   5,700   7,600 Meters

Post translocation analyses:

- Mortality rates

- Respiration rates

- Fauna sequencing – what species were they?

- Microbiome and gene expression

- Soft tissue fatty acid composition (feed signatures)

- Soft tissue stable isotope signatures

Basic survival / mortality (incl 'lost'…)

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Session 3: Advances in hard-bottom monitoring techniques (WP2)

Quantitative visual assessments

Microbial eDNA in surface flocs
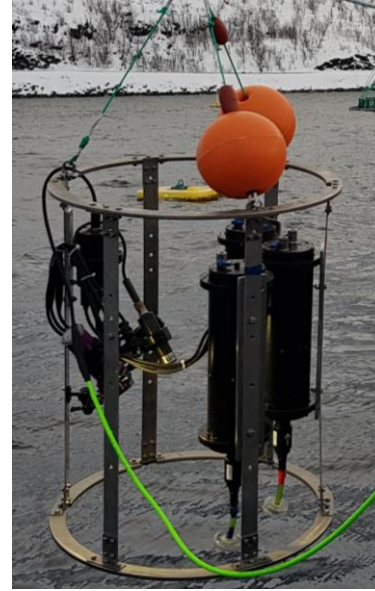
Using functional inference instead of ASV's (bioinformatics approach)

(Not strictly hard-bottom, but has applications for all microbial eDNA samples)

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Session 4: Advances in particle dispersion modelling (WP3)
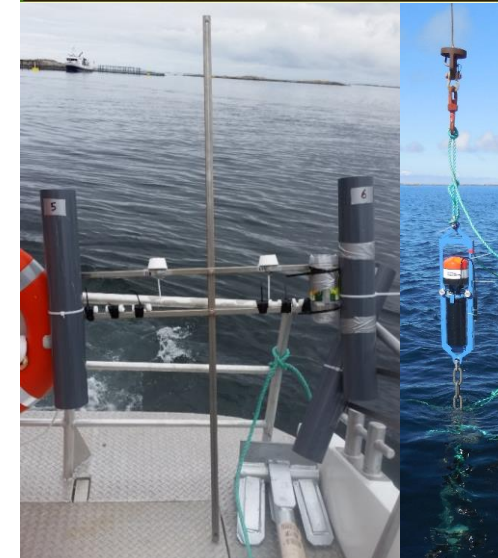

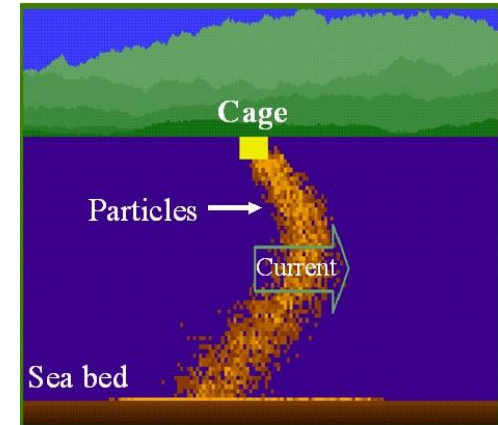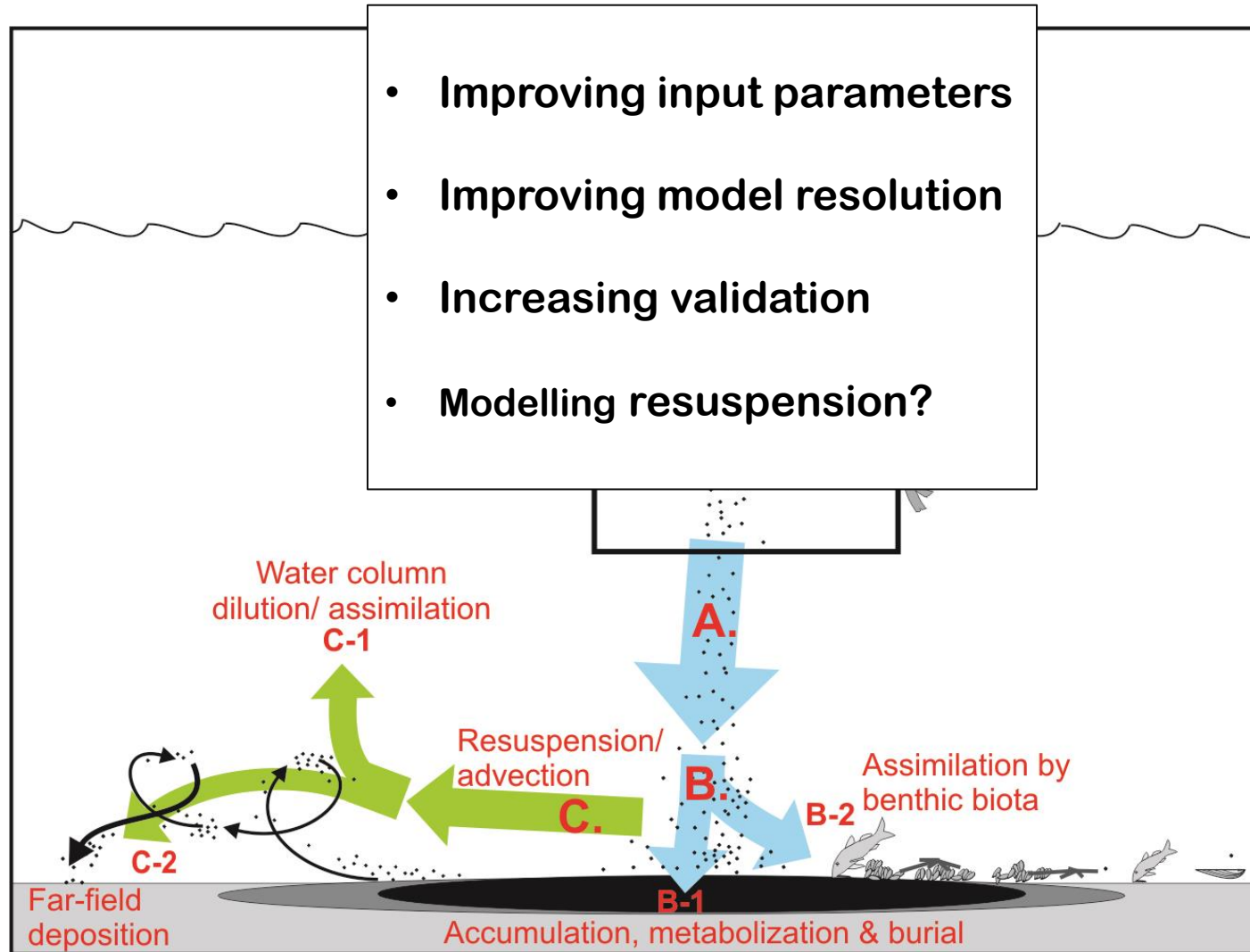
Low flow:

A = B1 + B2,

C ≈ Zero

High flow:

2xA = B2 + C1 + C2,

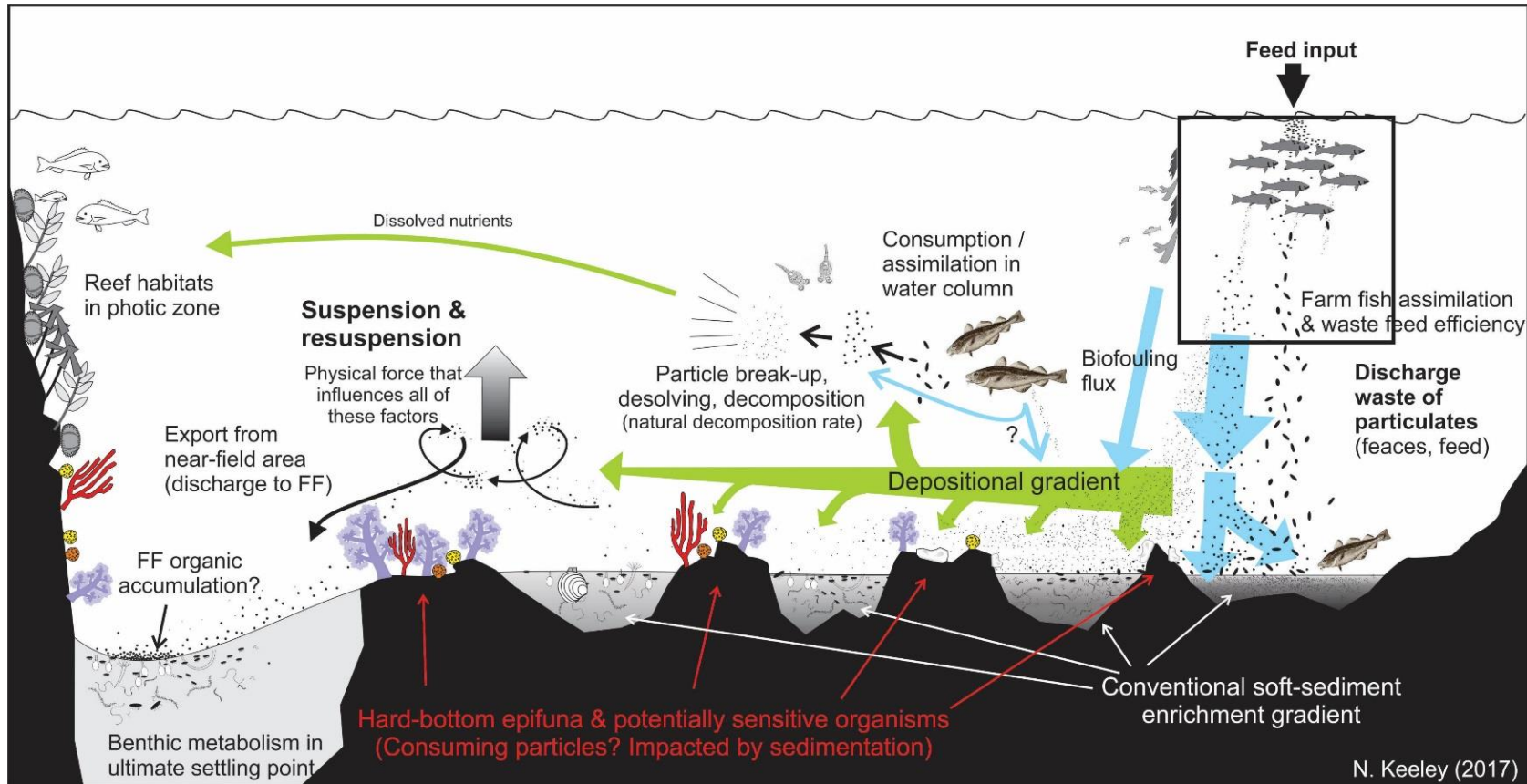B1 minimal,

C:B undetermined

C1:C2?

- Improving input parameters

- Improving model resolution

- Increasing validation

- Modelling resuspension?

Water column dilution/ assimilation
C-1

A.

Resuspension/ advection

B.

Assimilation by benthic biota

C.

B-2

Far-field deposition

C-2

B-1

Accumulation, metabolization & burial

What happens when the substrate is rock or 3-dimensionally complex?

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	1345	**COFFEE BREAK**	
Session 4	1400	**Advances in particle dispersion modelling** – Intro	
	1405	*Update on modelling system using NorKyst800, NorFjords with ROMS and LADIM.*	Lars Asplin (HI)
	1420	*Advances in modelling particle dispersion modelling including approaches for resuspension and substrate specificity.*	Marcos Fernandez (HI ())
	1445	*Modelling of hard-bottom sites using FVCOM and tracer approach* *Questions*	Frank Gaardsted (APN)
	1515	*Salmon feces decay & microbial pathway study – explanation and preliminary results.* Questions	Nigel Keeley /Kathy Dunlop (HI)
	1530	**DAY 1 ENDS**	

Picture: Nigel Keeley