Present and future environmental impacts of hydropower on Norwegian lakes

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Outline

- Aim of WP4 HydroBalance
- Biotic effects
  - Framework and study approach
  - Results
- Abiotic effects
  - Framework and study approach
- Expected final outcome

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WP4: Environmental impacts of new operational regimes

Task 4.1

Modelling ecological consequences along environmental gradients

→ Biotic effects (todays situation)

Task 4.2

Modelling hydro-dynamic changes introduced by new operational regimes.

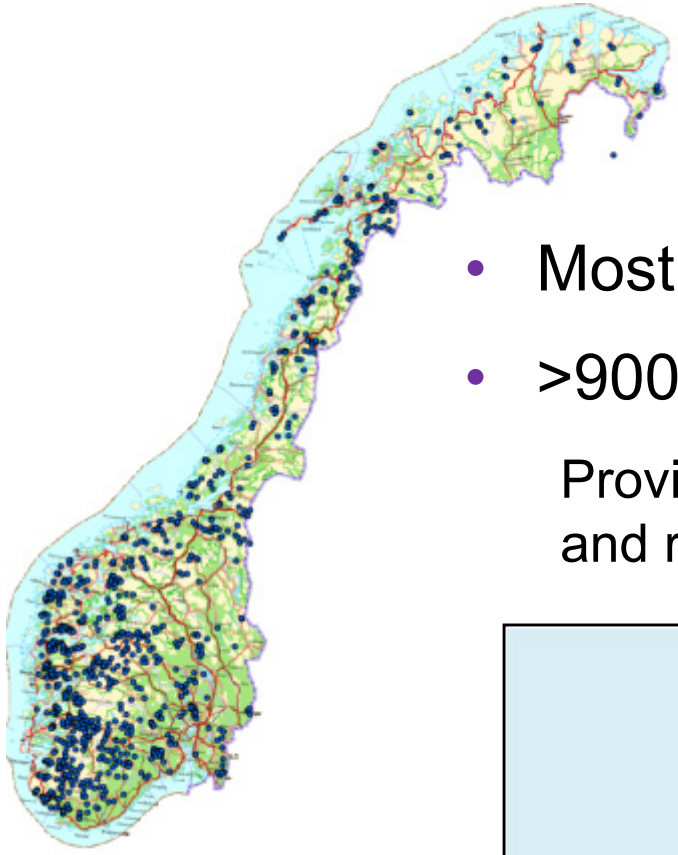
→ Abiotic effects (future operations)

Task 4.3

Mitigating ecological effects of new operational regimes

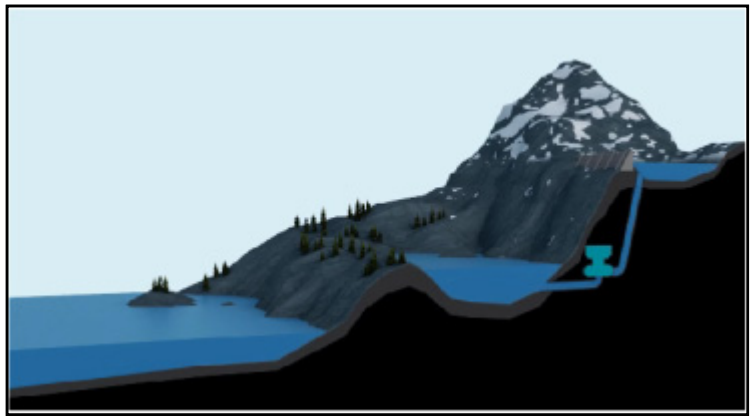
→ Combined model

WP4 focuses on reservoirs

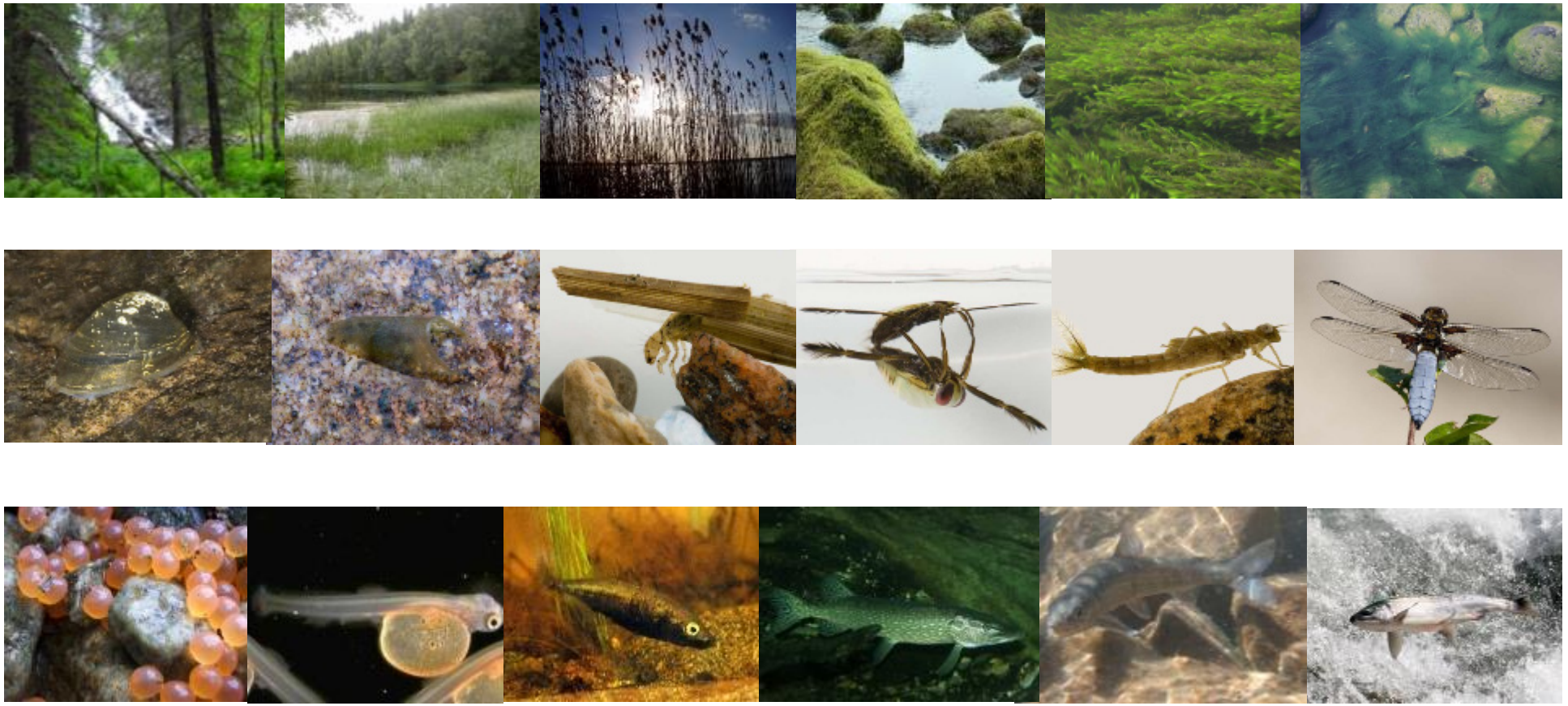


- Most studies done in rivers
- >900 reservoirs in Norway

  Provide important ecological services and recreational areas

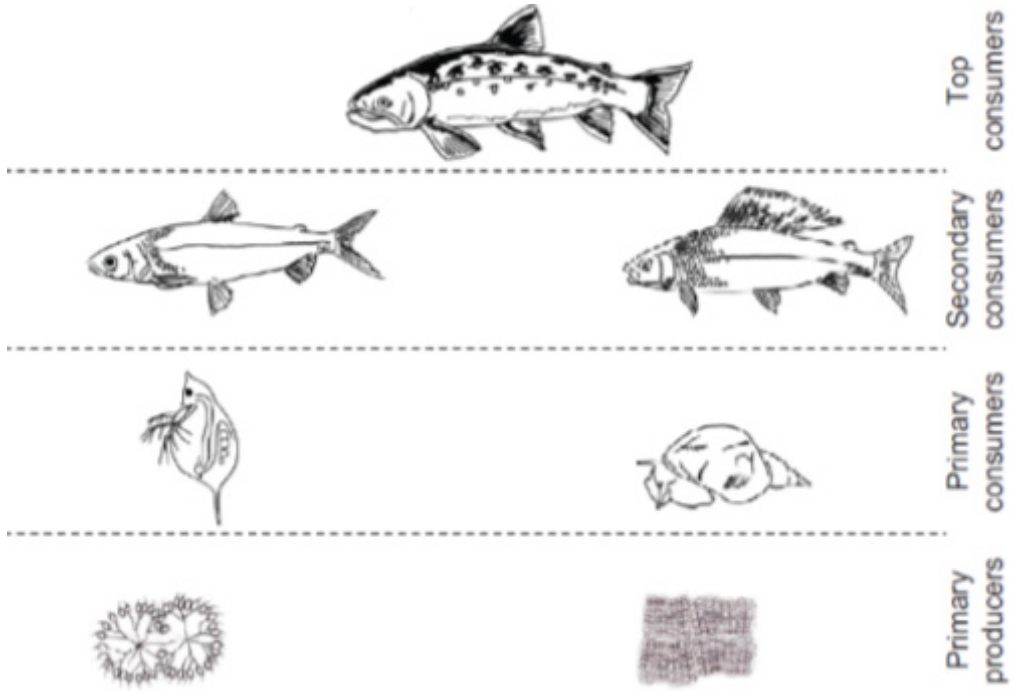


Biotic effects



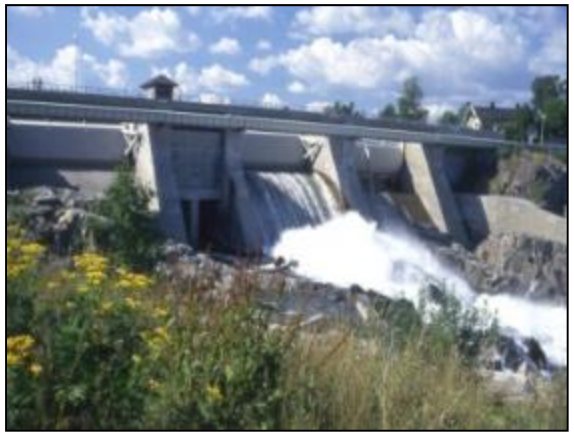
Focus on fish

Fish as top consumer – Bioindicator of ecosystem health



Focus on present...

… before future



Ecological consequences of todays pattern

+

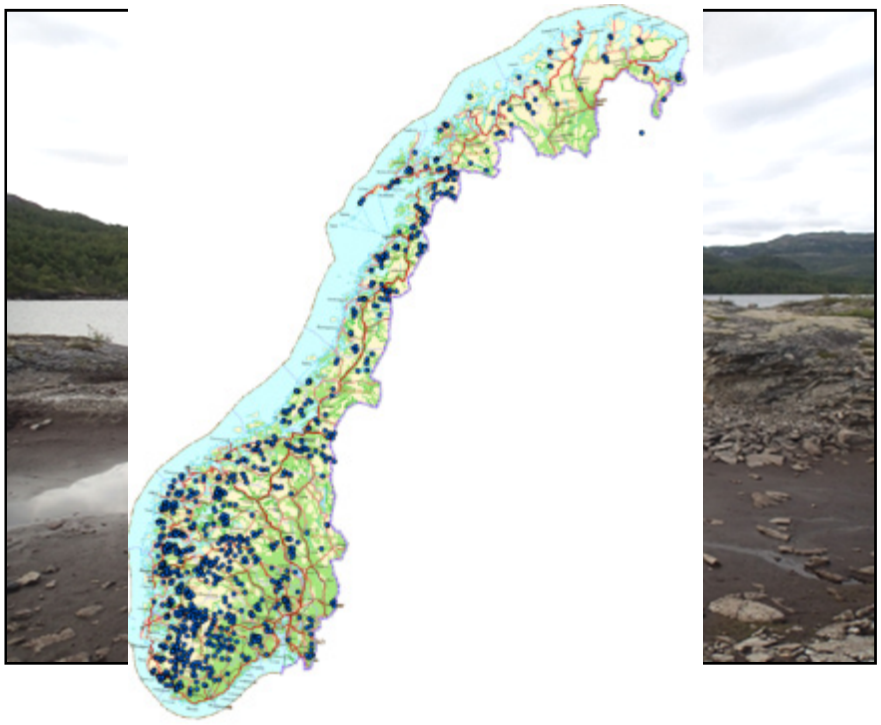
Hydro-dynamic changes introduced by new operational regimes

→ Predict ecological effects of future regime

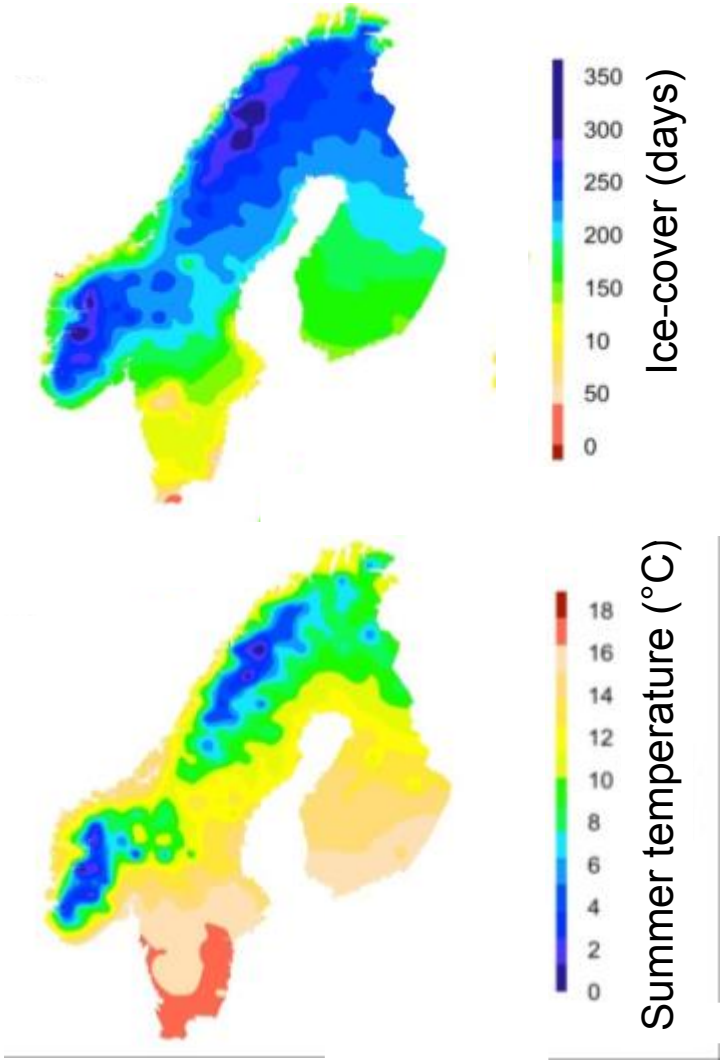
→ Mitigate ecological effects in future

Potential impacts of rapid water level fluctuations in reservoirs

- Abiotic changes
  - Lake shoreline, water quality, temperature, ice-cover period
- Biotic changes
  - Biological productivity, species composition, fish diet, growth and production



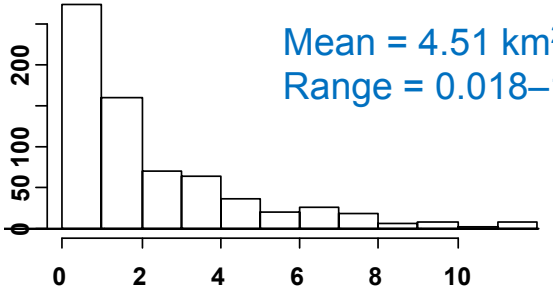
Natural variation in climate



Natural variation in catchment

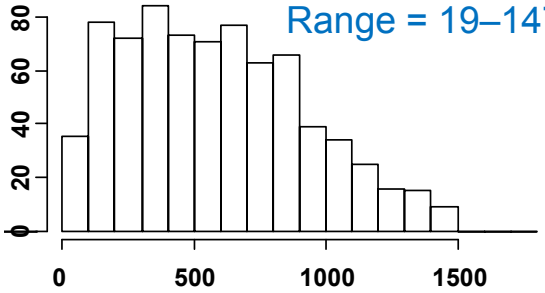
Natural variation morphology

Area



Mean = 4.51 km^2
Range = 0.018–122 km^2

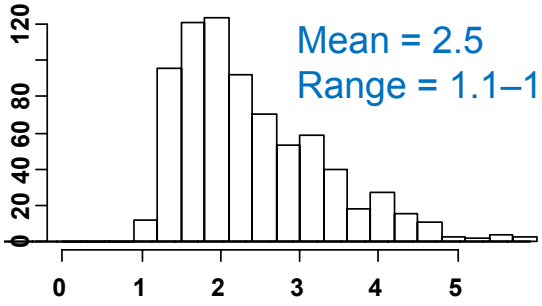
Altitude



Mean = 584 m a.s.l.
Range = 19–1477 m a.s.l.

Shape

$$Shape = \frac{L}{2\sqrt{\pi A}}$$



Mean = 2.5
Range = 1.1–10.5

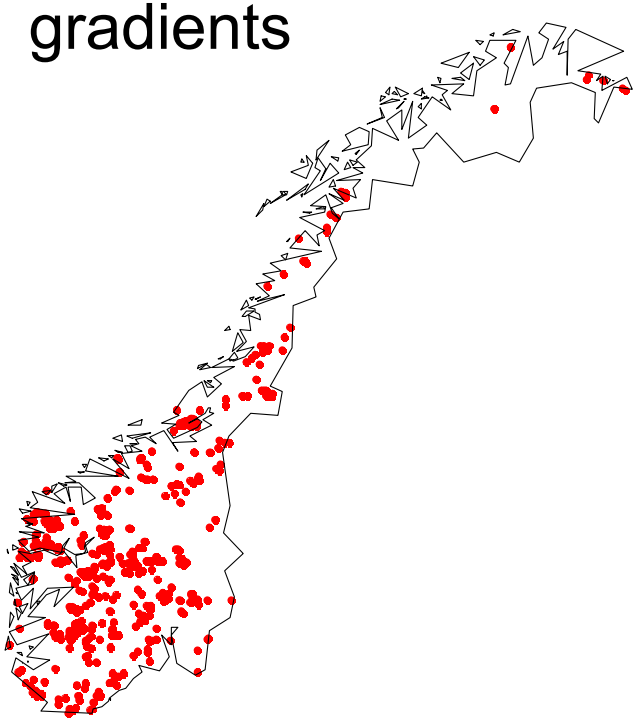
Natural variation in fish growth

How to separate effects of hydropower from natural variation?

Data collection

Large datasets of previously collected data:

- Compare high numbers of lakes and reservoirs
- Understand large-scale patterns across environmental gradients



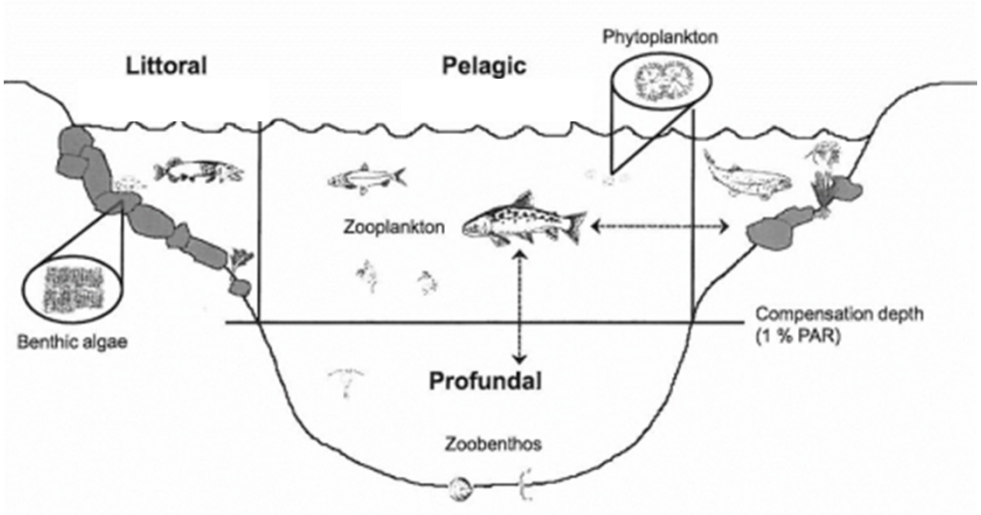
New field work:

- Details of individual fish
- Understand local ecosystems

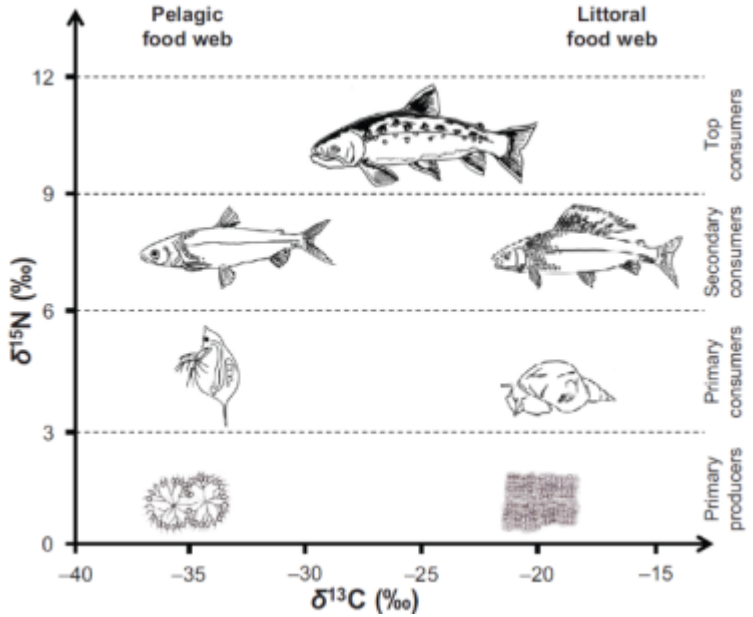
Fish population data

- Abundanc, growth, reproduction, diet
- Understand the structure and function of ecosystems
  - Stable isotope analyses

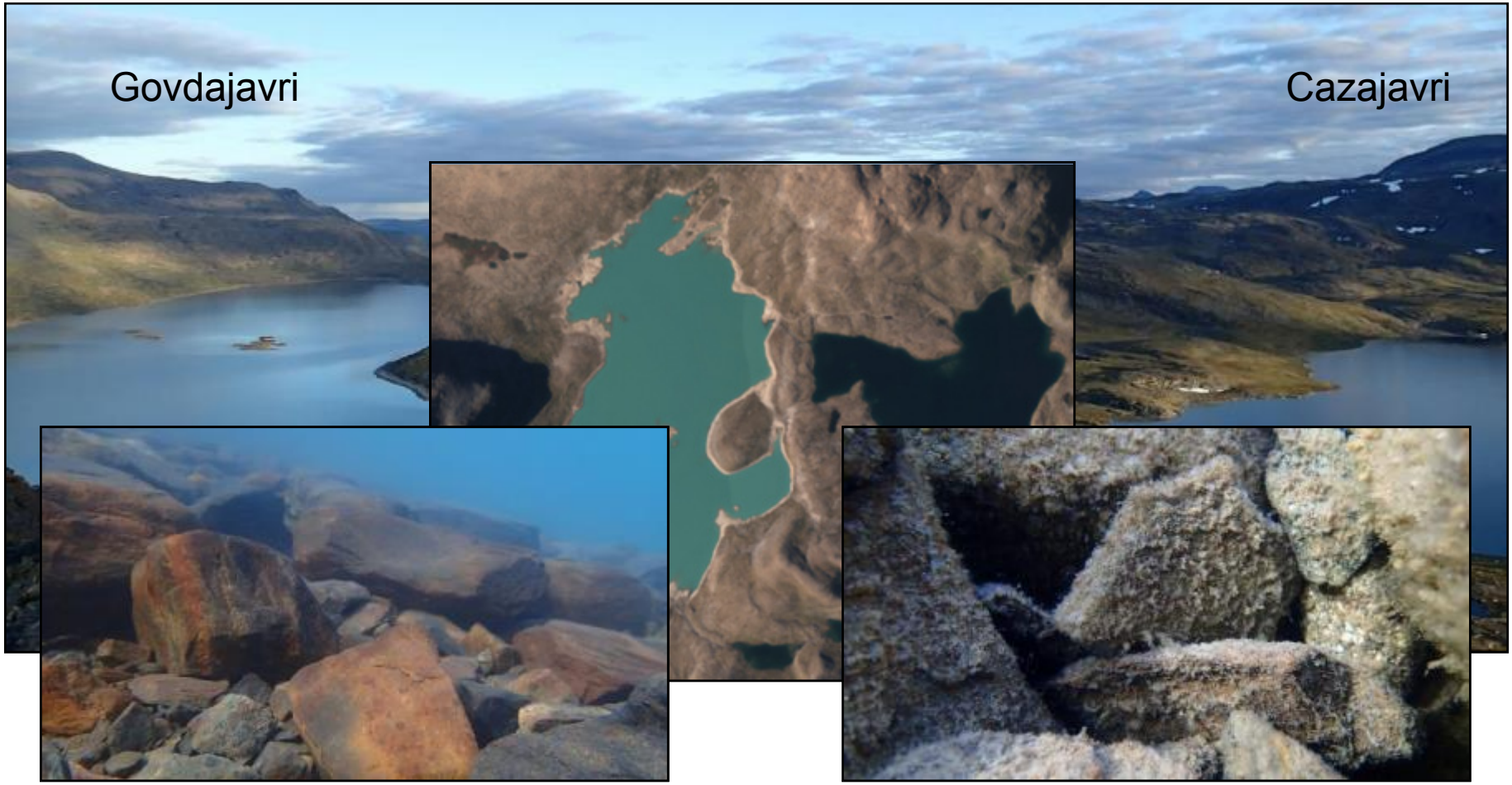
Habitat use



Food webs



Results part I:
A two-lake comparison

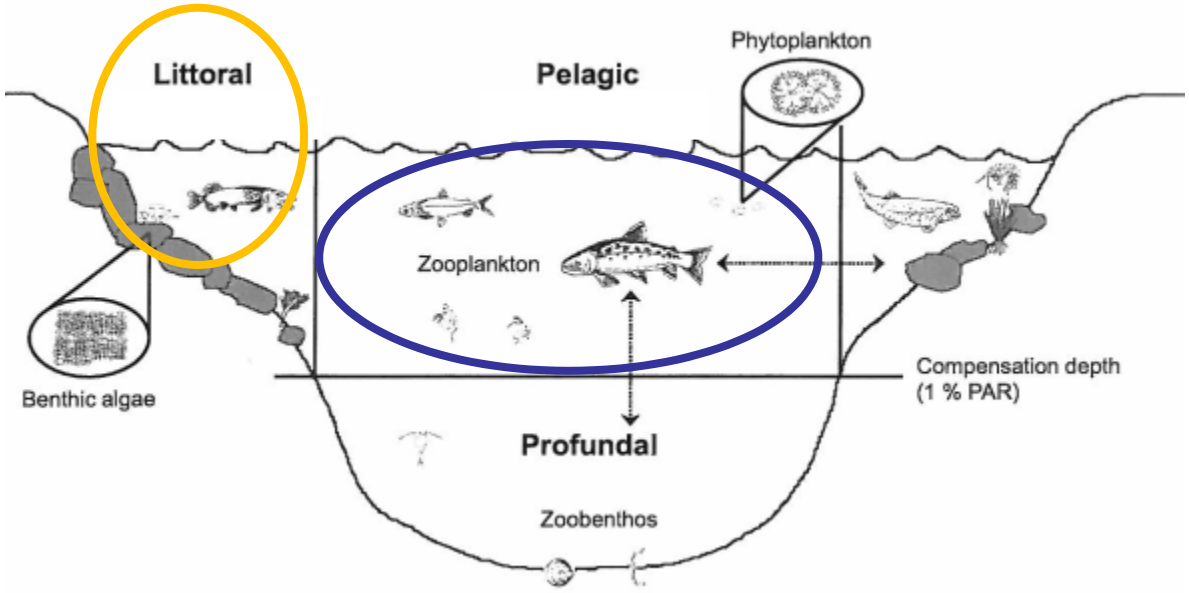


Similar natural conditions

Parameter	Cazajavri	Govdajavri
Annual regulation amplitude (m)	0	24
Altitude (m a.s.l.)	723	708
Surface area (km^2)	1.88	4.02 / 1.10
Maximum depth (m)	60	45
Shoreline length (km)	7.67	12.13
Secchi depth (m)	13	4
Colour	2	<1
Turbidity	0.32	0.47
TOC (mg l^{-1})	0.7	0.8
pH	7.0	6.9
Total phosphorus (µg l^{-1})	<2.0	<2.0
Total nitrogen (µg l^{-1})	92	86
Chlorophyll-a (µg l^{-1})	<0.7	<0.7

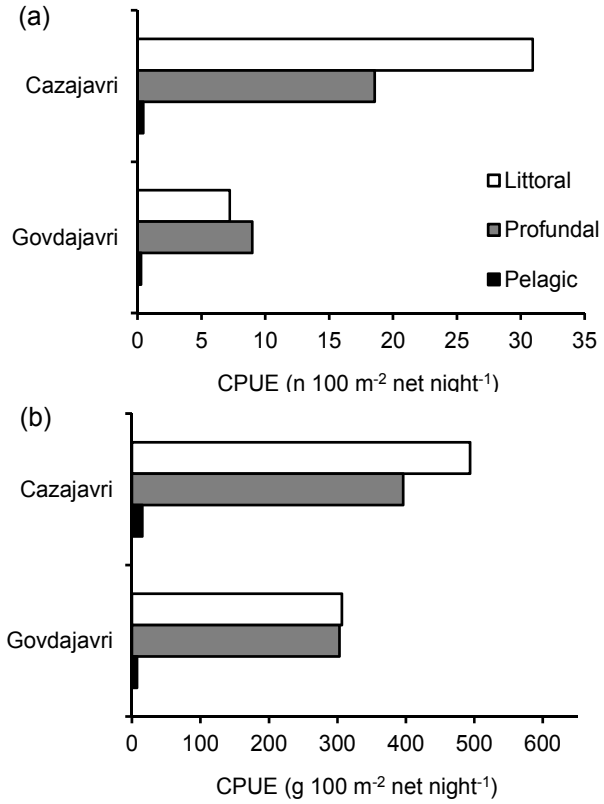
Expected main ecological effects

- The impact depends on how much of the biological productive areas are influenced i.e. Littoral zone and pelagic zone
- Expect charr to shift from littoral to pelagic food

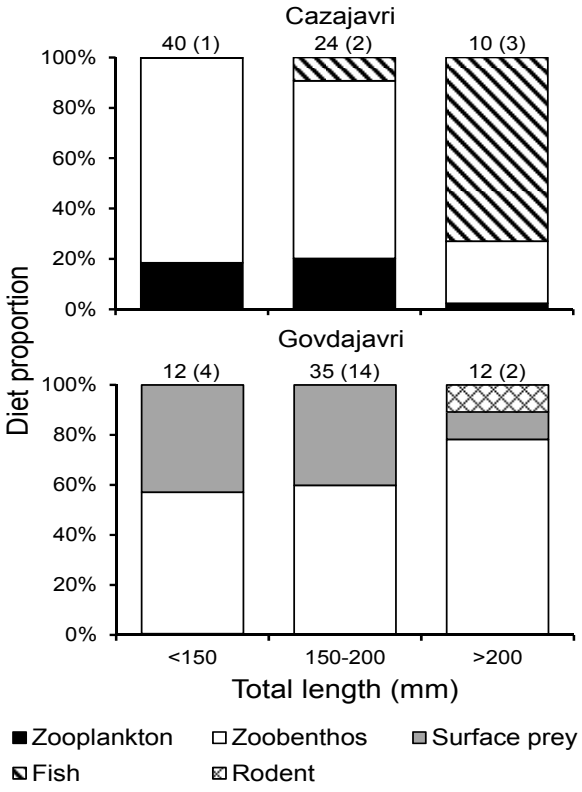


Hypothesis confirmed: Reduced use of littoral zone

Charr abundance

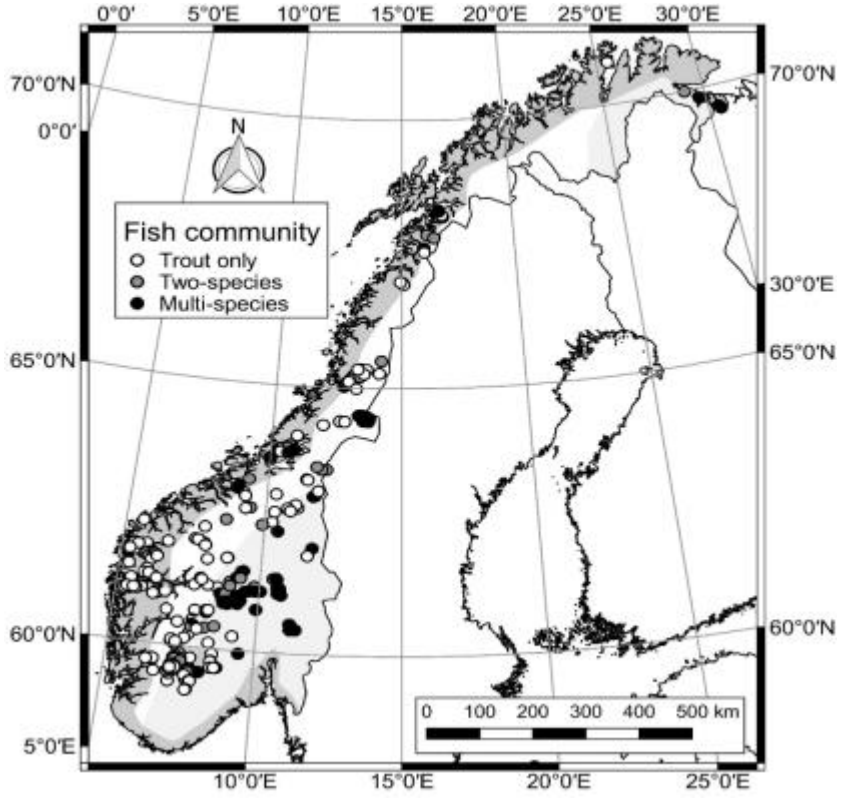


Diet items

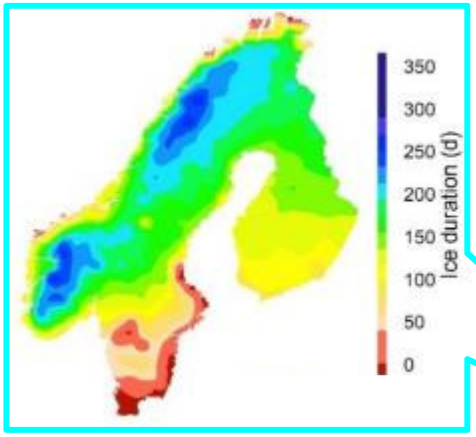


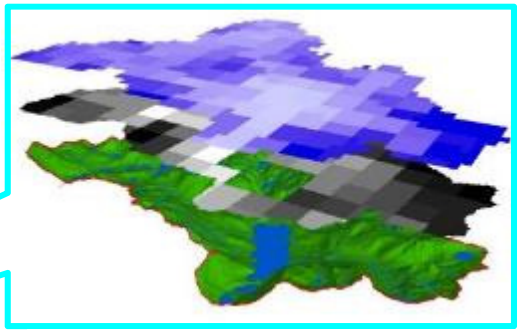
Results part II: Comparison along environmental gradients

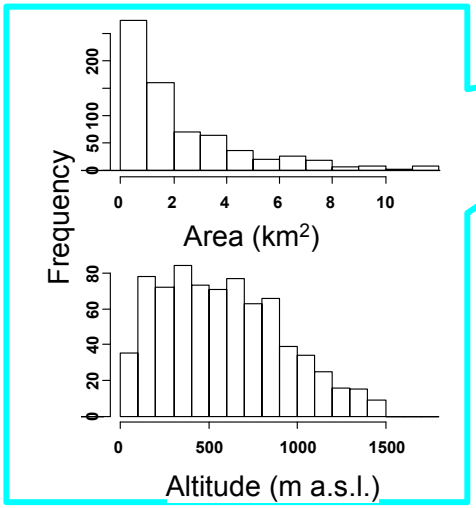
- Abundance of brown trout

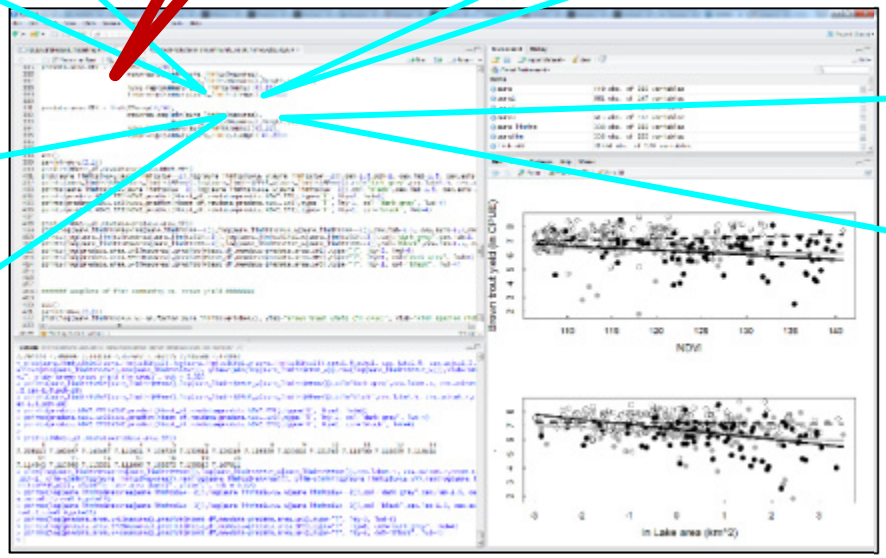


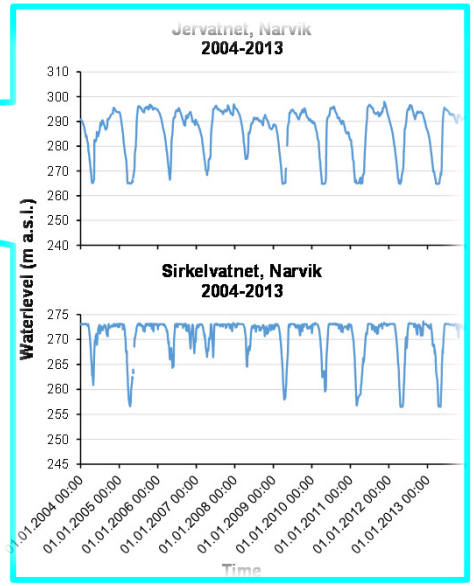
Separate hydropower from natural variation











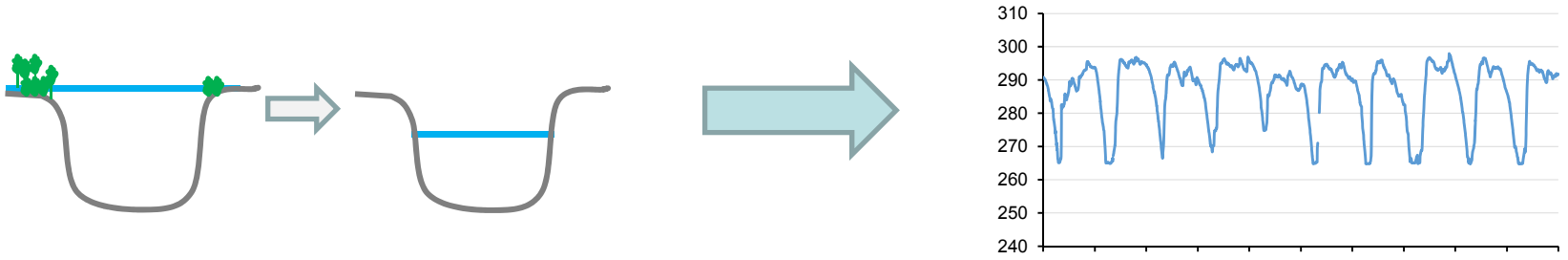
Significant factors for trout abundance

- Lower trout abundance in regulated lakes
- ...but also when
  - Several fish species are present (competition + predation)
  - The littoral zone is small – but only when other fish species are present
- Higher trout abundance when
  - More vegetation in the catchment (high nutrient run-off to lake)
    - but only when no other fish species were present
- Things are complex, but our approach can handle it!

What comes next?

- Improve modelling of large-scale variations by include more data points

- Move from HRW-LRW to real regulation pattern

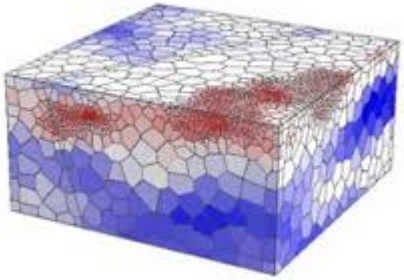


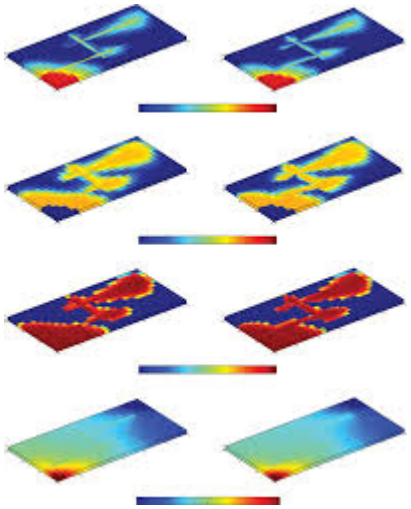
- Methodological challenge: Link time series of water level regulations to point measures of fish status

Abiotic effects

Modelling hydro-dynamic changes introduced by new operational regimes

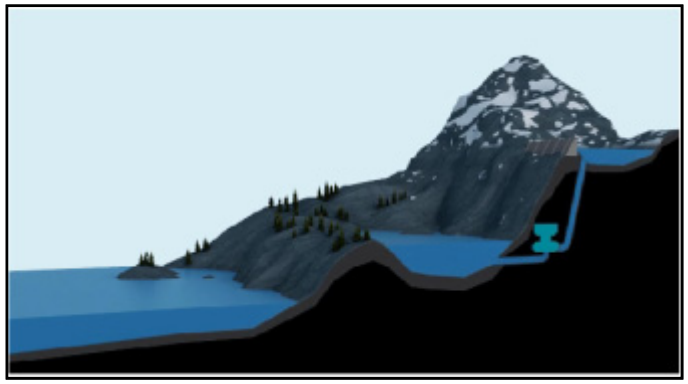
- 3D-modelling of reservoirs (GEMSS)
  - Water level fluctuations, currents, water temperature, stratification, ice conditions, littoral area





Modelling hydro-dynamic changes introduced by new operational regimes

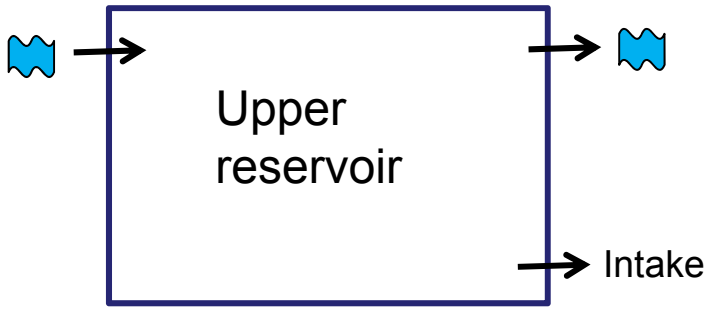
1. Calibration of one real case of three interconnected reservoirs, based on todays regulation regime

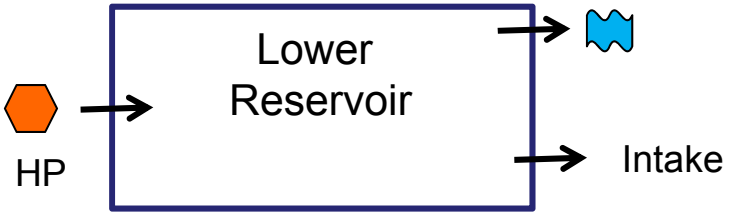


2. Study of abiotic effects in range of reservoir types along environmental gradients
   - Modification of reservoirs characteristics in calibrated case-study
   - Run scenarios for future operational regimes (WP1)

Calibration

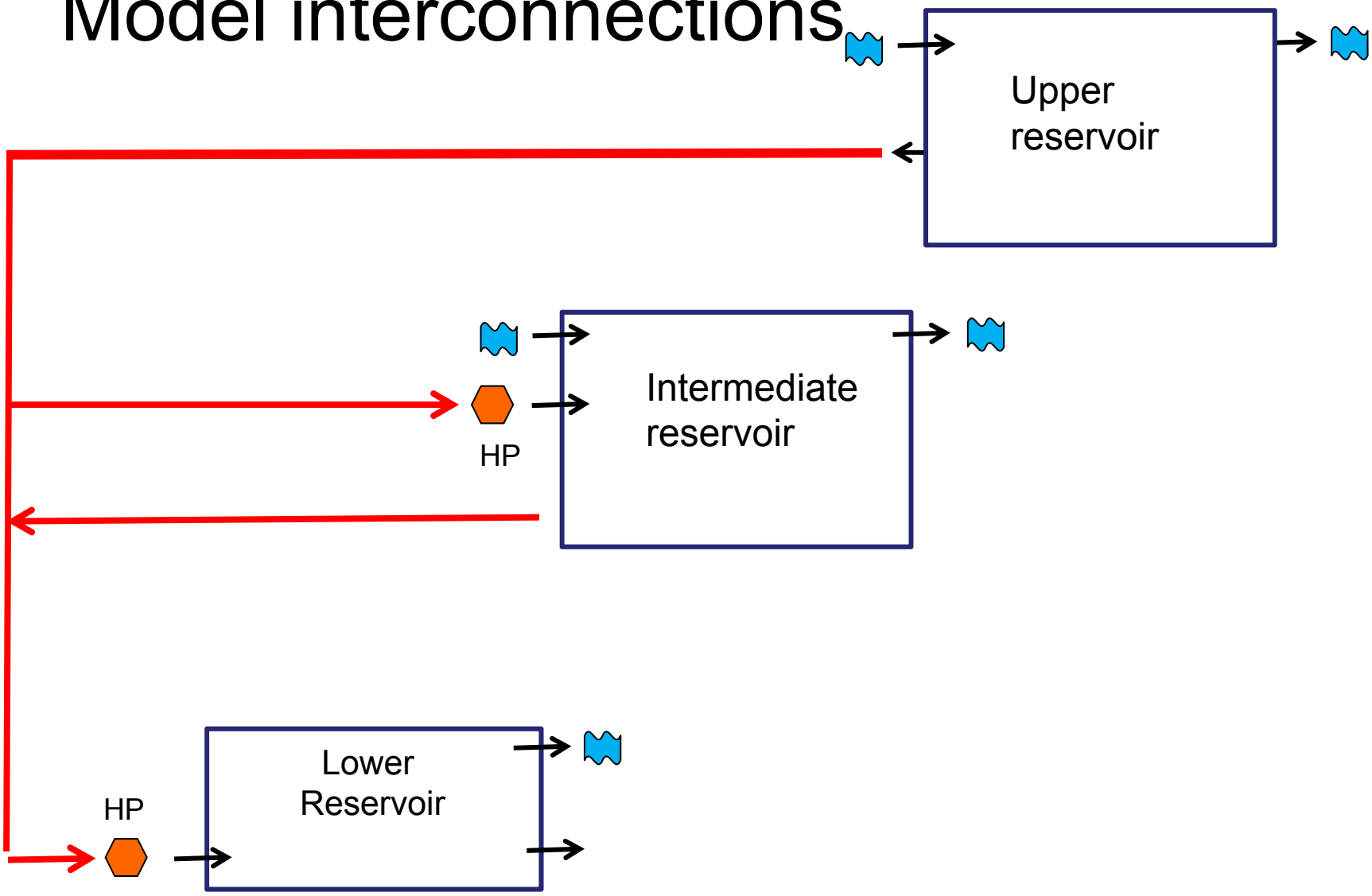
Based on real reservoirs with available data



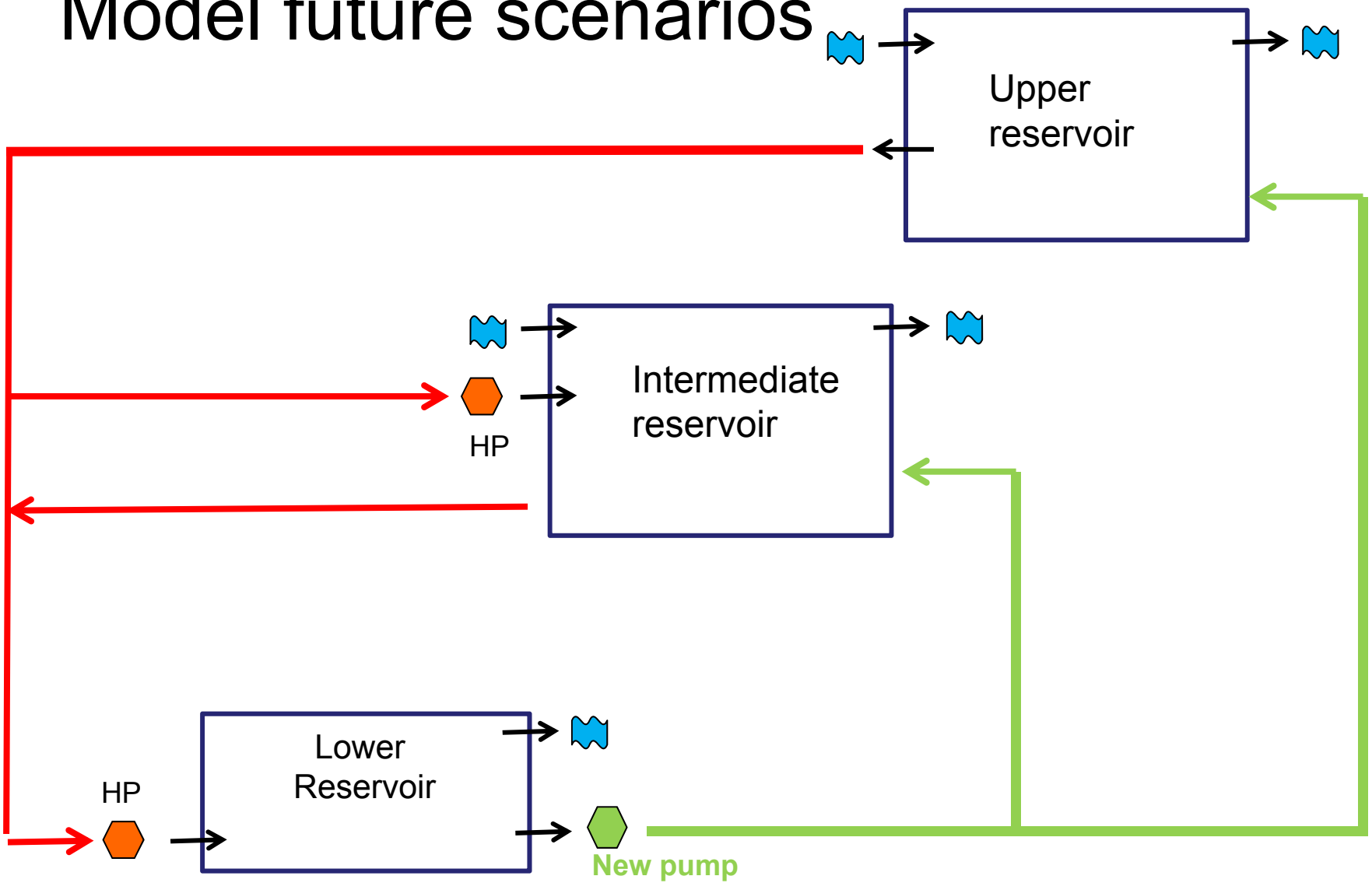


Water level fluctuations, currents, water temperature, stratification, ice conditions, littoral area

Model interconnections



Model future scenarios



Model a range of reservoir types

	Area		0.75 – 2 km²			20 km²			> 45 km²		
Climate	ΔH	Mean Depth (m)	8-15	25	> 85	8-15	25	> 85	8-15	25	> 85
warm	2-5 m		WH-1a	WH-1b	WH-1c	WH-2a	WH-2b	WH-2c	WH-3a	WH-3b	WH-3c
	20 m		WM-1a	WM-1b	WM-1c	WM-2a	WM-2b	WM-2c	WM-3a	WM-3b	WM-3c
	> 40 m		WH-1a	WH-1b	WH-1c	WH-2a	WH-2b	WH-2c	WH-3a	WH-3b	WH-3c
mild	2-5 m		MH-1a	MH-1b	MH-1c	MH-2a	MH-2b	MH-2c	MH-3a	MH-3b	MH-3c
	20 m		MM-1a	MM-1b	MM-1c	MM-2a	MM-2b	MM-2c	MM-3a	MM-3b	MM-3c
	> 40 m		MH-1a	MH-1b	MH-1c	MH-2a	MH-2b	MH-2c	MH-3a	MH-3b	MH-3c
cold	2-5 m		CH-1a	CH-1b	CH-1c	CH-2a	CH-2b	CH-2c	CH-3a	CH-3b	CH-3c
	20 m		CM-1a	CM-1b	CM-1c	CM-2a	CM-2b	CM-2c	CM-3a	CM-3b	CM-3c
	> 40 m		CH-1a	CH-1b	CH-1c	CH-2a	CH-2b	CH-2c	CH-3a	CH-3b	CH-3c

Modify:

Water level

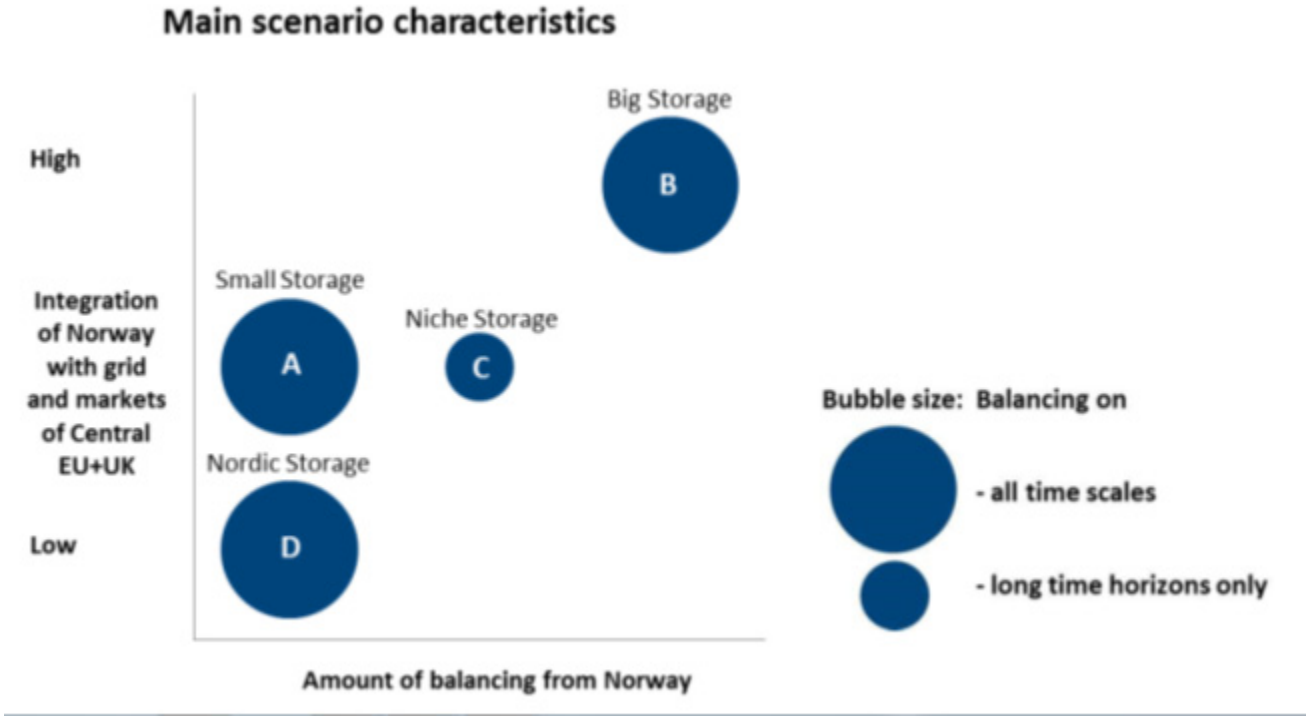
Area

Mean depth

Climate region

Model three scenarios

- Today
- «Big Storage»
- «Niche Storage»



Expected final outcome WP4

Combine ecological models with hydro-dynamic models

- Predict how future operational regimes influence ecological communities
- Identify mitigation measures

Main link to other WPs

- WP1 roadmaps
- WP3 business models
- WP 5 social acceptance

Thank you!

Contact

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