     

Present and future environmental impacts of hydropower on Norwegian lakes
HydroBalance project

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1. CEDREN HydroBalance: Facts

- **CEDREN project**
- **2013-2017**
- 24,864 MNOK (about 2.7 mill. EUR)
- Research partners (11)
  - **SINTEF** Energy Research,
  - **NTNU**: Norwegian university of Science and Technology,
  - **NINA**: Norwegian Institute for Nature Research,
  - UiO: University of Oslo,
  - UiT: University of Tromsø,
  - NIVA: Norwegian Institute for Water Research
  - ECN: Energy Research Centre of the Netherlands,
  - University of Waterloo,
  - University of Exeter,
  - University of Aachen & E.ON
  - EdF: Electricite de France
- Funding:
  - Research Council of Norway
  - Statnett,
  - Sira Kvina kraftselskap,
  - Statkraft,
  - EnergiNorge,
  - Agder Energi,
  - BKK,
  - Listerrådet,
  - EdF: Electricite de France,
  - NVE (Norwegian Water Resources and Energy Directorate)
  - E.ON,
  - ECN: Energy Research Centre of the Netherlands,

1. CEDREN HydroBalance: Facts

Feasibility of **large scale** development of energy **balancing and storage** from **Norwegian** hydropower in the **future European** electricity market with respect to the **power system**, **environmental** aspects, **economic** viability and **social acceptance**.

WP 2
Demand for energy balancing storage

WP4
Environmental impact of operation schemes for balancing

WP 1
Roadmaps for balancing from Norwegian hydropower

WP 3
Analyses to develop relevant business models

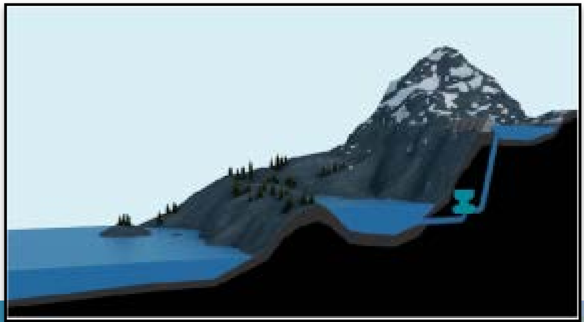
WP 5
Social acceptance and regulatory framework

1. Future energy demand and water level fluctuations

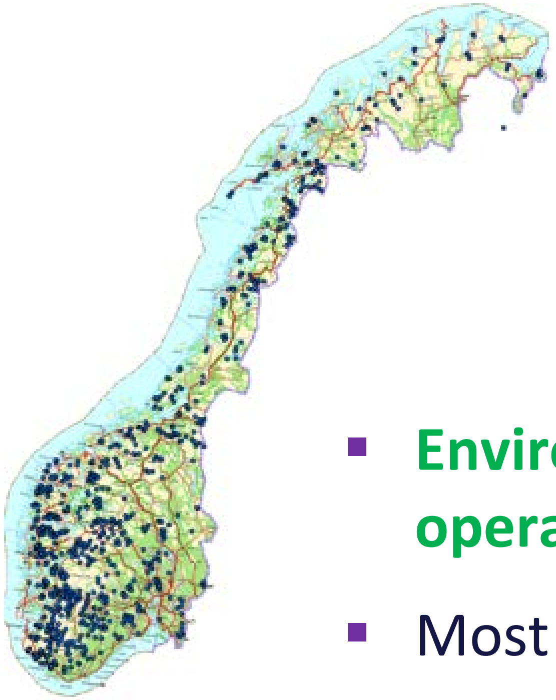
- Integration of **renewable** from **intermittent** sources
- Future energy demand: more **flexibility**, more **storage**
- New operational regimes

  → More rapid, intense and frequent **water level fluctuations** (WLF)

  → Pump-storage

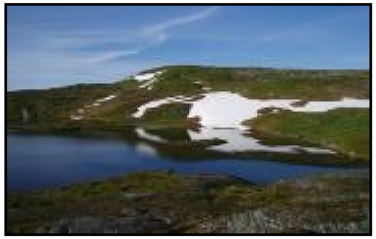


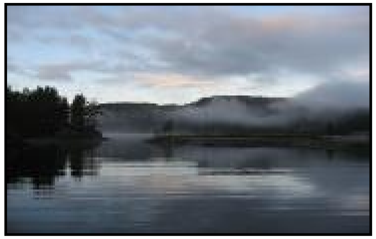
1. WP4 focuses on HP reservoirs



- **Environmental impacts of new operational regimes in reservoirs**
- Most of studies in rivers
- > 900 reservoirs (lakes) in Norway

  Also used as recreational area





1. Potential impacts of water level fluctuations in reservoirs

- **Abiotic consequences**
  - Water temperature
  - Stratification period/duration/intensity
  - Ice cover thickness/period/duration…
  - Water quality

- **Biotic consequences**
  - Biological productivity
  - Species composition
  - Fish diet
  - Growth and reproduction…

1. HydroBalance WP4: Environmental impacts of new operational regimes

Task 4.1
Modelling **ecological** consequences of WLF along environmental gradients

→Biotic effects (**current situation**)

NINA

Task 4.2
Modelling lake **physical properties** changes introduced by new operational regimes

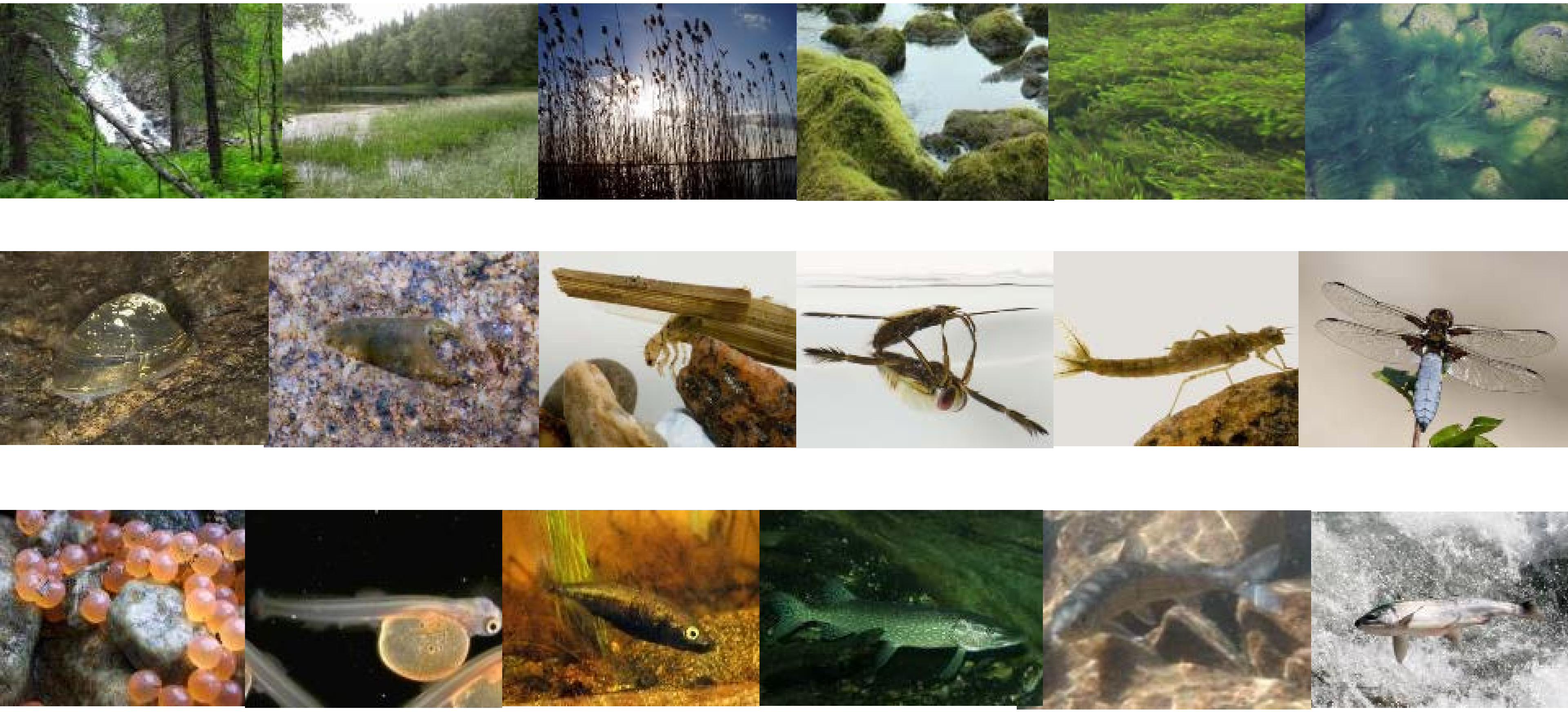
→ Abiotic effects (**future operational regimes)**

SINTEF

Task 4.3

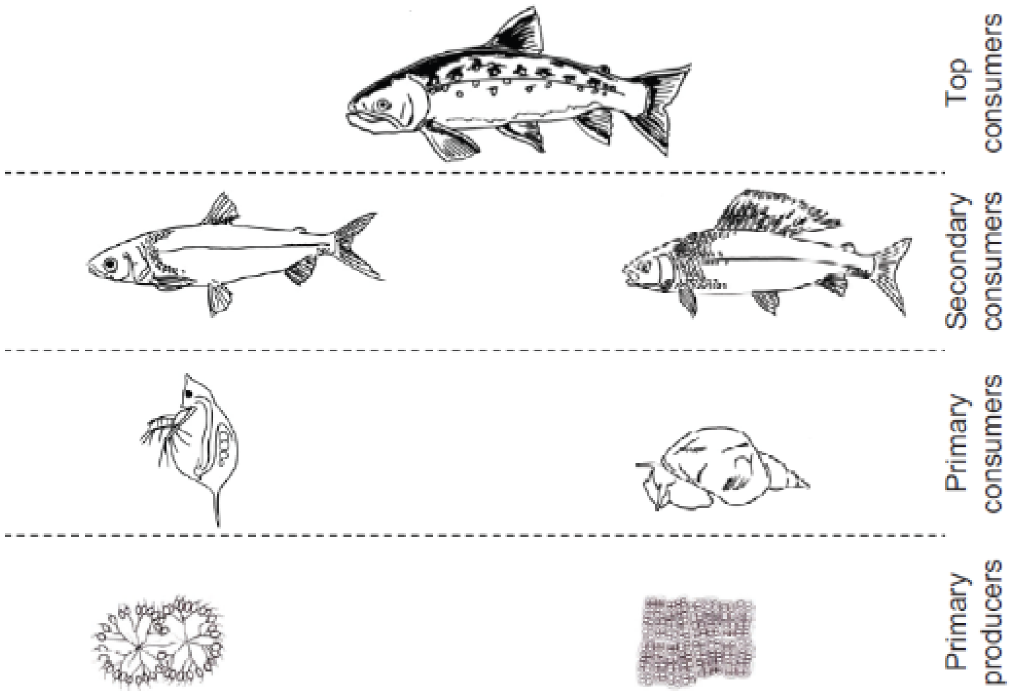
→ Combined results to **predict** how future operational regimes can impacts lakes ecosystems
→ Define **mitigation** measures to reduce potential negative impacts

2. Biotic impacts *of new operational regimes*



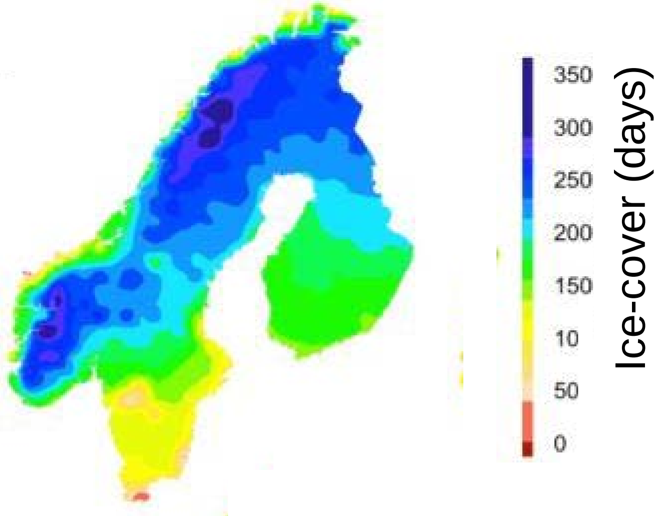
2. Focus on fish

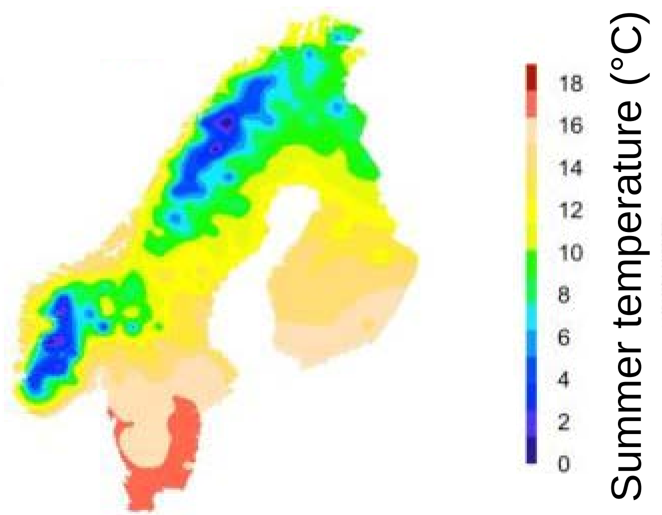
Fish as **top predator** : bio-indicator for **ecological status**



2. Natural variation due to climate

… *which impacts lakes ecological status*



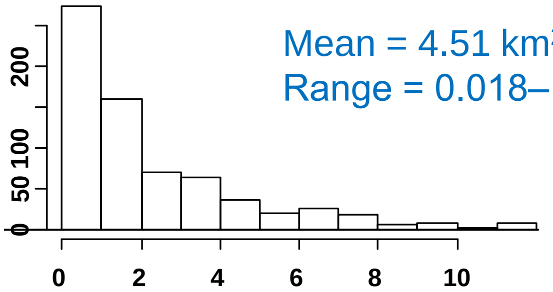


2. Natural variation in drainage basin

… *which impacts lakes ecological status*

2. Natural variation in morphology
… *which impacts lakes ecological status*

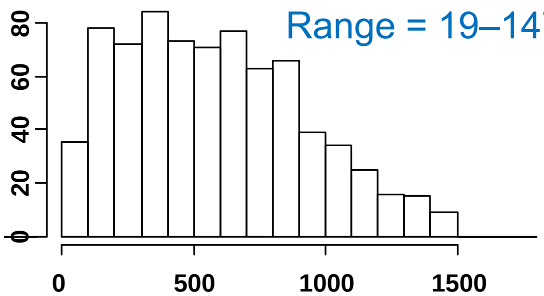
Area



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

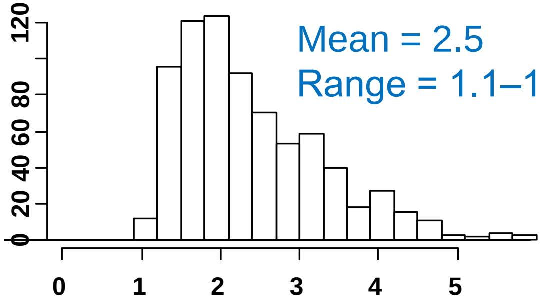
Altitude

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

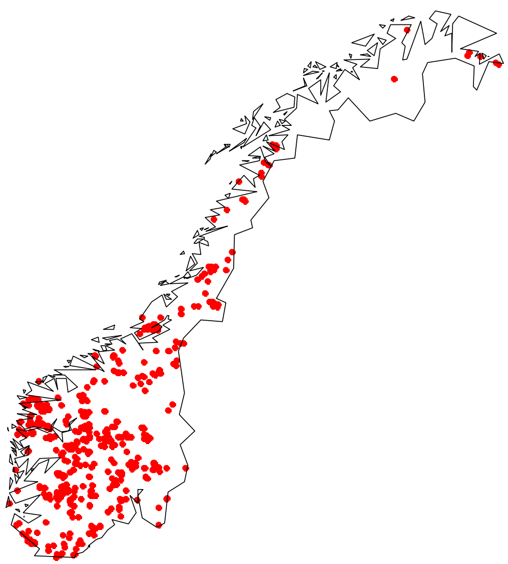
2. Natural variations in fish growth

How to separate effects from **hydropower** from **natural** variation?

2. Data collection

Large dataset from previous field campaign + Field work in 2014

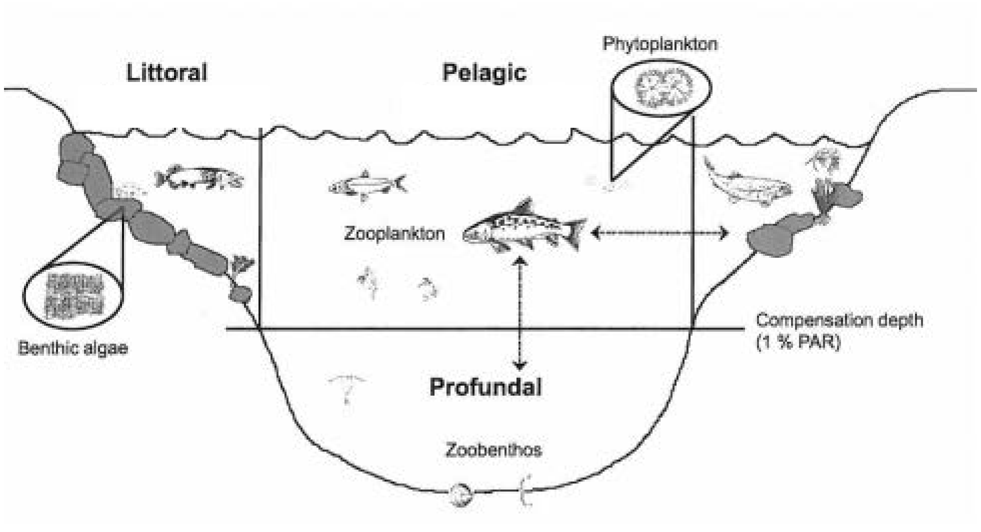
- Compare **natural lakes** and **regulated lakes** (reservoirs)
- Understand large-scale trend along **environmental variations**



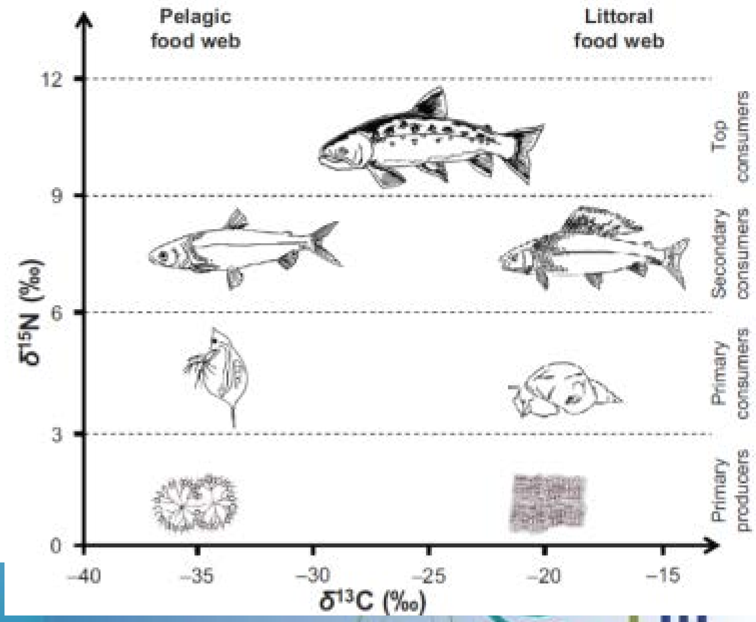
2. Data about fish population

- Fish communities: Density, Growth, reproduction, diet
- Understand the structure and the function of food chain
  - Stable isotopes analyses

Habitat use

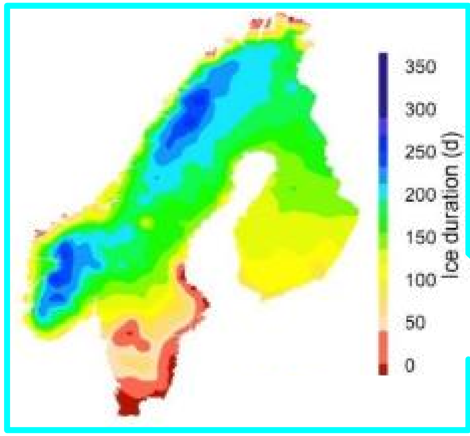


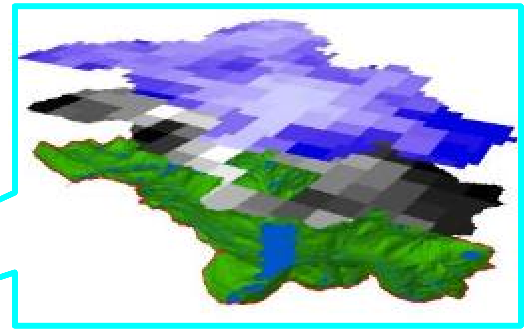
Food web

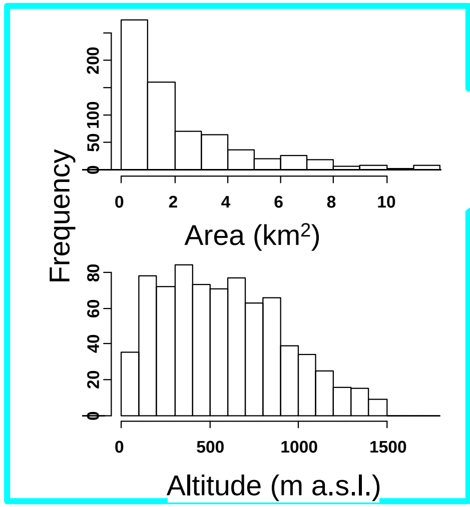


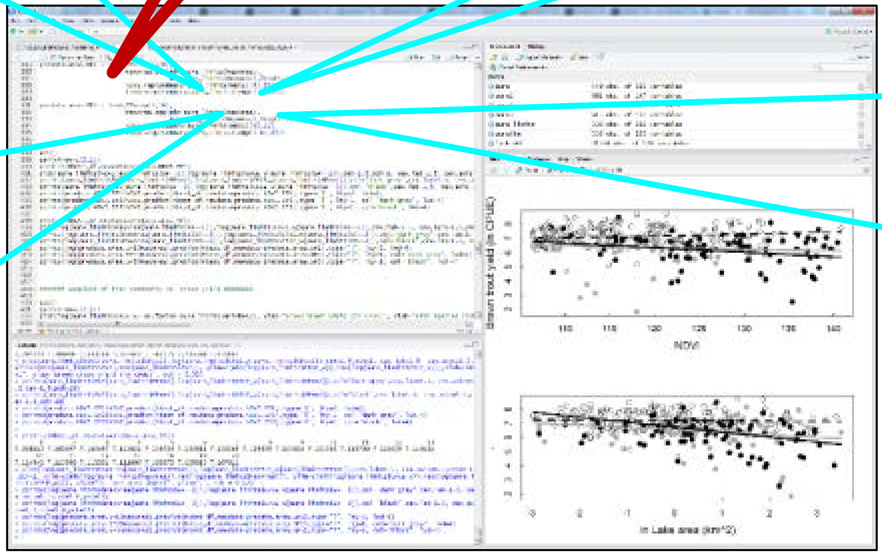
2. Statistical analysis and modelling of interactions

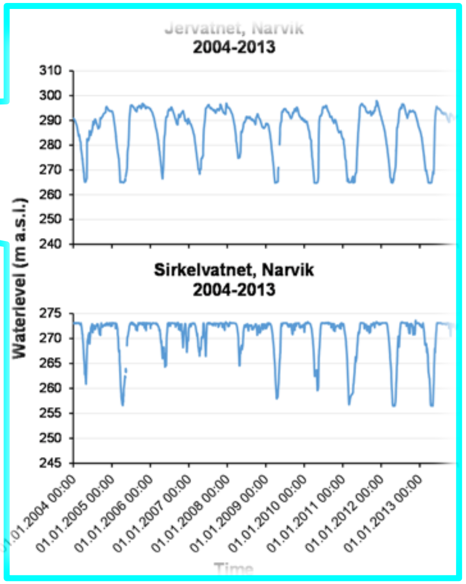
…for separating impacts from hydropower and natural variations







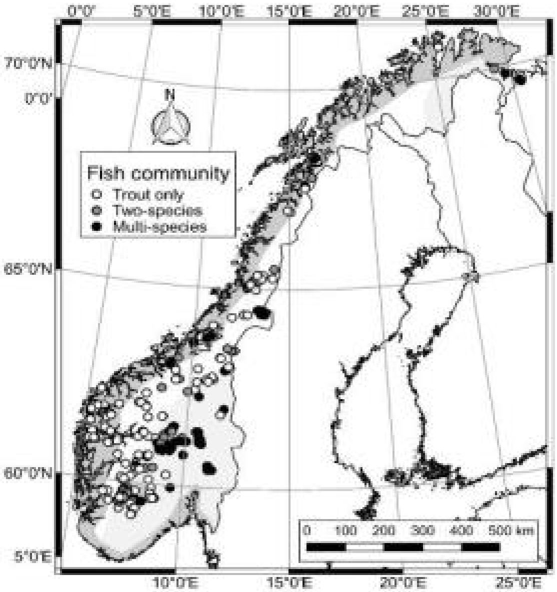




2. Some results:
Fish abundance along environmental gradients

- Lower trout abundance in regulated lakes
- …but also when:
  1) Competitive & predatory fishes are present
  2) Littoral zone is small and dominated by other fishes

- Trout abundance higher in lakes with productive catchments
  → but only when competitors are absent



Journal of Animal Ecology

Journal of Animal Ecology 2016, **85**, 273–282 doi: 10.1111/1365-2656.12461

Community structure influences species' abundance along environmental gradients

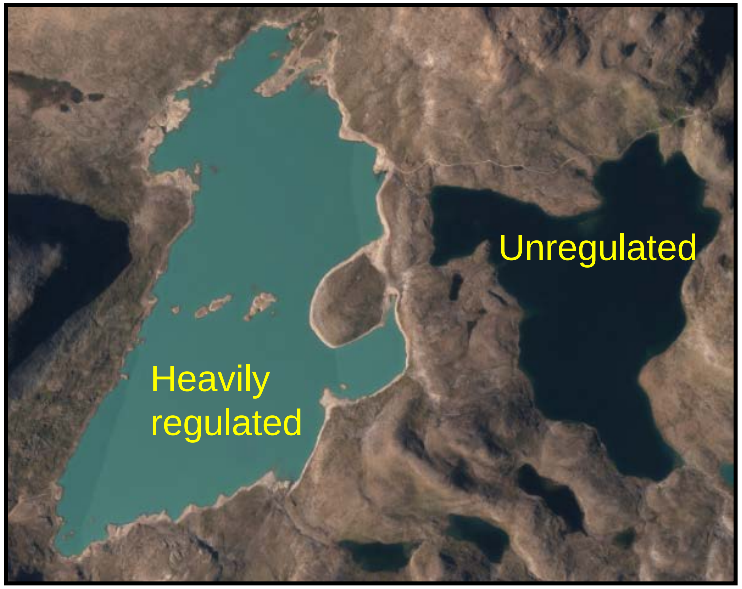
Antti P. Eloranta[1*], Ingeborg P. Helland[1], Odd T. Sandlund[1], Trygve Hesthagen[1], Ola Ugedal[1] and Anders G. Finstad[1,2]

2. Some results:
WLF impacts on Arctic charr niche

- More turbid water and limited littoral production has resulted to:

1) Decreased use of littoral food and habitat resources

2) Increased infections by zooplankton-transmitted parasites

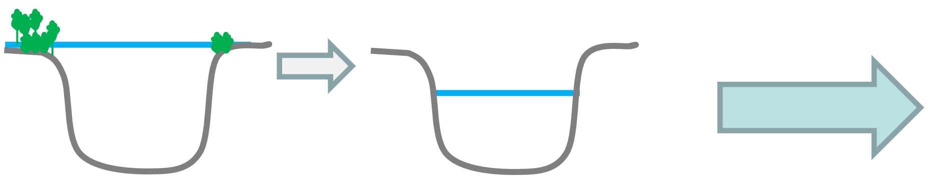


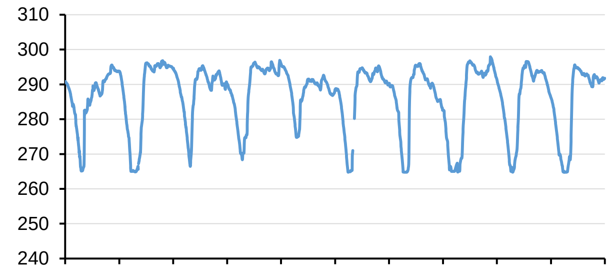
Eloranta et al. (2016) Water level fluctuations affect niche use of a lake top predator. *Freshwater Biology*, in review

2. On-going work

Understand link between WLF and ecological status

- Establish parameters for WLF and not only HRWL-LRWL





- Link WL timeseries to fish caught date

- Renforce/Establish relationships between large-scale variations by including more data-points

3. Abiotic consequences *of new operational regimes*







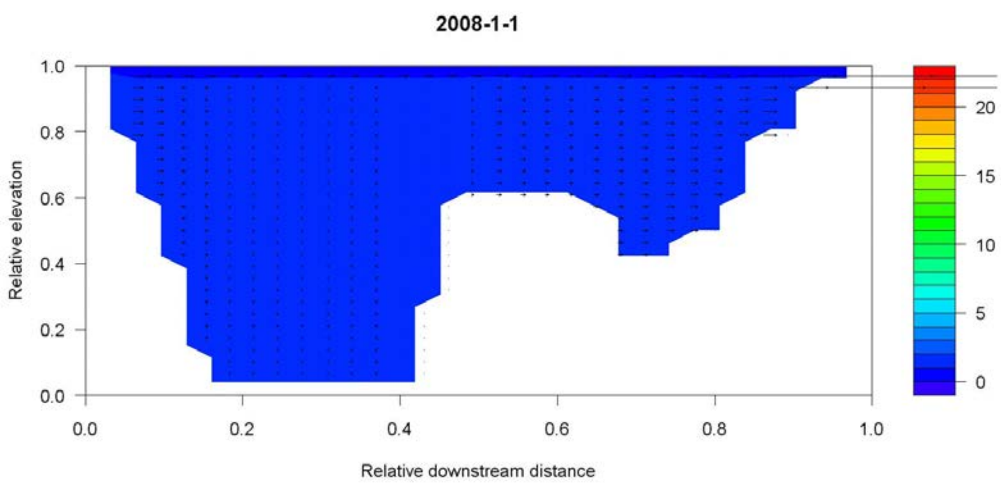


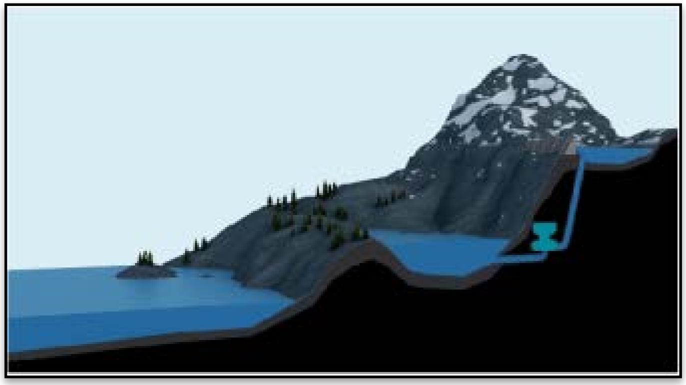
3. Modelling hydro-dynamics consequences from new operational regimes

1. **2D Hydro-Dynamic modelling of a regulated reservoir and calibration**

    → water temperature and stratification characteristics

    → Ice cover period-thickness-duration

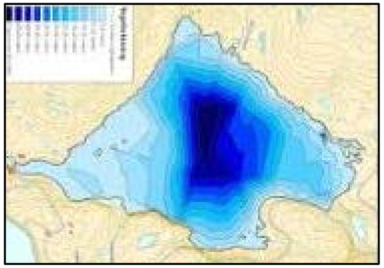




3. Modelling hydro-dynamics consequences from new operational regimes

1. 2D modelling of a regulated reservoir and calibration
2. Extension of the existing case to **additional cases**

Reservoirs types:
- **Regulated amplitude**
- **Area**
- **Mean depth**
- **Climate region**



3. Modelling hydro-dynamics consequences from new operational regimes

	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

Reservoir types:

Climate region

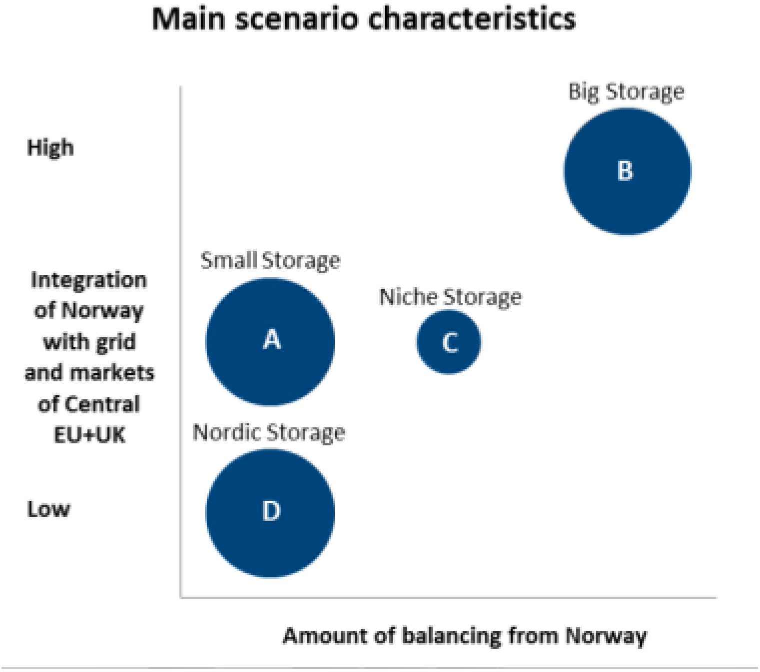
Regulated amplitude

Mean depth

Area

3. Modelling hydro-dynamics consequences from new operational regimes

1. 2D modelling of a regulated reservoir and calibration
2. Extension of the existing case to additional cases
3. Run simulations of futrue operational regimes
   - (present regime)
   - Big Storage
   - Niche Storage



Key messages

- Integration of **renewable** from **intermittent** sources
  → new operational regimes

- Within **HydroBalance** project: environmental impacts of future operational regimes

  - **Biological impacts**: field work and stastistical analysis of present regimes

  +

  - **Physical impacts**: 2D modelling of new regulation regimes

→ **Predict** ecological impacts for future operational regimes

→ Define **mitigation measures** to reduce potential negative impacts in the future

Thank you for your attention!

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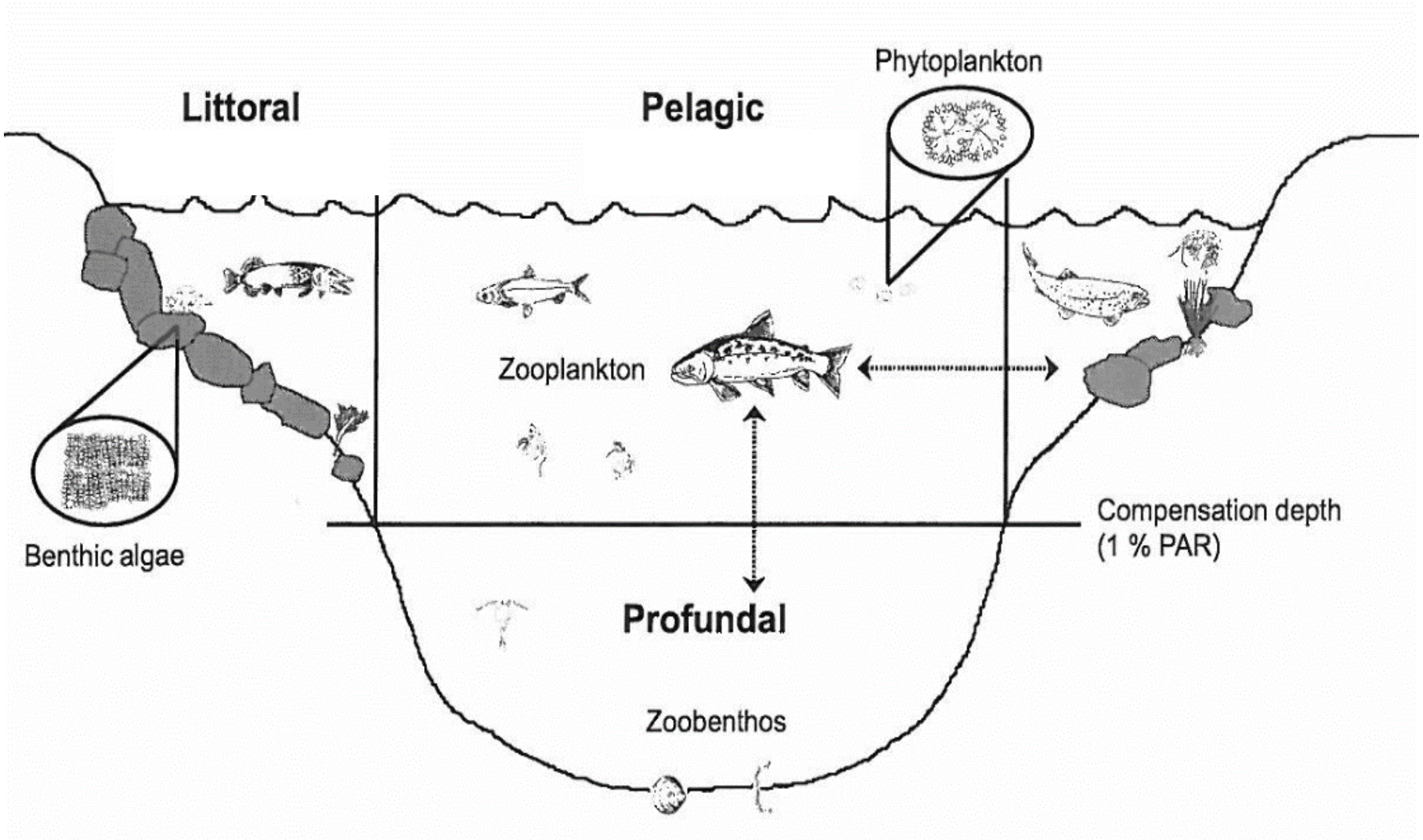
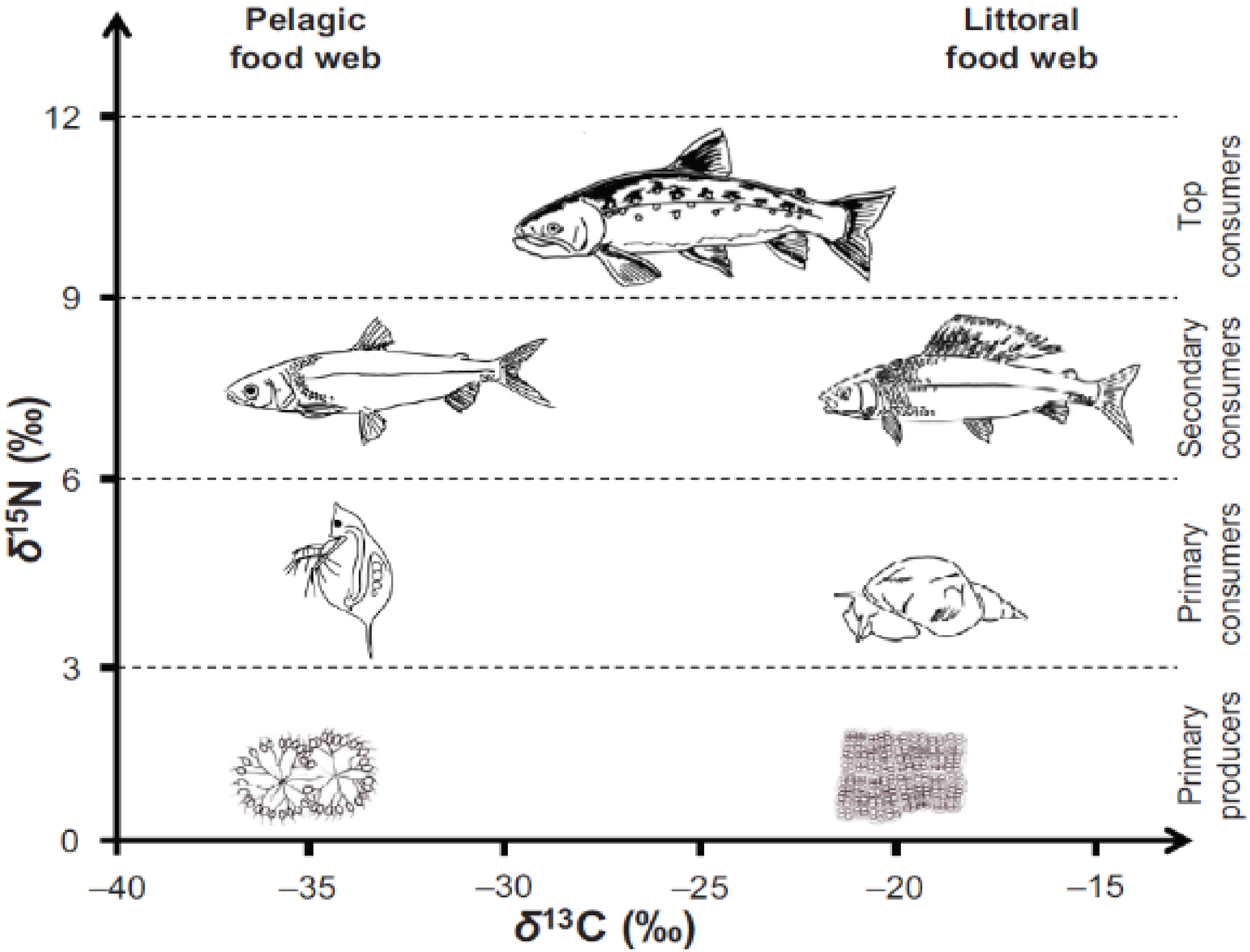
www.cedren.no/Projects/HydroBalance

Habitat use



Phytoplankton
Littoral
Pelagic
Zooplankton
Benthic algae
Compensation depth
(1 % PAR)
Profundal
Zoobenthos

Food chain



Pelagic food web
Littoral food web
12
9
6
3
0
δ15N (‰)
–40
–35
–30
–25
–20
–15
δ13C (‰)
Top consumers
Secondary consumers
Primary consumers
Primary producers

Publications

Community structure influences species’ abundance along environmental gradients

AP Eloranta, IP Helland, OT Sandlund, T Hesthagen, O Ugedal, AG Finstad

Journal of Animal Ecology

Water level regulation affects niche use of a lake top predator

AP Eloranta, J Sánchez-Hernández, IP Helland, PA Amundsen, S Skoglund, J Brush, M Power

Manuscript to *Freshwater Biology* submitted

Effects of anthropogenic water level fluctuations in hydropower reservoirs – an ecosystem approach with a special emphasis on fish

Hirsch, P.E.,*, A.P. Eloranta, P.-A. Amundsen, Å. Brabrand, J. Charmasson, I.P. Helland, M. Power, J. Sánchez-Hernández, O.T. Sandlund, J.F. Sauterleute, S. Skoglund, O. Ugedal & H. Yang

Manuscript to*Ambio* submitted