Modelling environmental impacts in hydropower reservoirs

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Leader WP4 HydroBalance

Outline

- Reminder of WP4 work plan
- Quick recap of previous results on ecosystem effects
- **Ongoing simulations of physical effects**
- Summary

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WP4: Environmental impacts of new operational regimes

Task 4.1

Modelling ecological consequences along environmental gradients

→ Ecosystem effects (todays situation)

Task 4.2

Modelling hydro-dynamic changes introduced by new operational regimes.

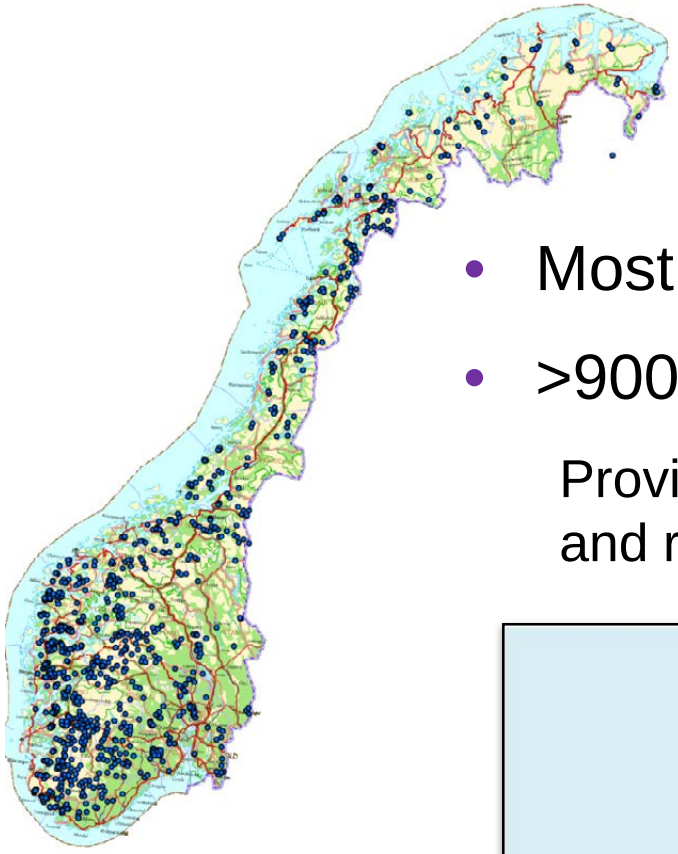
→ Physical effects (future operations)

Task 4.3

Mitigating ecological effects of new operational regimes

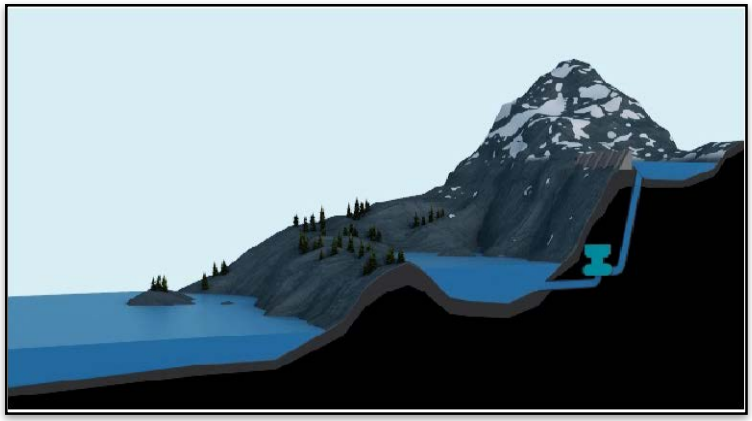
→ Combine 4.1 and 4.2

WP4 focuses on reservoirs



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

  Provide important ecological services and recreational areas



Quick recap of ecosystem effects

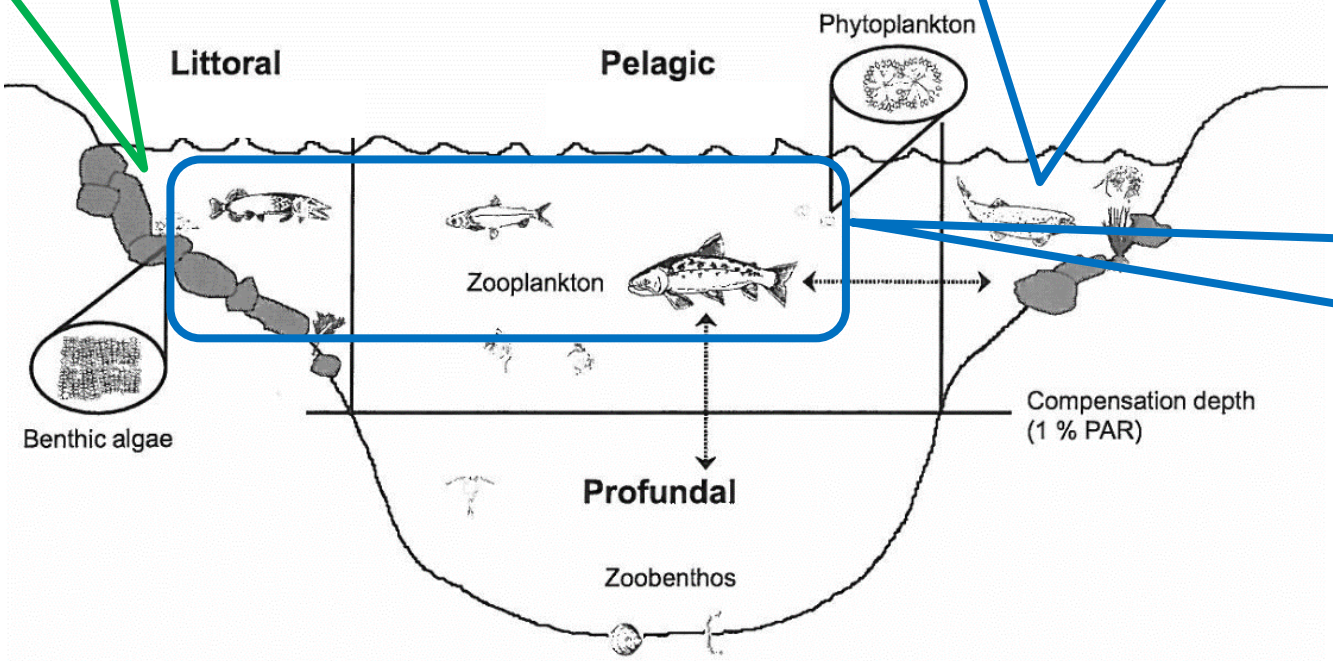
(Task 4.1)

Ecosystem effects: trout abundance

Most productive habitat

Trout abundance decreases with decreasing littoral availability…

…and increasing interspecific interactions



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Community structure influences species' abundance along environmental gradients

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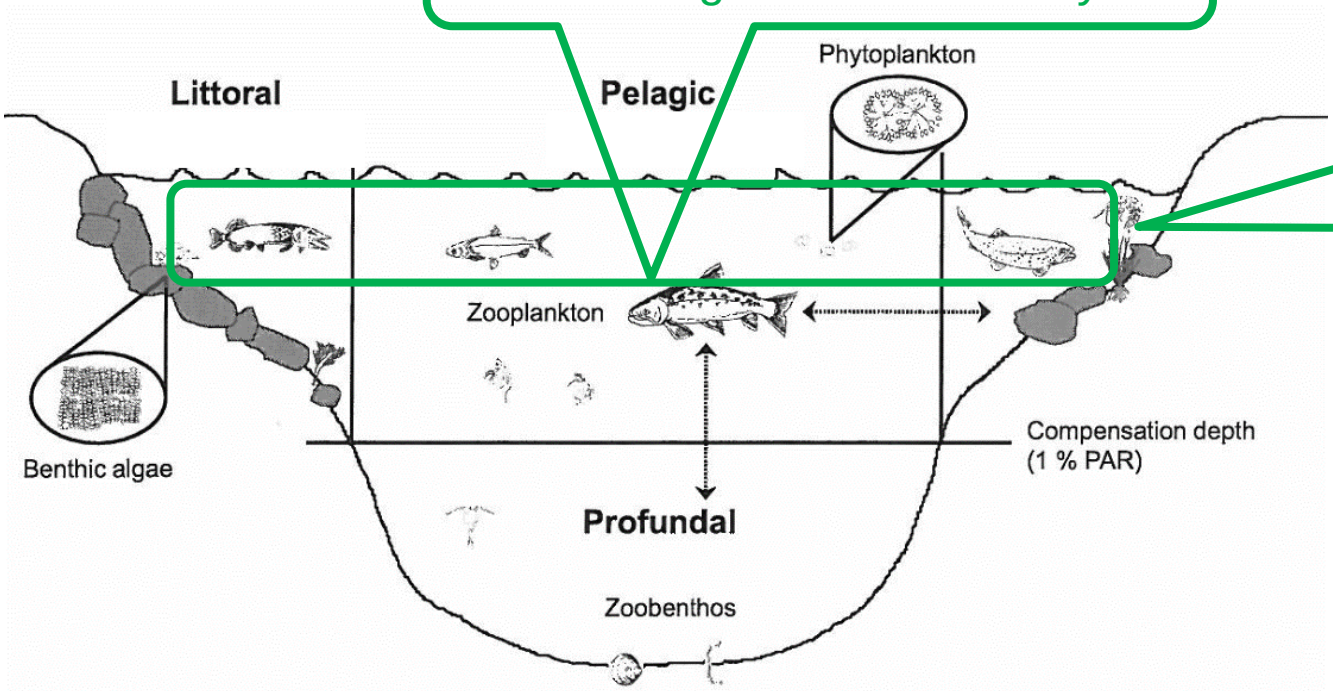
Ecosystem effects: charr niche use

Charr become more pelagic with decreasing littoral availability…



…and increasing interspecific interactions

Ecology and Evolution

Open Access

Lake size and fish diversity determine resource use and trophic position of a top predator in high-latitude lakes

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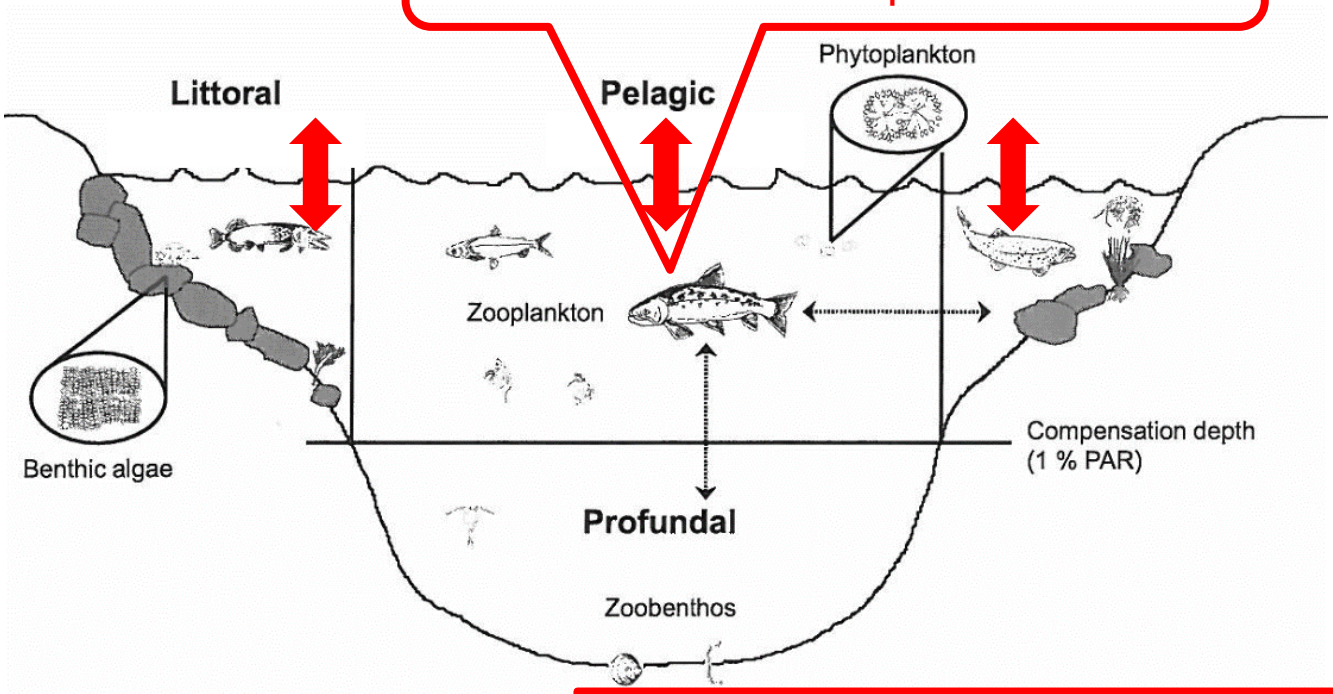
Ecosystem effects: charr niche use

Charr become more pelagic due to reduced littoral production



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WILEY

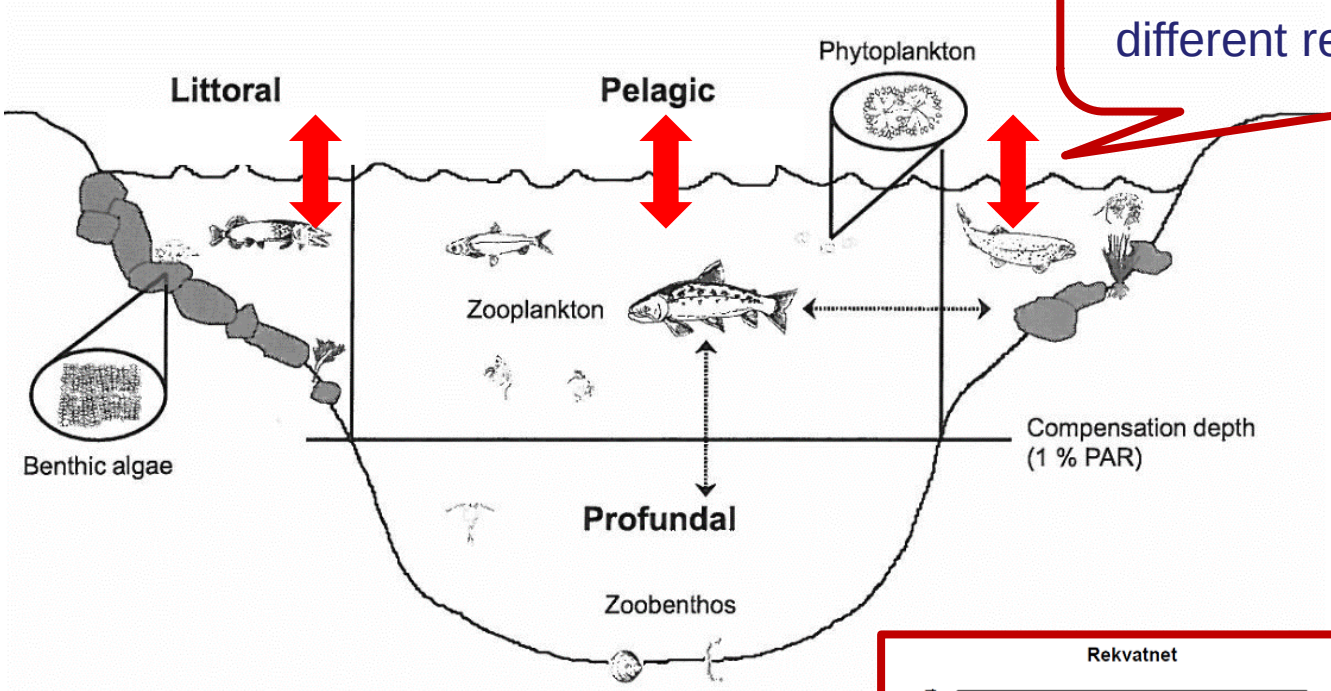
RESEARCH ARTICLE

Water level regulation affects niche use of a lake top predator, Arctic charr (*Salvelinus alpinus*)

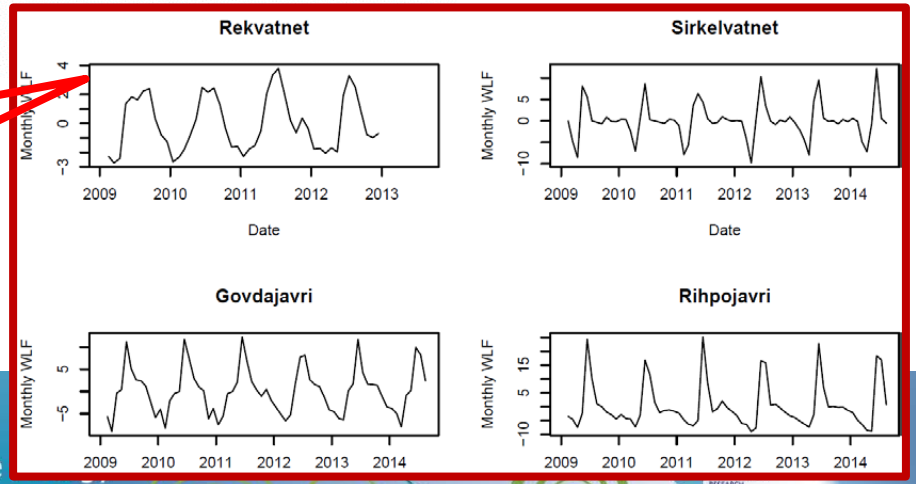
Antti P. Eloranta[1*] | Javier Sánchez-Hernández[2] | Per-Arne Amundsen[3] | Sigrid Skoglund[1] | Jaclyn M. Brush[4] | Eirik H. Henriksen[3] | Michael Power[4]

Ecosystem effects: next step

How are fish abundance and lake food webs affected by different regulation patterns?



WLF metrics:
- Maximum amplitude
- Weekly rate of change
- Duration of low water level
- etc.



Simulating physical effects
(Task 4.2)

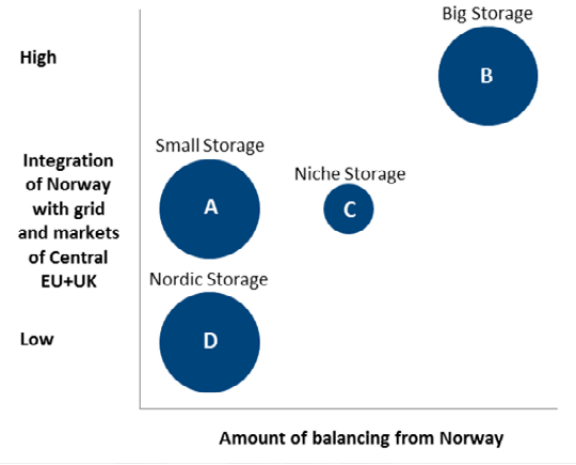






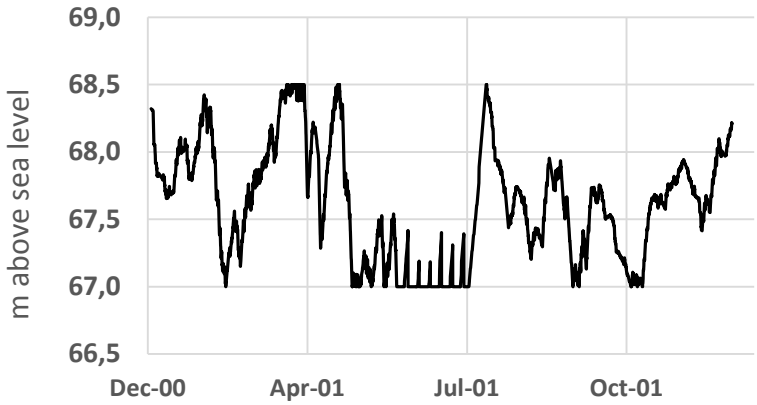



Integrating results from several WPs

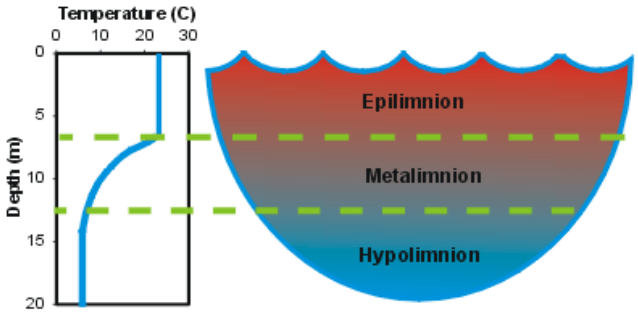


WP1

WP3

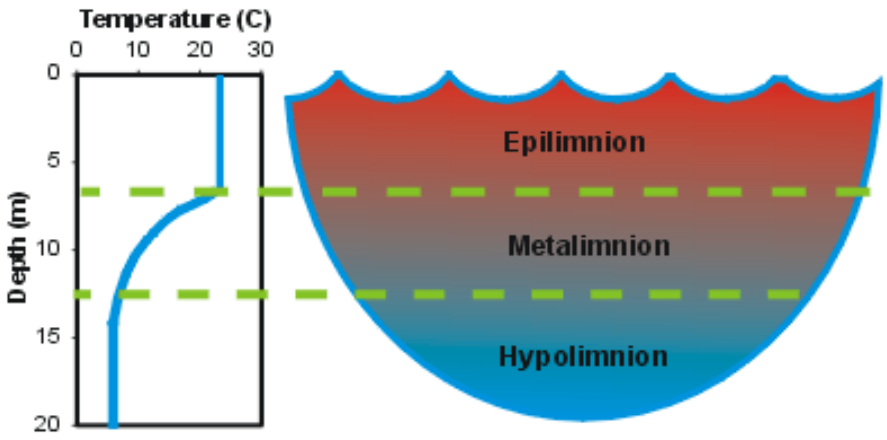


WP4

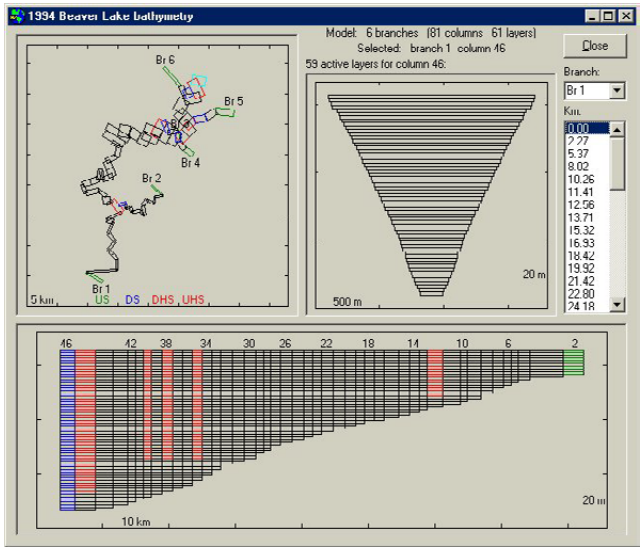


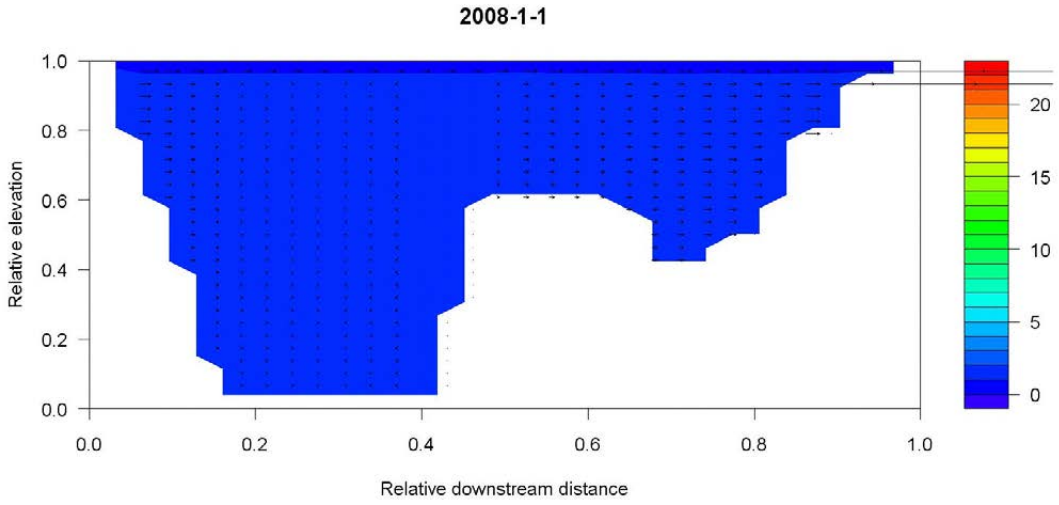
Temperature as measure of environmental impacts

- Temperature important factor for habitat suitability
- Fish are poikilothermic (= cold-blooded):
  - All physiological processes depend on surrounding temperature
- Lakes are divided in distinct temperature zones
- Organism adapted to certain zones



CE-QUAL-W2:
Modelling physical properties in lakes

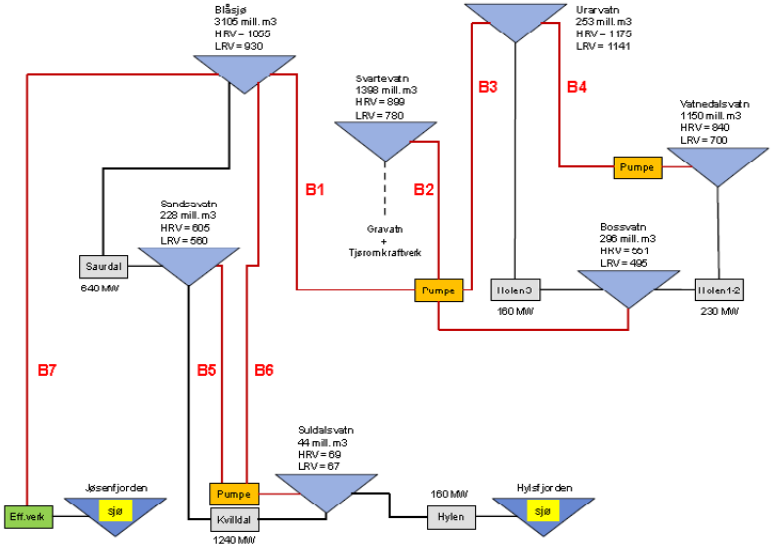




- Data requirements for calibration of model:
  - Depth map
  - Inflow and outflow
  - Seasonal temperature changes in water column

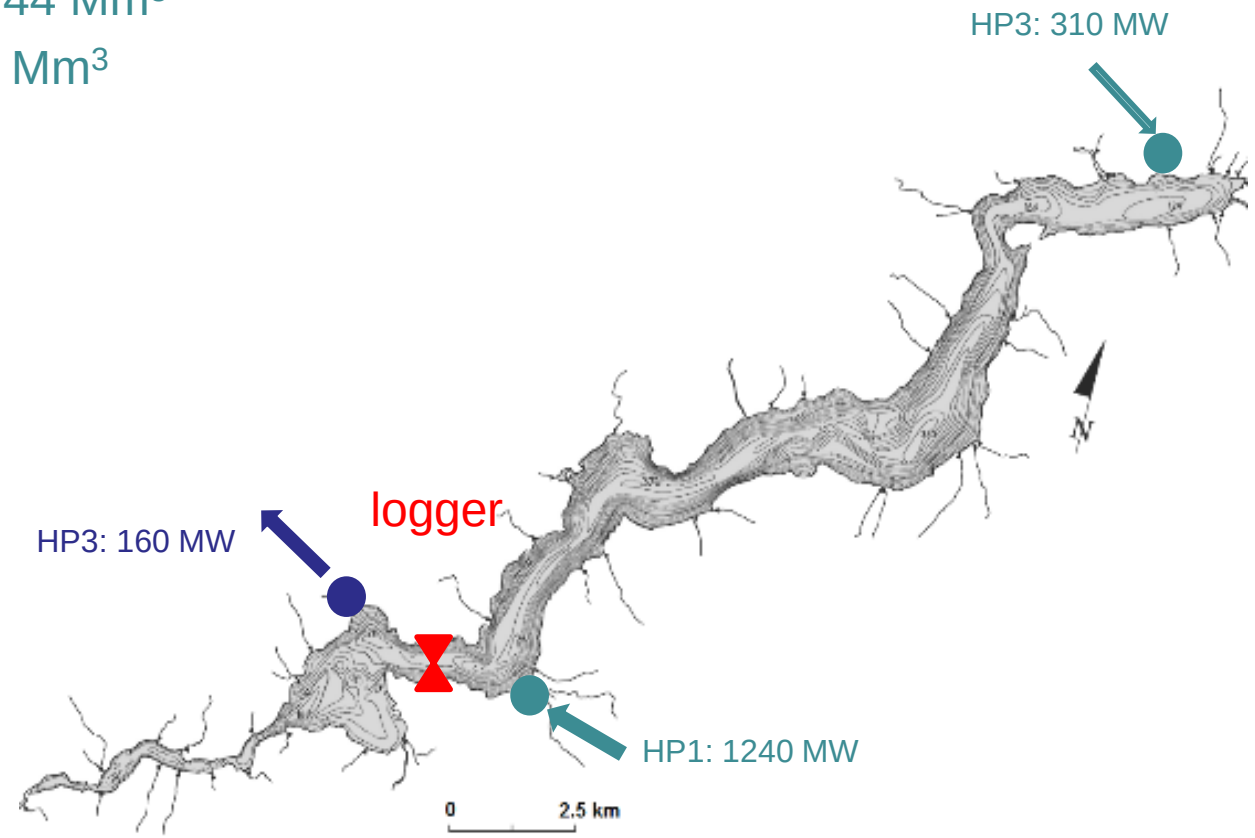
Lake Suldalsvatnet as case

- The only reservoir that met data requirements
- Included as case in HydroBalance phase 1
- In WP4 not selected due to prospects for balancing - Only illustration and test of method

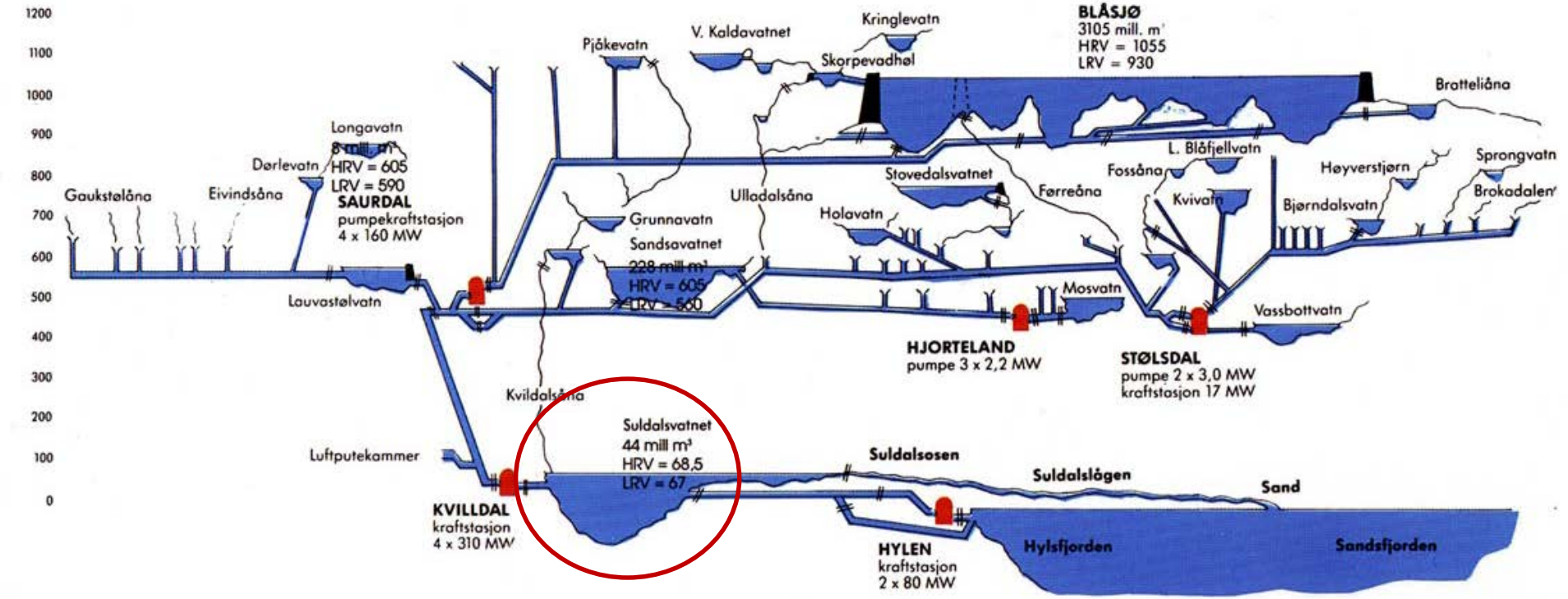


Lake Suldalsvatnet as case

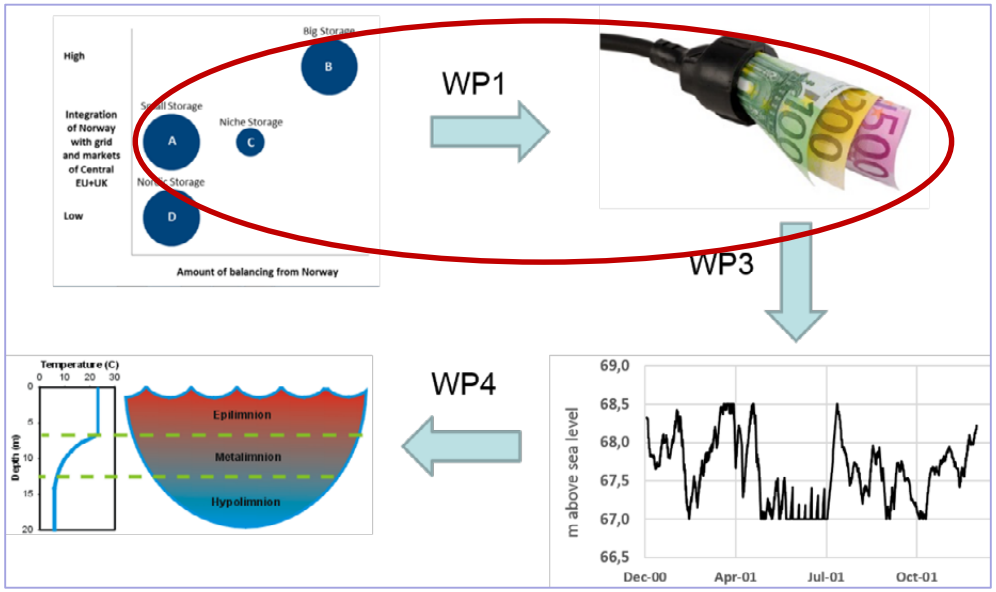
Regulation Amplitude: 1.5 m
Regulated volume: 44 Mm^3
Total volume: 1860 Mm^3
Max depth: 376 m
Area: 28 km^2
Altitude: 67 m.a.s.l.



Lake Suldalsvatnet as case

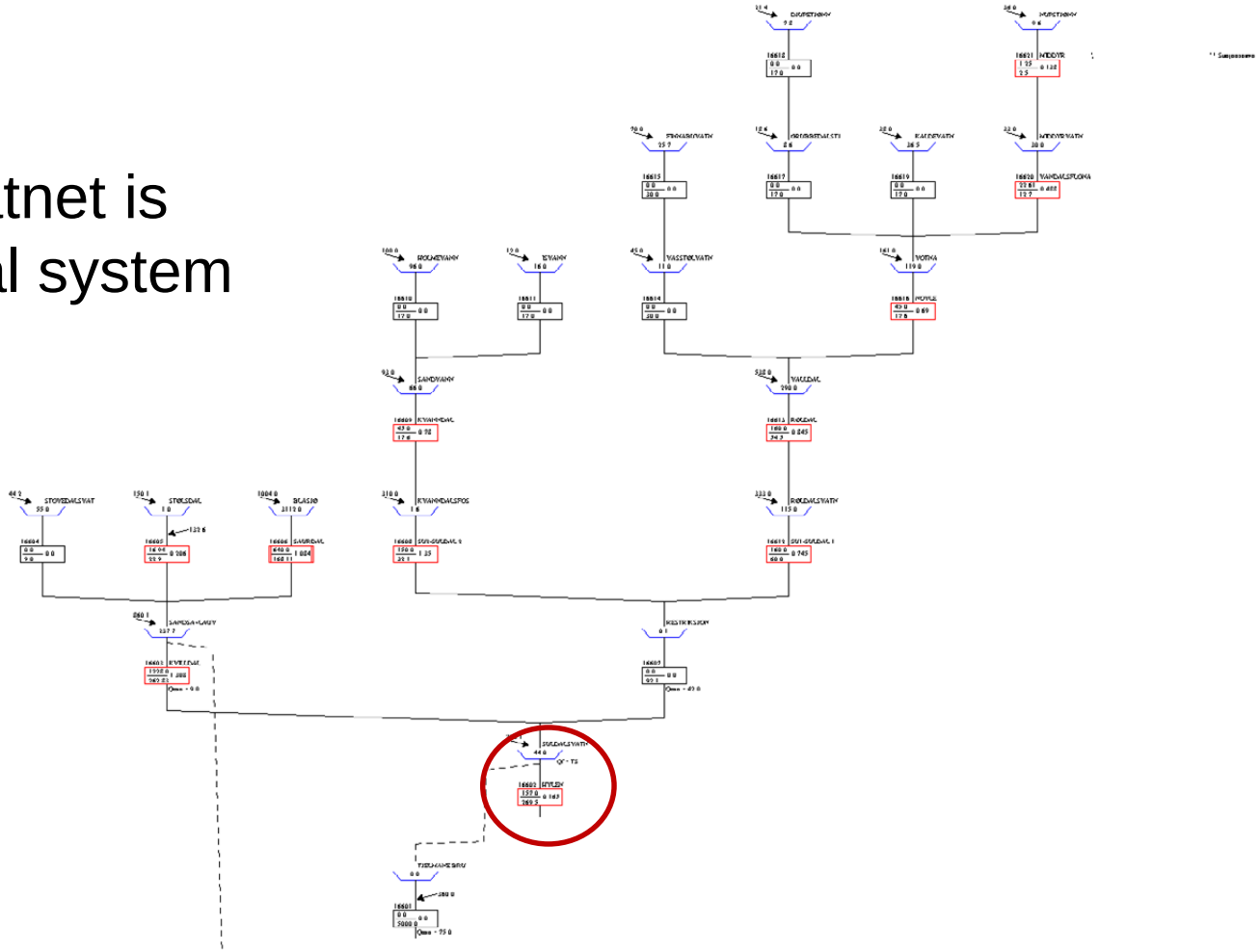


Optimizing system in ProdRisk with prices for different scenarios



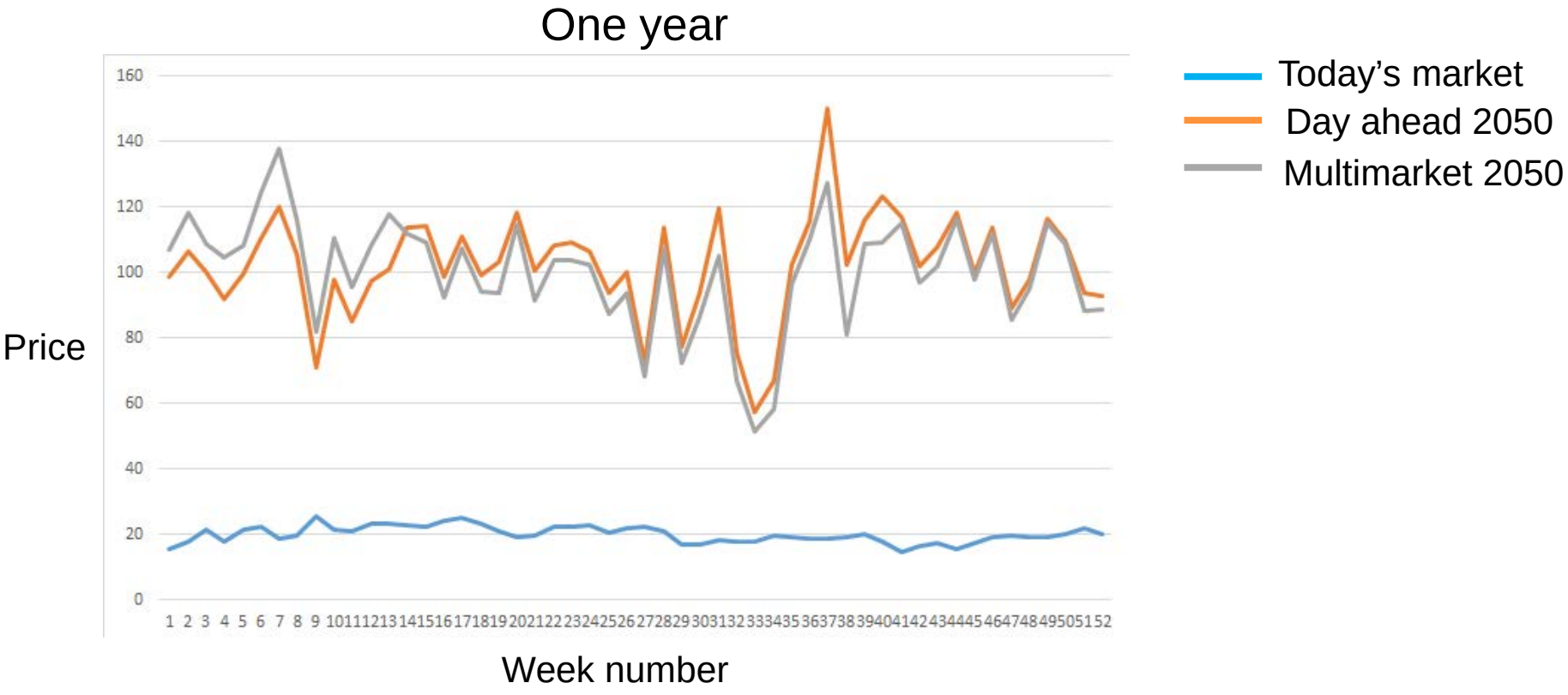
Optimizing system in ProdRisk with prices for different scenarios

Lake Suldalsvatnet is affected by total system

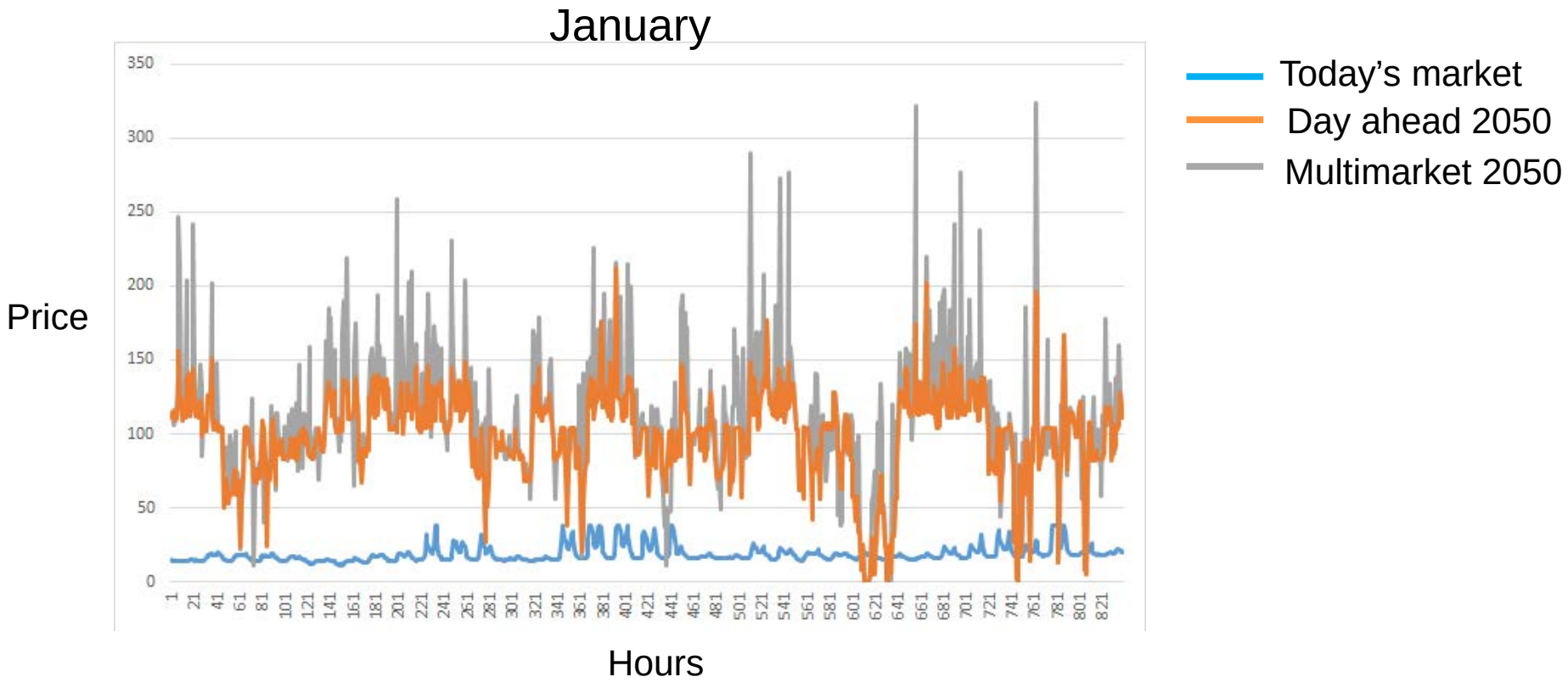


Prices for different scenarios

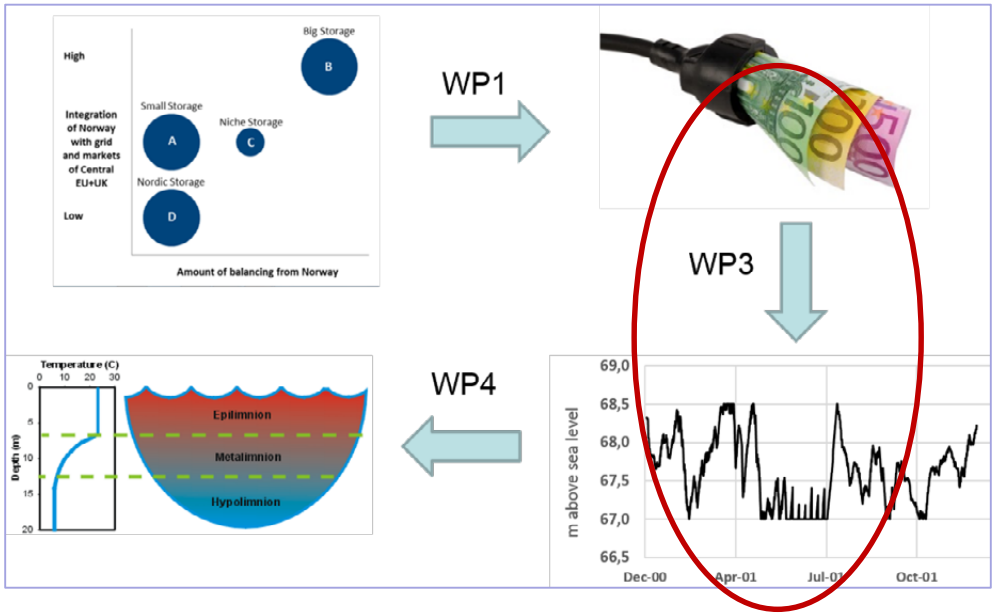
One year



Prices for different scenarios



Effects on operational regime in Lake Suldalsvatnet

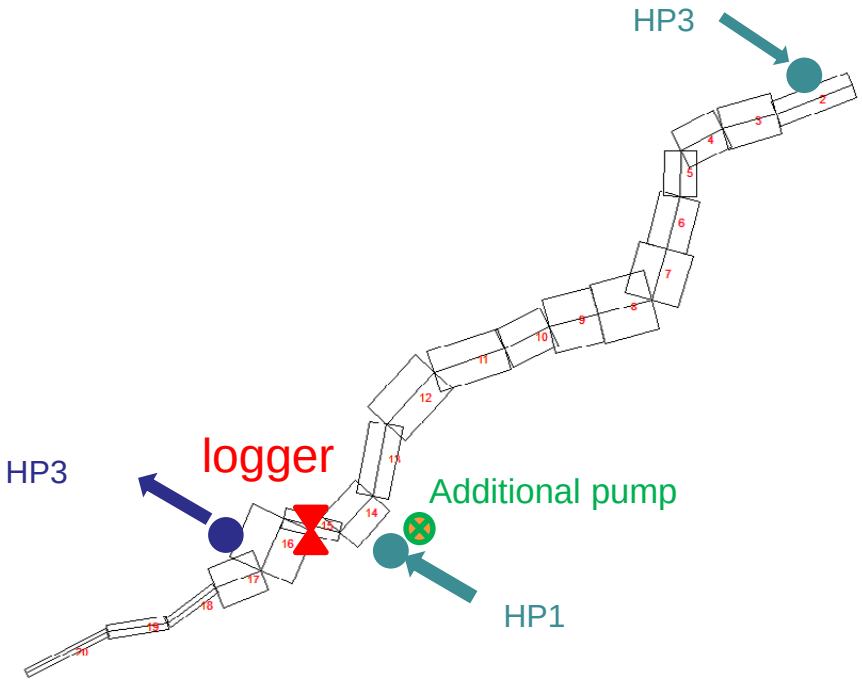


Modelling 5 comparisons

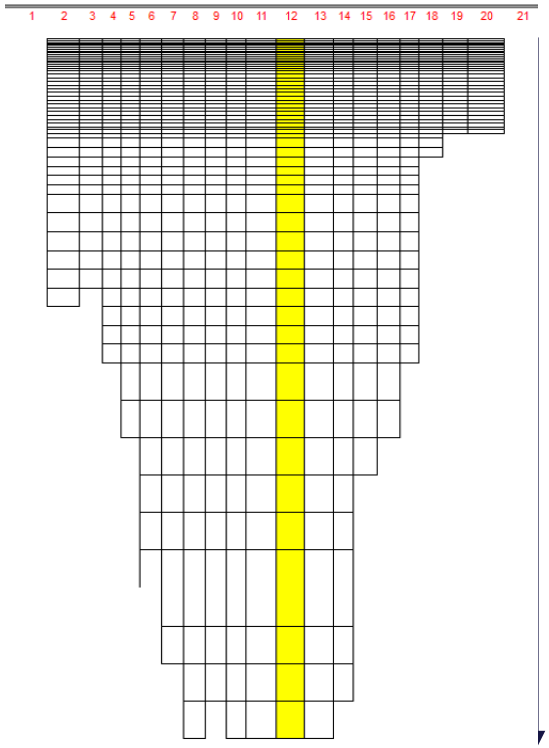
- Today
- Multimarket scenario
- Day ahead scenario
- Multimarket scenario + pump
- Day ahead scenario + pump

Lake Suldalsvatnet in CE-QUAL-W2

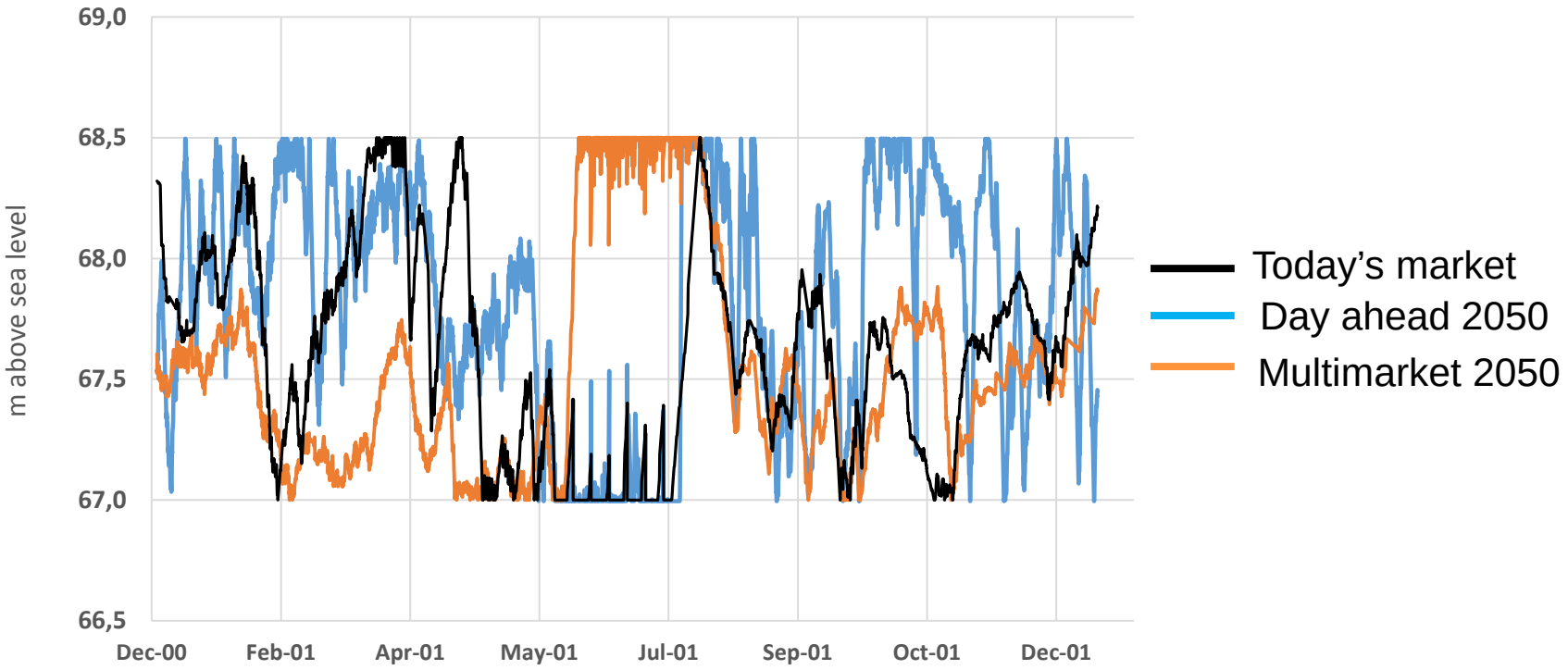
Top view



Side view

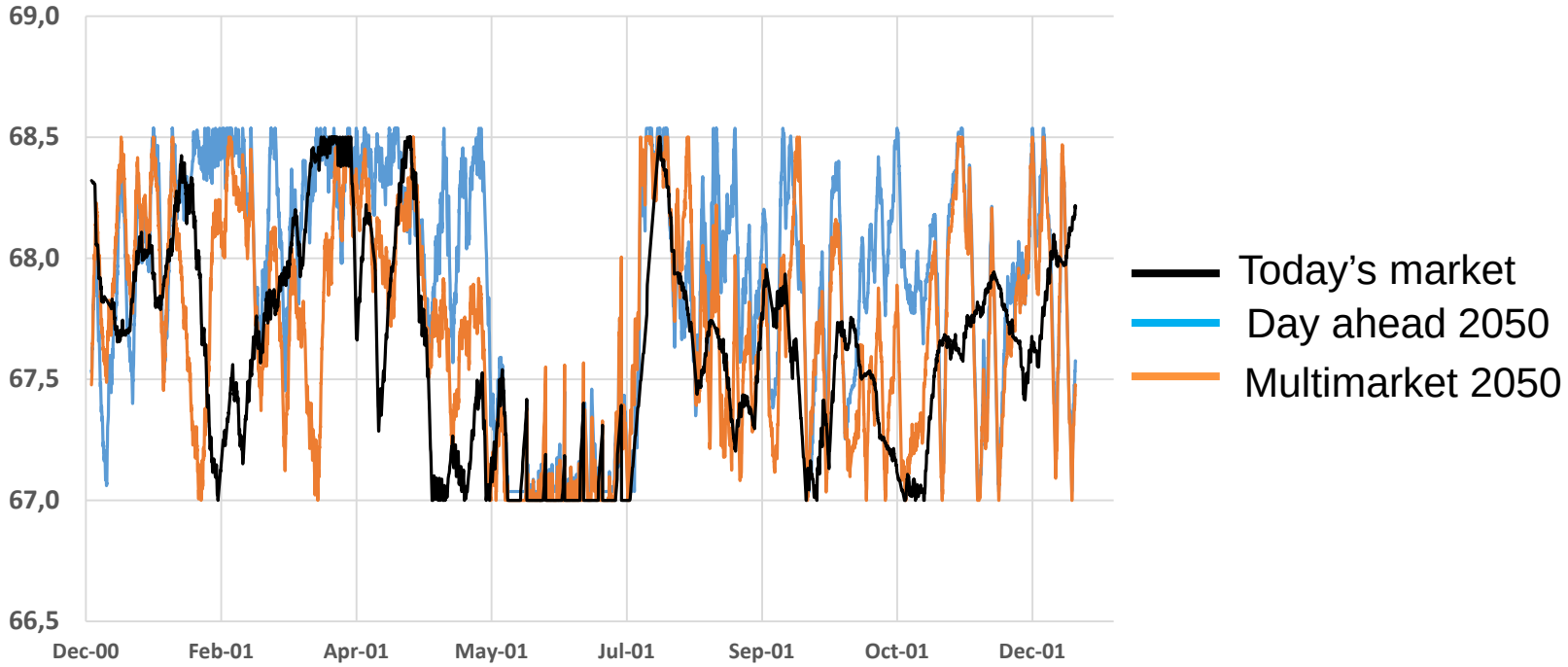


Effects on water level fluctuations

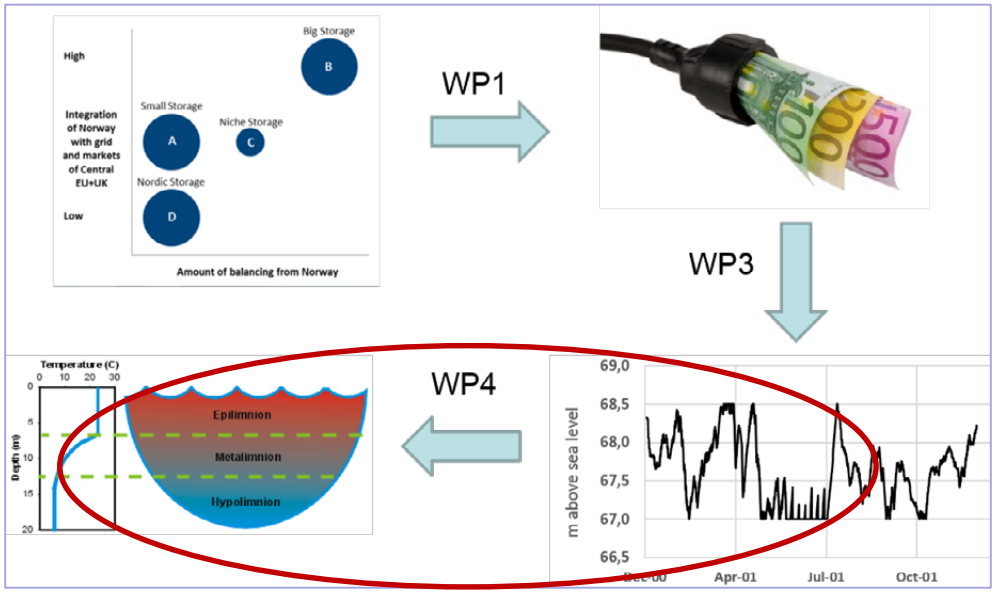


Effects on water level fluctuations

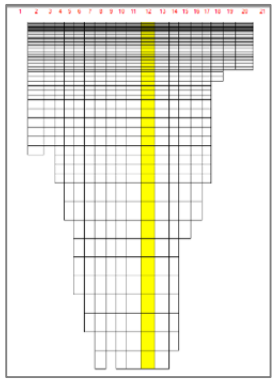
With additional pump

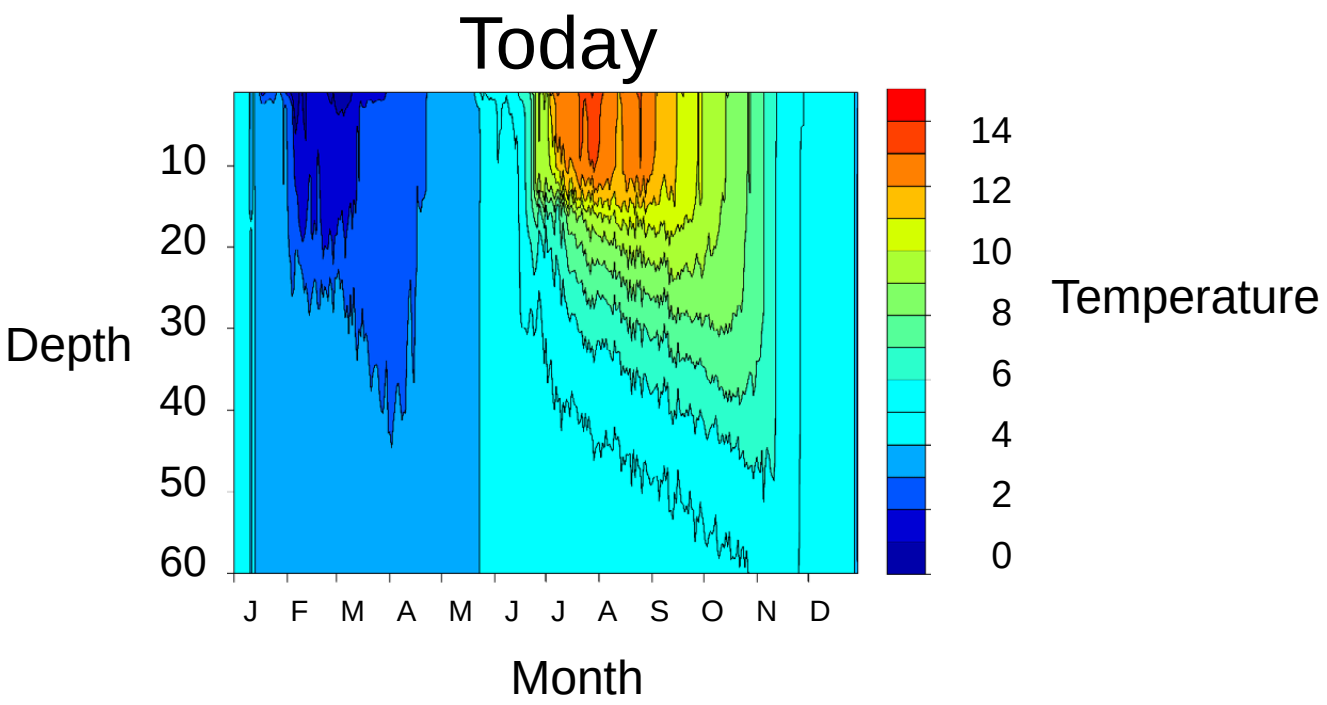


Effects on reservoir temperature

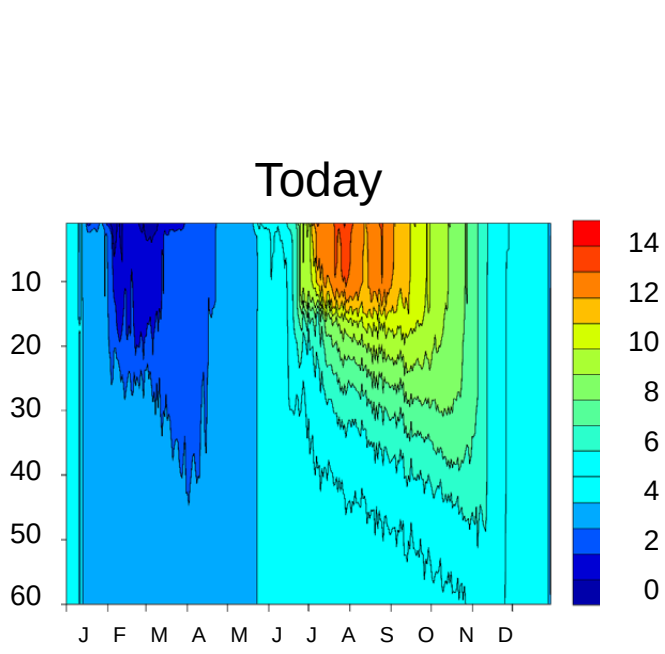


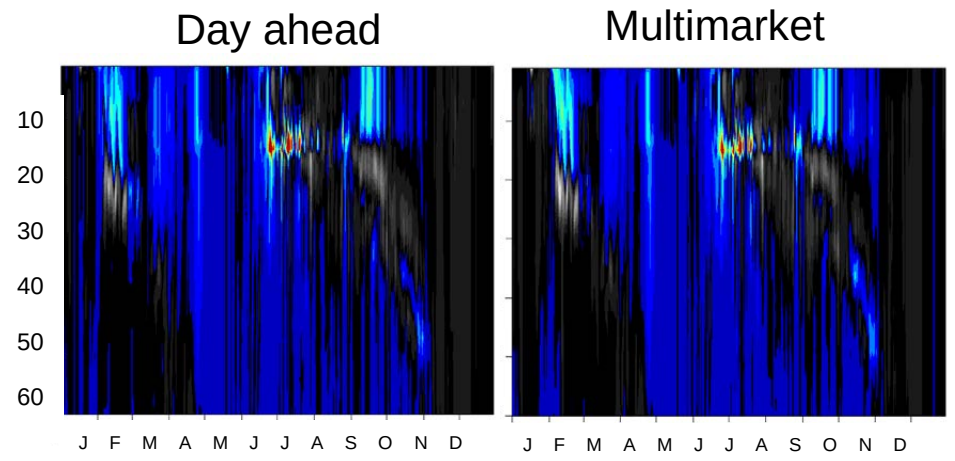
Temperature profile Lake Suldalsvatnet

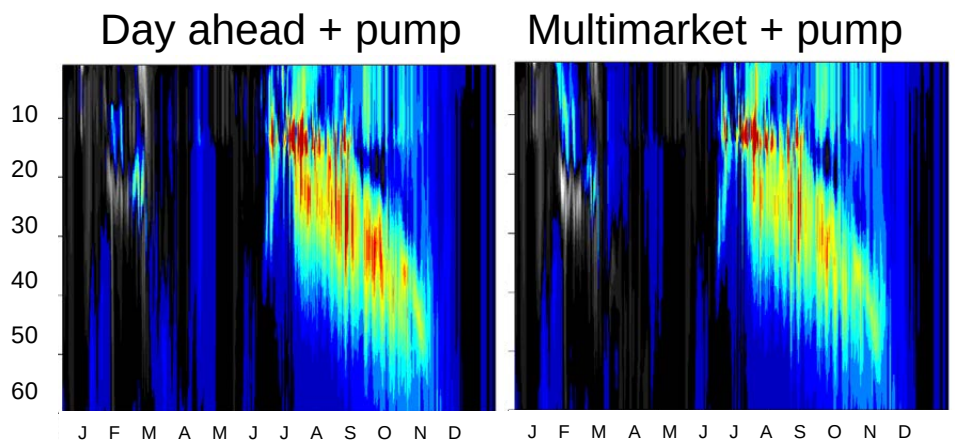


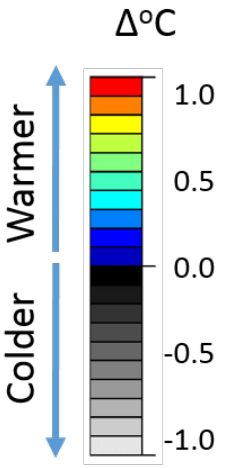


Temperature changes



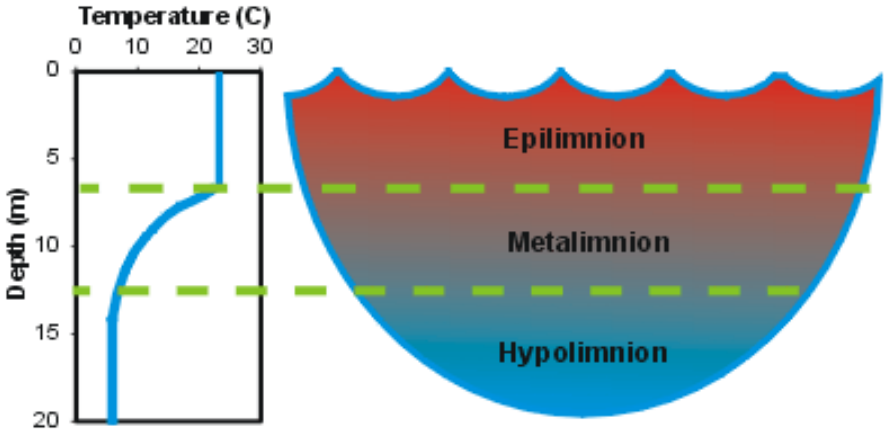






Thermocline and heat sum

	Today	Day ahead	Mulimarket	Day ahead + pump	Multimarket + pump
Thermocline depth (m)	62.3	60.2	60.4	75.8	75.4
Sum of temperature	892.5	882.1	873.6	1018.2	1002.2



Preliminary conclusions from Lake Suldalsvatnet

- Small temperature changes in both future price scenarios without additional pump
- With additional pump:
  - Temperature increase in several depths over several months
  - Thermocline 15 m deeper
  - Large increase in total heat sum
  - Similar effect in both price scenarios
- Depends on pump properties!

Lake Suldalsvatnet a typical reservoir?

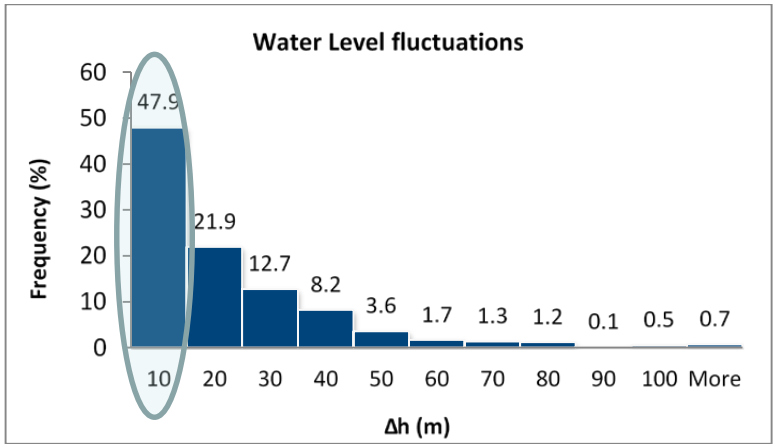
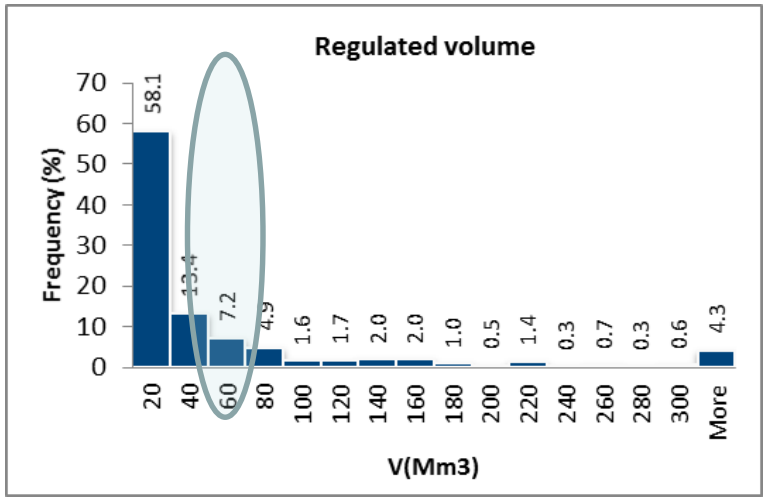


Figure 1. Water level amplitude distribution



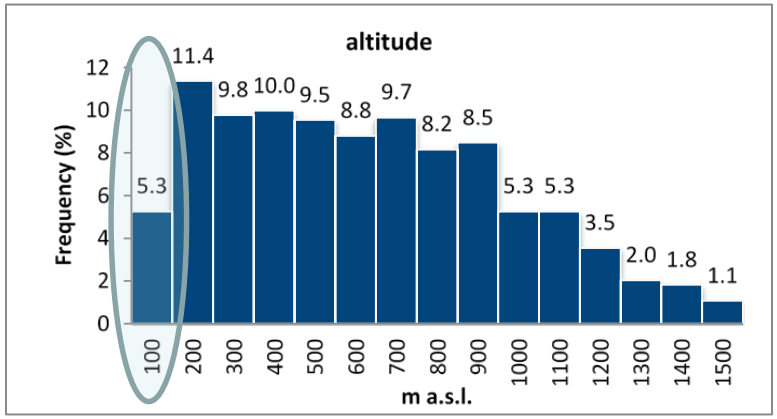


Figure 1. Altitude distribution

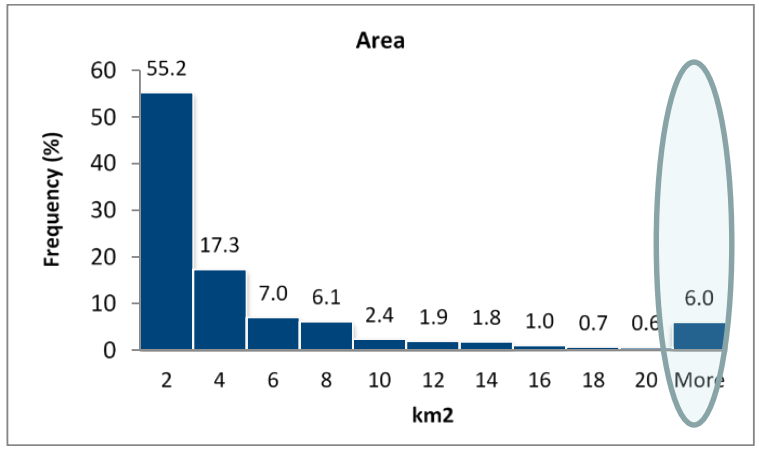
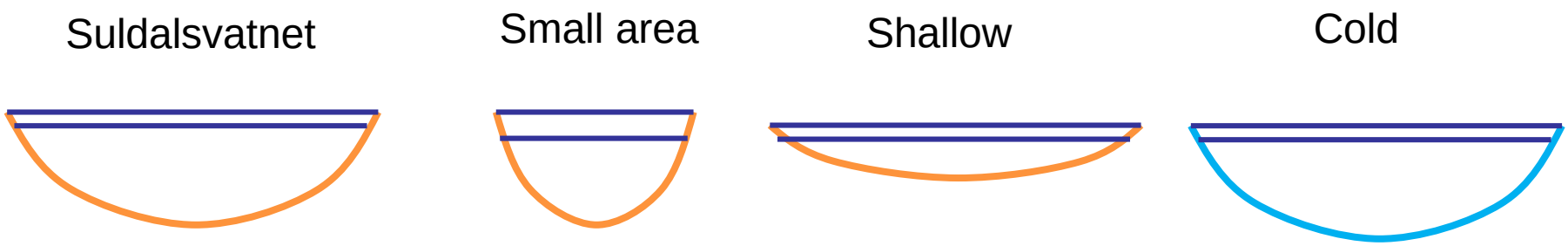


Figure 1. Area distribution

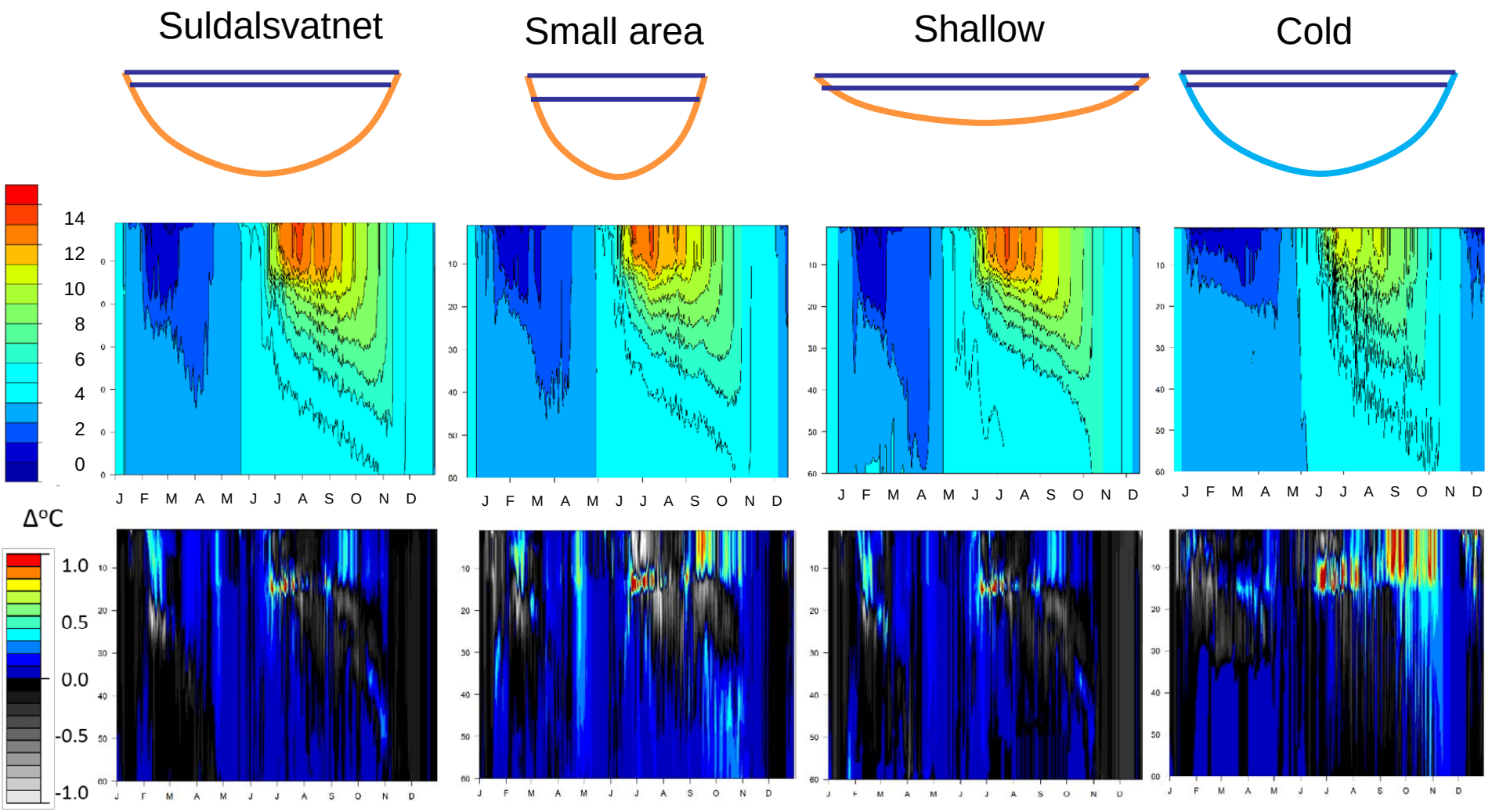
What if Lake Suldalsvatnet had different properties?

- Repeated exercise with different «reservoir types»
- Keep same regulated volume (44 Mm^3), but vary
  - Area
  - Depth
  - Climate zone

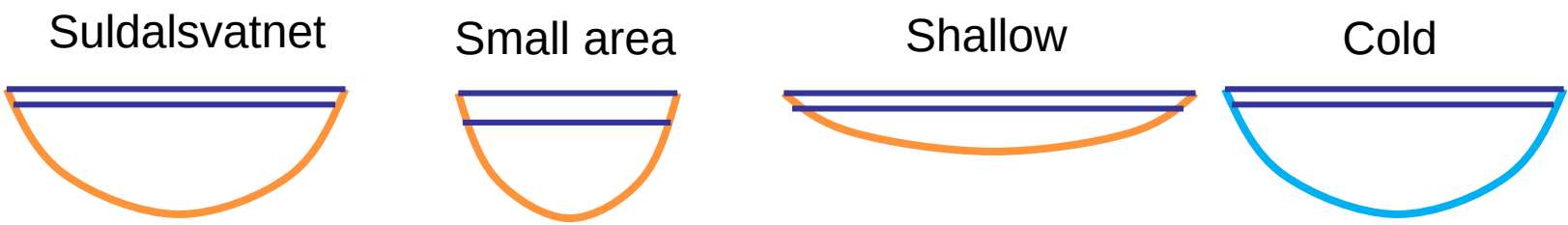
- 4 preliminary comparisons:



Today vs. multimarket



Today vs. multimarket



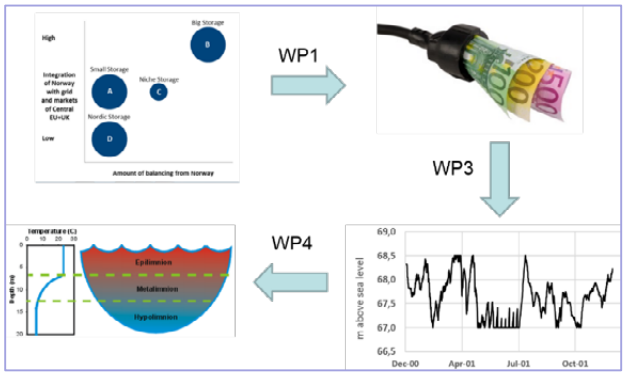
	Suldal today	Suldal multimarket	Small today	Small multimarket	Shallow today	Shallow multimarket	Cold today	Cold multimarket
End of spring mixing	Jun 03	Jun 03	Jun 15	Jun 15	Jun 03	Jun 03	Jun 05	Jun 18
Beginning of autumn mixing	Nov 09	Nov 08	Nov 05	Nov 06	Okt 29	Okt 29	Okt 29	Nov 05
Thermocline depth (m)	62.3	60.4	67.5	57.2	44.1	52.1	36.4	28.7
Sum of temperature	892.5	873.6	914.3	865.1	935.5	918.9	773.6	731.6

Preliminary conlusions from «reservoir type» comparisons

- Larger changes in depth of thermocline in smaller, shallower and colder lakes, than in Lake Suldalsvatn
- Decrease in total temperature sum in all types
- Temperature changes strongest in colder lakes
  - Changes in timing of spring and autumn mixing
- We will continue with more types comparisons during autumn, including interactions

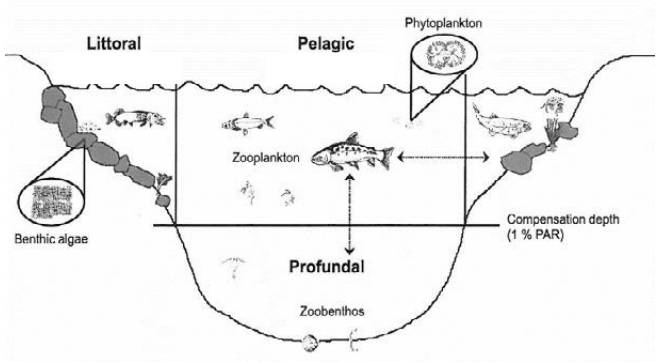
Take home message 1

- We develop a methodology in HydroBalance
  - New link between market optimization and environmental effects in reservoirs
  - First project about environmental effects of balancing
  - No general, final conclusions at this stage, but still very useful for understanding mechanisms and potential effects



Take home message 2

- Still weak understanding of actual processes in reservoirs under todays operational regime
  - Environmental effects in reservoirs poorly studied
  - Link between physical and ecological processes not properly tested
  - Effects are local and many things interact with each other



Take home message 3

- The method we have tested can improve future studies
  - In order to give better recommendation for reservoirs and environmental effects we need more data
  - Temperature loggers and depth maps please!
  - We can predict more details in more cases if calibration data are available

Contact

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