Hydropower impacts on brown trout production in Norwegian reservoirs

**Antti Eloranta**, Ingeborg Helland, Ola Ugedal, Anders Finstad & Odd Terje Sandlund
The Variable Position of Arctic Charr (*Salvelinus alpinus* (L.)) in Subarctic Lake Food Webs
Hydropower in Norway

- 97 % (~143 TWh) of energy production in 2012
- 70 % of large watersheds are affected
Norway as a study system

- Altitudinal and latitudinal gradients
- >450,000 lakes, >40,000 with fish
- Brown trout economically important and most common fish
- Most studies done in rivers, few in reservoirs

→ HydroBalance aims to fill this gap
"Eye-balling" lakes and reservoirs
"Eye-balling" catches in reservoirs
LAKES ($n = 81\ 636$)

- **Area**
  - Mean = 0.21 km$^2$
  - Range = 0.001–369 km$^2$

- **Altitude**
  - Mean = 518 m a.s.l.
  - Range = 0–1844 m a.s.l.

- **Shape**
  - Mean = 1.6
  - Range = 1.0–12.9

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

RESERVOIRS ($n = 757$)

- **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**
  - Mean = 2.5
  - Range = 1.1–10.5
Study question and method

- How lake characteristics and hydropower affect brown trout production?
  - Trout CPUE (g/100 m² net/night) data from test fishings and reports (615 lakes)
  - Other data from national and international authorities and GIS databases (477 lakes)

- Linear models in R 3.1.1
  - Generalized Least Squares
  - AIC for model selection (backward elimination)
Explanatory variables

- Regulation (unregulated vs. regulated)
- Fish community (allopatric vs. sympatric)
- Lake surface area
- Catchment productivity: NDVI = “greenness index”
  - Correlates with climate and catchment properties
- Ice cover period
  - Based on annual mean air temperature

NDVI = Normalized Difference Vegetation Index
Results (615 lakes)

- Slightly lower trout biomass in regulated lakes

![Box plot showing log CPUE (g/100 m²/night) for unregulated and regulated lakes. The plot indicates a statistically significant difference with t = 2.67, p = 0.008. Unregulated n = 384, Regulated n = 229.]
Results (615 lakes)

- Lower trout biomass in large lakes and in sympatric fish communities

![Graph showing the relationship between log CPUE (g/100 m²/night) and log Area (km²)](image)

*Correlation coefficient: r = -0.27, p < 0.001*

![Box plots showing CPUE comparison between Allopatric and Sympatric lakes](image)

- **Allopatric**:
  - n = 358
  - t = 10.2, p < 0.001
- **Sympatric**:
  - n = 242
Modelling results (477 lakes)

- Best model:
  \[ \log(\text{CPUE}) \sim \log(\text{Area}) + (\text{FishCom}) + \text{NDVI} + \log(\text{Area}) : \text{NDVI} + \text{FishCom} : \text{NDVI} \]

<table>
<thead>
<tr>
<th>Parameter</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(Area)</td>
<td>2.43</td>
<td>0.015</td>
</tr>
<tr>
<td>FishCom</td>
<td>2.11</td>
<td>0.035</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.35</td>
<td>0.726</td>
</tr>
<tr>
<td>log(Area) : NDVI</td>
<td>-2.80</td>
<td>0.005</td>
</tr>
<tr>
<td>FishCom : NDVI</td>
<td>-2.66</td>
<td>0.008</td>
</tr>
</tbody>
</table>
Modelling results (477 lakes)
Modelling results (477 lakes)

**Allopatric**

- Unregulated
- Regulated

**Sympatric**

- 1st quantile NDVI
- 3rd quantile NDVI

log CPUE (g/100 m²/night) vs. log Area (km²)
Conclusions

- Lake size and presence of other fish species have stronger impact on trout production than hydropower
  - Particularly evident in lakes with "greenest" catchments
- Compensatory trout stockings may partly mask hydropower impacts
Future plans

- More study lakes
- Studying realized regulation patterns prior to test fishing
- Food webs in unregulated, moderately and heavily regulated lakes
  - Stable isotope analyses
  - Parasites, heavy metals, fatty acids?
Thank you!