Hydropeaking in Norway: Economy and ecology

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What we will talk about

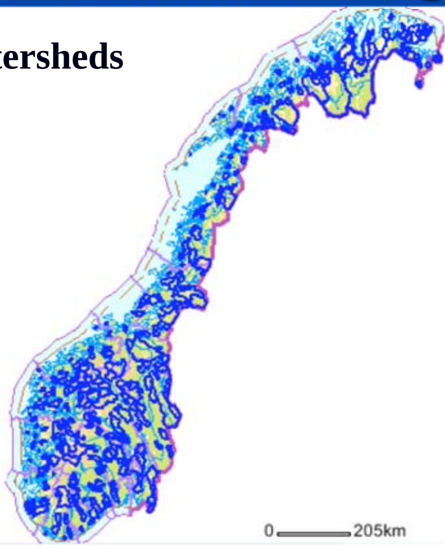
Background
- Hydropower in Norway

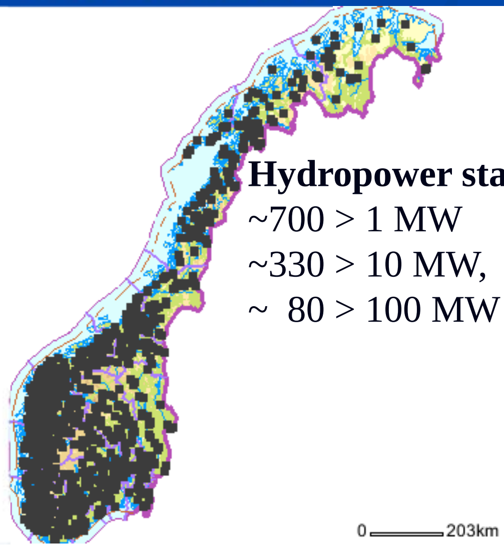
Hydropeaking
- Hydropower licences
- Change in energy policy
- Ecological impacts and research
- Case studies

Hydropower in Norway

- 99% hydropower
- 2/3 of all watersheds are affected
- ~ 700 stations larger than 1 MW

Affected watersheds





Hydropower stations
~700 > 1 MW
~330 > 10 MW, 97%
~ 80 > 100 MW

Hydropower production in Norway

- Total production about 121 TWh
- **Hydropower stations are energy-dimensioned (stable domestic supply)**
- Installed effect 29 000 MW
- Average run time 4 200 hours/year
- **Large reservoir capacity: ~ 50% of European reservoir capacity, about 85 TWh (62 mill. m^3), i.e. 70% of annual total production → flexibility**
- **85% of production facilities are publicly owned, all projects publicly regulated (by law)**
- Statkraft **Crown corporation, ~40%**

Blåsjø reservoir
Area 84.5 km
Volume 3.1 km^3
Energy 7.8 TWh

How is hydropower and hydropeaking regulated?

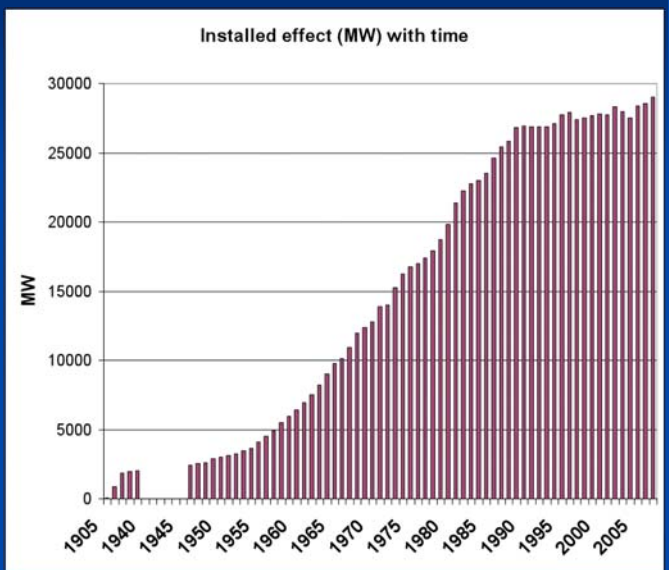
Water/hydropower licences

- **Federal licence required** to build and operate
- Such decisions and licences are regulated by three acts:
- **The Water Resource Act** (2000) – general, min. flows
- **The Water Regulation Act** (1917) – hydropower licences
  - specific, detailed
- **The Energy Act** (1991)
  - new market energy policy

Hydropeaking
Water/hydropower licences

- **The licence will specify how to operate**, based on
  - political (economic) decisions
  - best knowledge (at the time)
- The licence is given **for a time period** (~ 50 years);

  most licences given 1960-1990 (see Figure)
- **Few changes** within that period



Hydropeaking
Water/hydropower policy/licences

- **Stable national energy supply until ~ 1990**

  large reservoirs

  sufficient domestic effect

  → little hydropeaking
- **The water licences did not consider hydropeaking**

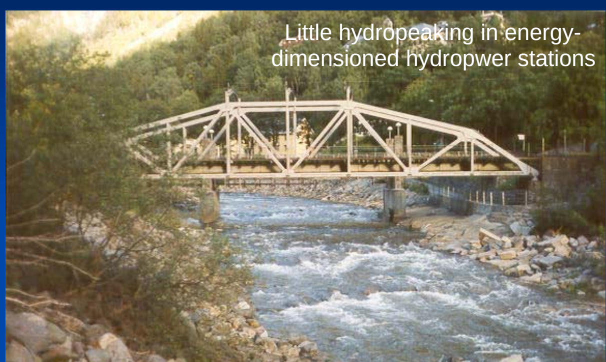
  → hydropeaking unregulated

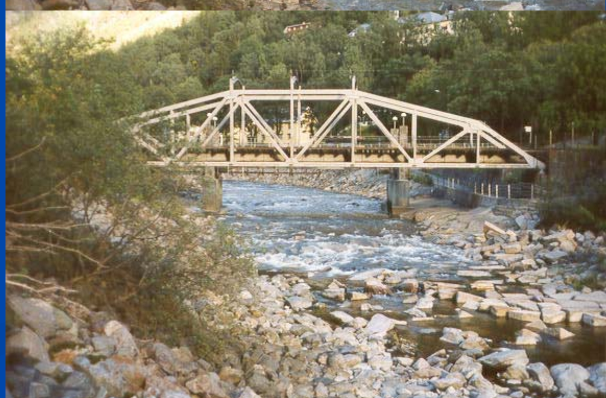
Hydropeaking – right now
Deregulation and flexibility

- **Few hydropeaking operations**
- A new **deregulation policy** with **export/import** to an effect-demanding (North-) European market → **hydropeaking**
- **Large reservoirs → hydropeaking**
- **Combine with alternative energy sources** (wind, wave) → **hydropeaking**
- **Many licences are coming up for renewal**
- **Response:**

  Federal: fund research on feasibility and ecological impacts in rivers

  Producers: fund research on feasibility and mitigation





"Effect" project 1997-2004 2008-

Ecological impacts of hydro peaking in rivers :

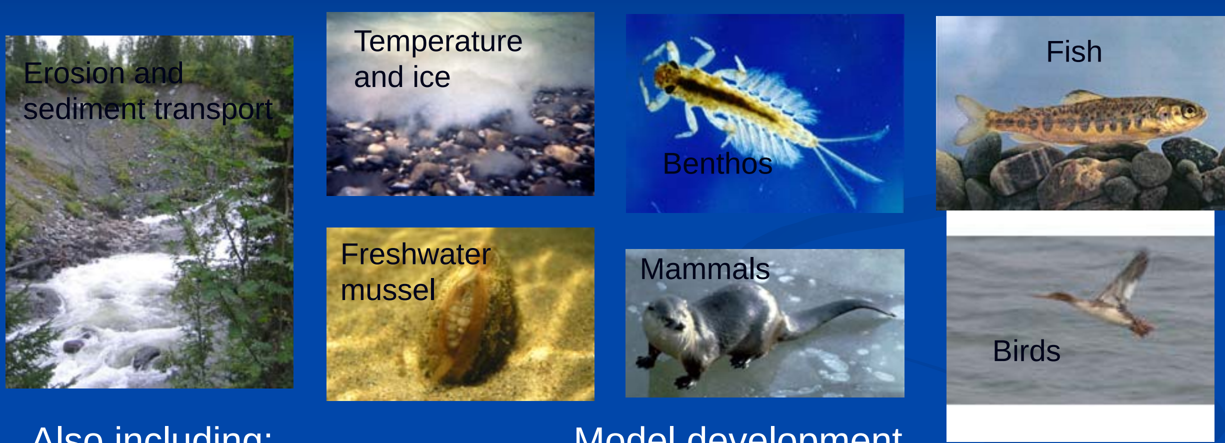
Focus on fish stranding, stress, behaviour, habitat, movement

A research collaboration between:

SINTEF NTNU NINA Norsk institutt for naturforskning Universitas Osloensis NIVA

Environmental impacts of hydropeaking

The main objective is to assess environmental impacts of hydropeaking and to describe how, when and where hydropeaking may be done with acceptable impacts on the ecosystem. Mitigation strategies will also be addressed.



Also including:

Model development

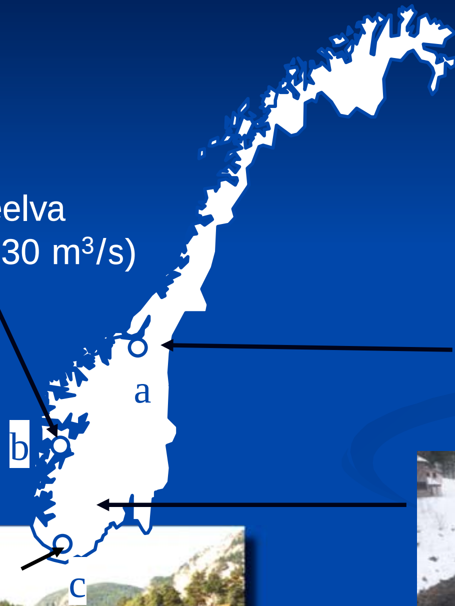
Catalogue of measures and mitigation

Categorizing hydropower plants

KMB project 2009-2012

Hydropeaking case studies - Norway

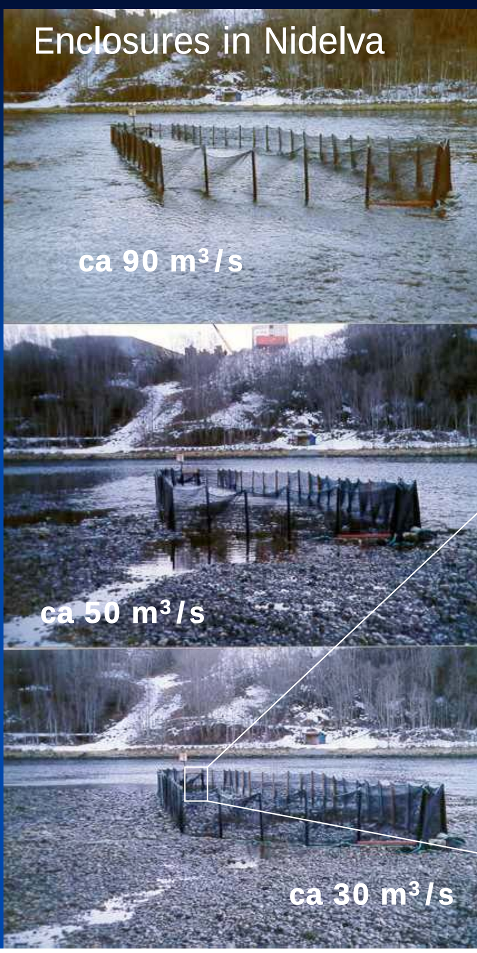
Daleelva (5 - 30 m³/s)



Nidelva (30 - >110 m³/s)
+ experimental stream

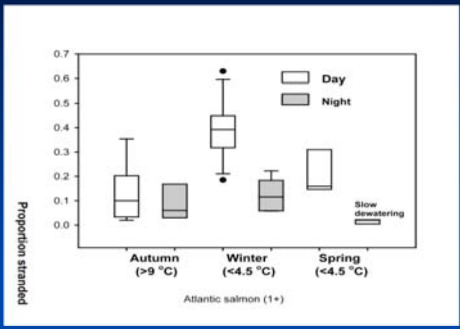
Stranding of young fish during de-watering events

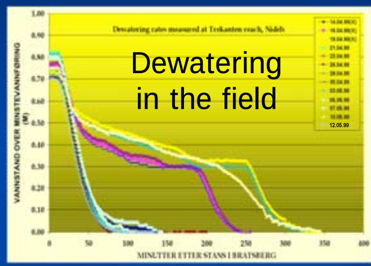
Stranding experiments



Netbag
at low flow

Stranding field experiments - wild Atlantic salmon (1+) - normal substrate



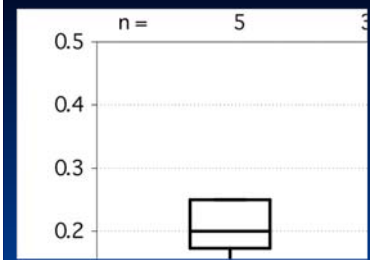


Saltveit *et al.* 2001

- High stranding at low temperatures (in winter) in the day
- Low stranding during slow drawdown

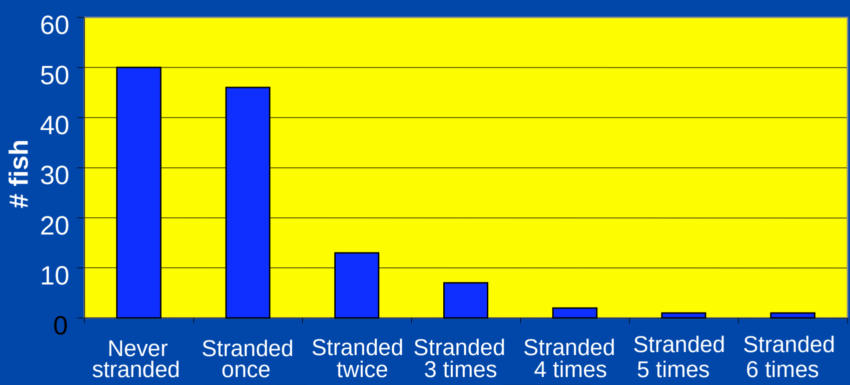
Saltveit et al, 2001

Experimental stream

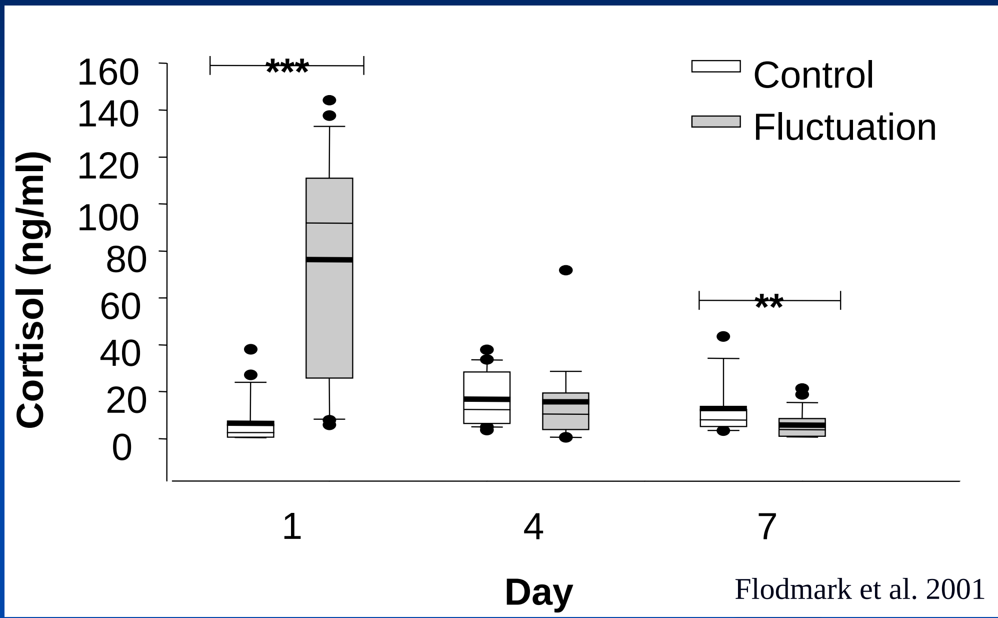


Upper figure. Box plot comparison of proportion stranded summer-old (0+) brown trout depending on dewatering speed. The figure shows reduced stranding by reduced dewatering speed, but not total elimination of stranding.

Lower figure. Stranding of individual fish (PIT tagged) subject to daily peaking. (Water was put back on to avoid mortality.) The figure shows that 50 fish never stranded.

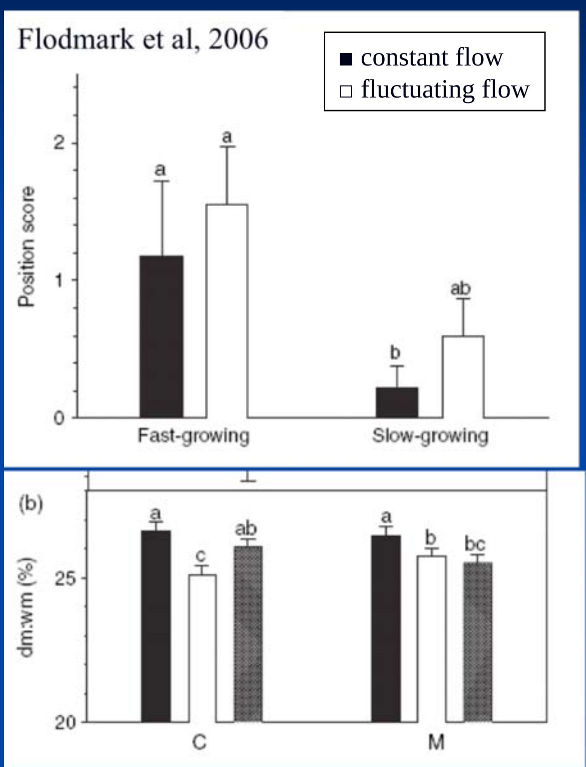


Stress response and habituation to daily flow fluctuations (brown trout)

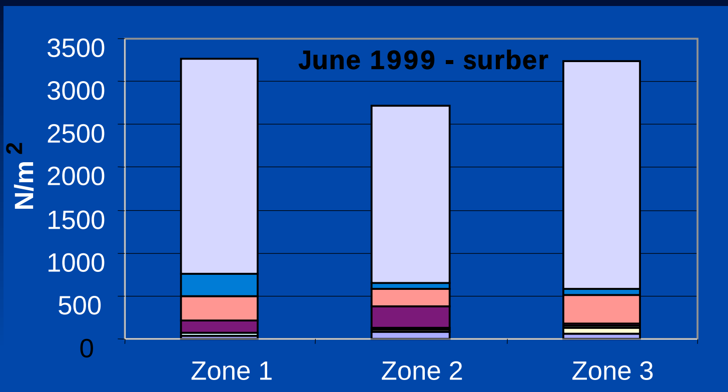


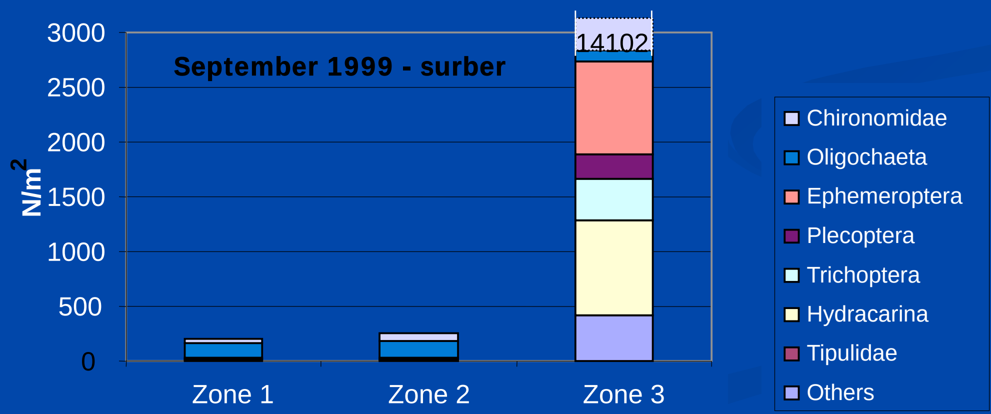
- **Non-stranded brown trout seems to adapt to flow fluctuations within 4 days**
- **Flow fluctuations with little increase in dry river banks may be less harmful to fish**

Behavioural habituation to daily flow fluctuations (brown trout)



Hydropeaking and benthic fauna (invertebrates) : before and after one month of hydro peaking





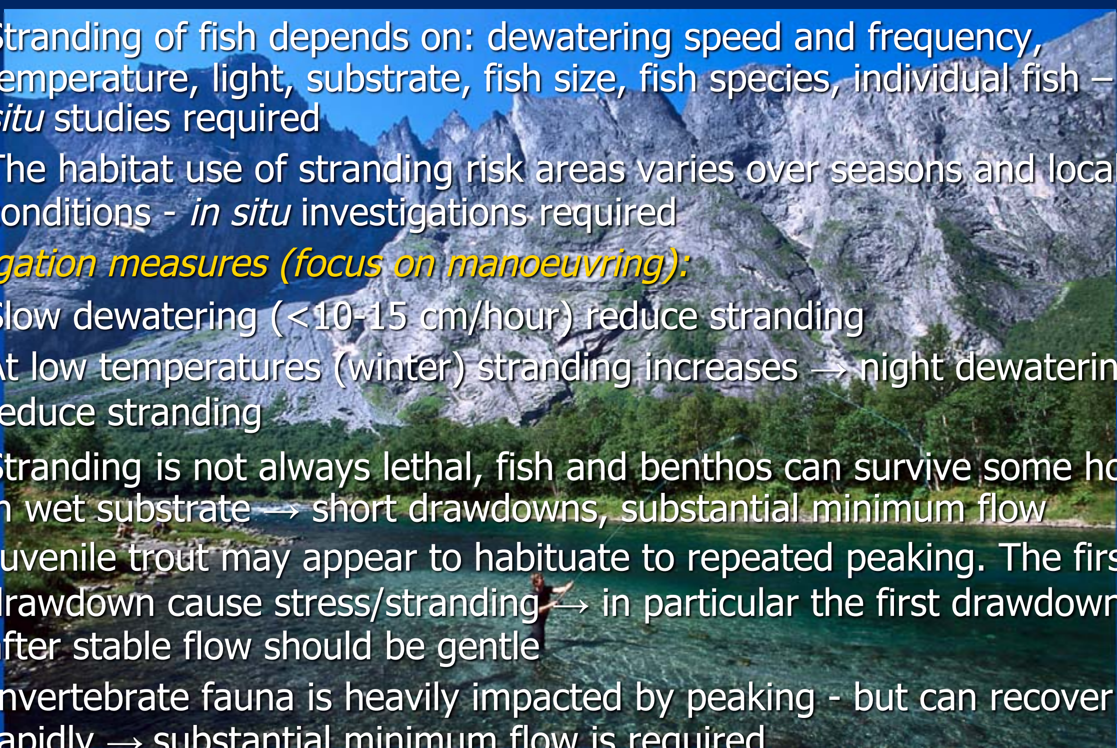
Zone 1:
Dry during all peaking

Zone 2:
Dry at most peaking

Zone 3:
Always in water

Hydropeaking in Norway:

How to do peaking environmental friendly in rivers?



- Stranding of fish depends on: dewatering speed and frequency, temperature, light, substrate, fish size, fish species, individual fish – *in situ* studies required
- The habitat use of stranding risk areas varies over seasons and local conditions - *in situ* investigations required

Mitigation measures (focus on manoeuvring):

- Slow dewatering (<10-15 cm/hour) reduce stranding
- At low temperatures (winter) stranding increases → night dewatering reduce stranding
- Stranding is not always lethal, fish and benthos can survive some hours in wet substrate → short drawdowns, substantial minimum flow
- Juvenile trout may appear to habituate to repeated peaking. The first drawdown cause stress/stranding → in particular the first drawdown after stable flow should be gentle
- Invertebrate fauna is heavily impacted by peaking - but can recover rapidly → substantial minimum flow is required

THANK YOU!

http://www.energy.sintef.no/avd/Energisystemer/hydrology/effekt/hydpeak.htm

Some references:

Vehanen, T., Bjerke, P. L., Heggenes, J., Huusko, A. & Mäki-Petäys, A. 2000. Effect of fluctuating flow and temperature on cover type selection and behaviour by juvenile brown trout in artificial flumes. *Journal of Fish Biology* **56**: 923-937.

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Hydropeaking
Preliminary federal criteria for licencing

Economy:

- Size of hydropower station
- Reservoir capacity
- Location
- Transmission capacity

Ecology:

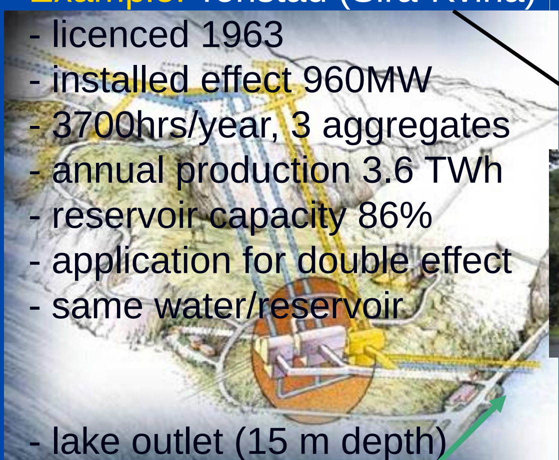
- Outlet (ocean, large lake/ reservoir)
- Waterways – length, type

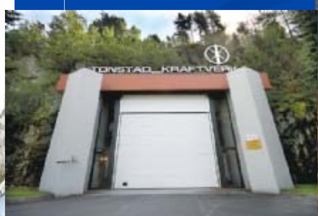
Hydropeaking:
An ongoing development in Norway

Estimated potential for hydropeaking: ~ 90 hydropower stations with installed effect 17000 MW today, increase by 16200 MW

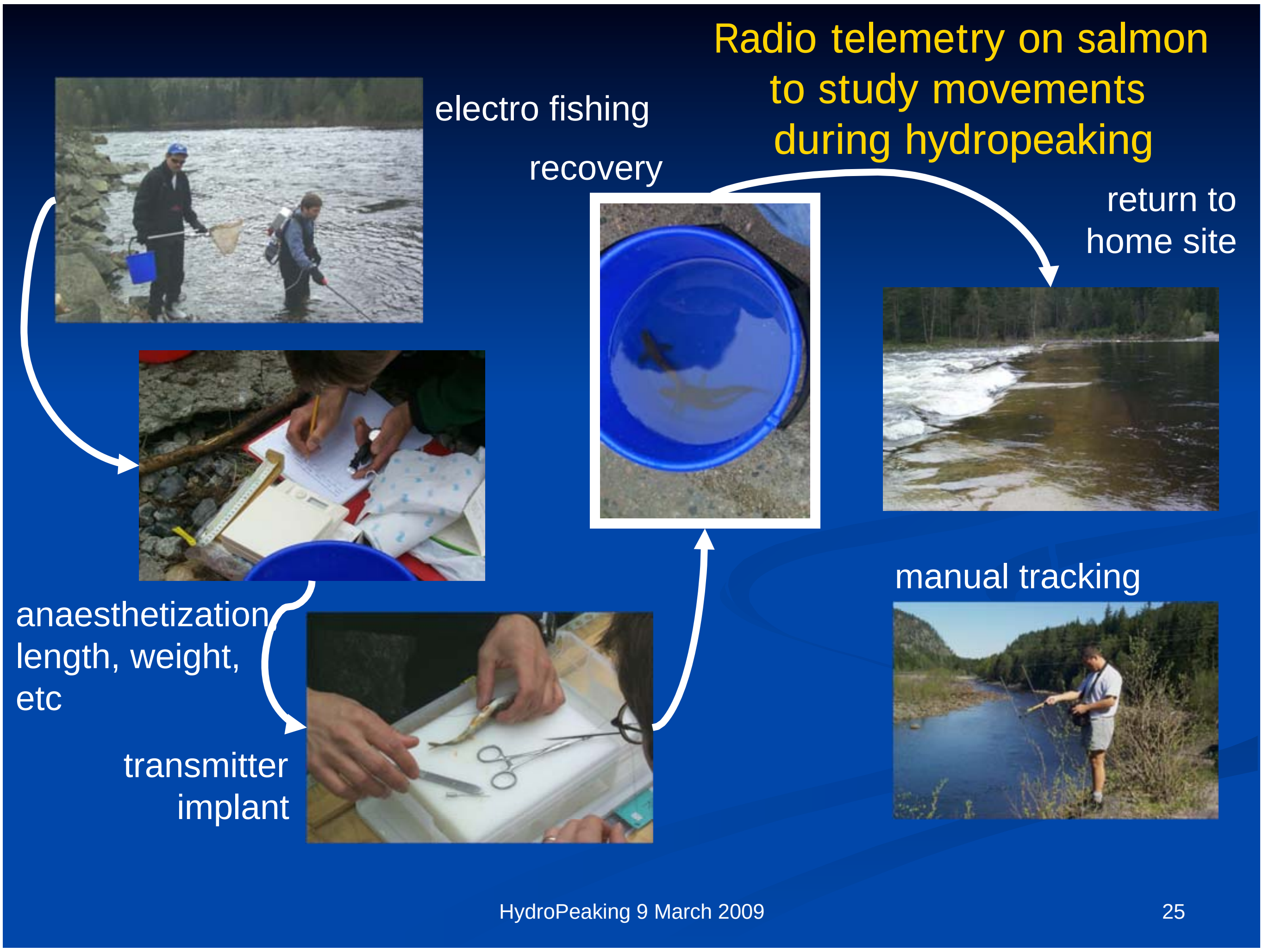
Example: Tonstad (Sira-Kvina)

- licenced 1963
- installed effect 960MW
- 3700hrs/year, 3 aggregates
- annual production 3.6 TWh
- reservoir capacity 86%
- application for double effect
- same water/reservoir
- lake outlet (15 m depth)





Tonstad Hydropeaking Licence Application



Juvenile (>10 cm) Atlantic salmon movement and habitat use during hydropeaking

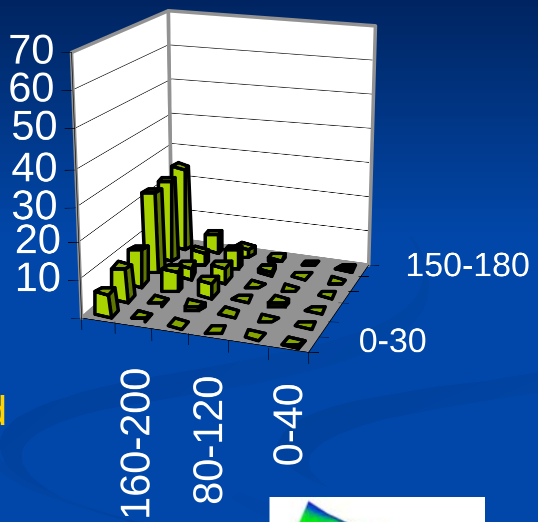
- Large **individual variations** in movements
- Juvenile salmon and trout **move more in more diverse habitats** (and less in homogenous habitats like large pools).
- Juvenile salmon and trout subjected to **hydropeaking did not change position** more often than during stable flows.
- Juvenile salmon was observed to never occupy areas with high stranding risk.
- Juvenile salmon and trout move when habitat quality is radically reduced, but not necessarily by habitat changes alone.
- Juvenile salmon changed positions less frequently after rapid increase in flow compared to decreasing or stable flow.

Berland *et al.* 2003

Hydropeaking and water vegetation

Hydropeaking produces specialisation:

- Some species were only found in permanently wetted areas
- Some species were only found in the ”regulated zone”



Hydropeaking may increase production of water vegetation because of repeated flushing of biomasses

- There was a relationship between depth and water vegetation
- No such relationship were found between water velocity and water vegetation