Multiconsult

Restoring Connectivity in Practice

- Innovative Mitigation Solutions

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(Discipline leader in Aquatic ecology)

- New Frontiers in Sustainable Hydropower Development -

Hydropower Sustainability Forum

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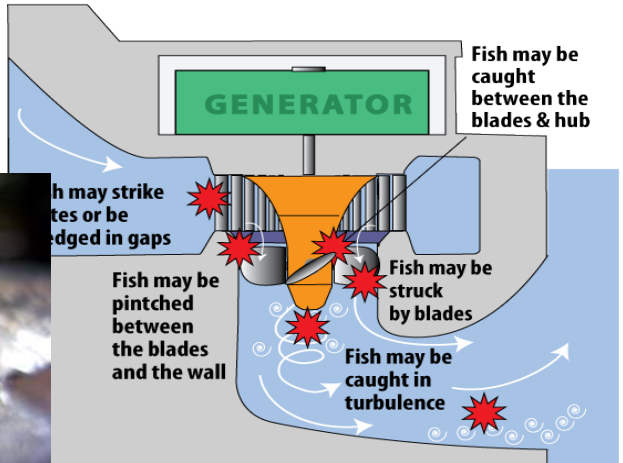
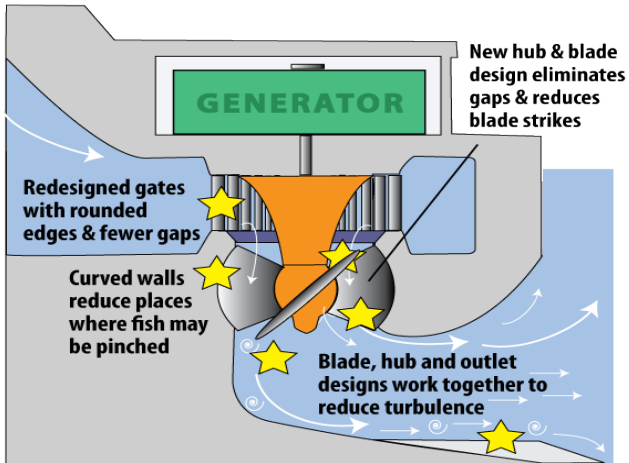
CONVENTIONAL TURBINES



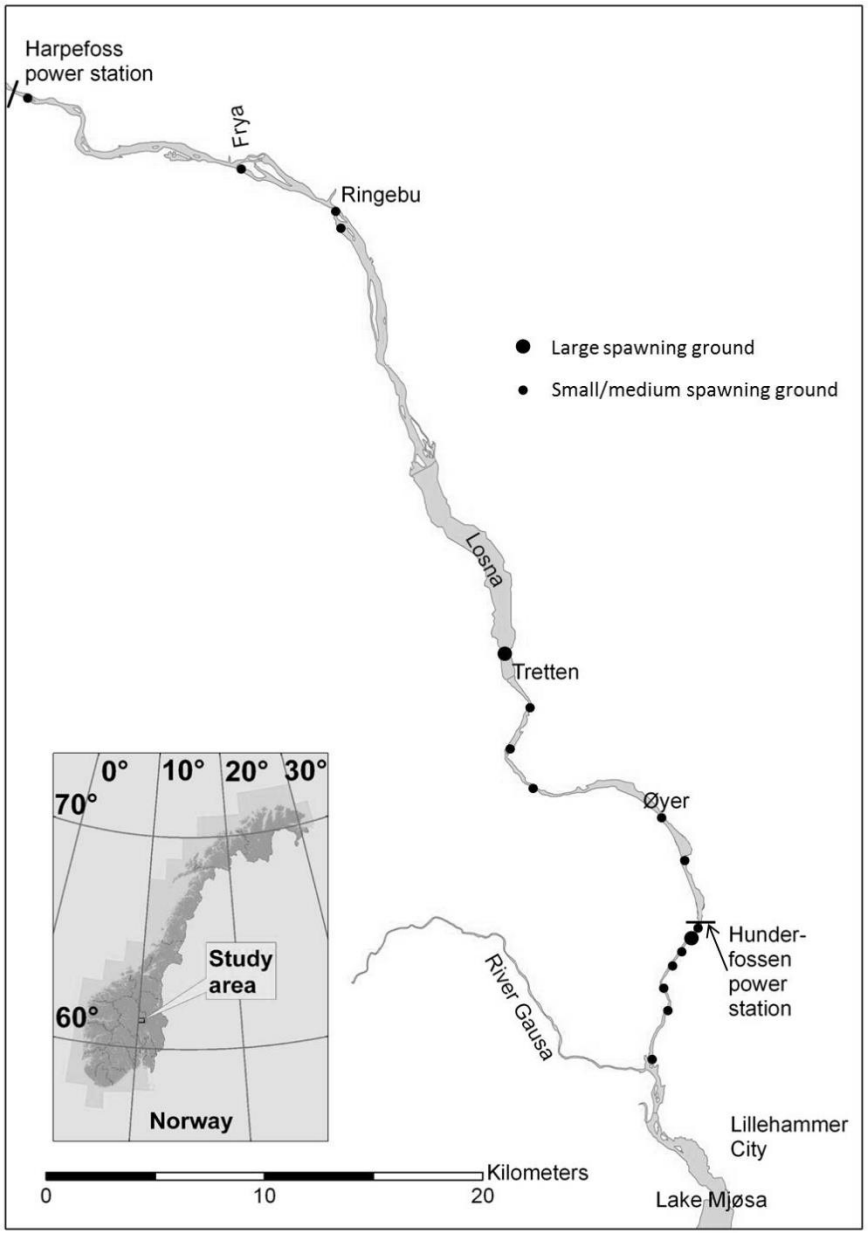
IMPROVED TURBINE DESIGN



Contents

- Practical studies on migrating brown trout past Hunderfossen power plant on River Gudbrandsdalslågen
  - Investigations of fishway efficiency
  - Investigations of downstream migrations past the dam
- Video from Hellefoss HPP on River Drammenselva
  - Downstream migrating salmon kelts in front of trash racks

Study area



- **River Gudbrandsdalslågen:**
  - Catchment area 11.500 km^2, of which 65% are alpine areas
  - Main river stem; 200 km
  - Discharge: 80-2500 m^{3}s^{-1}

- **Lake Mjøsa**

  Largest lake in Norway, 362 km^2

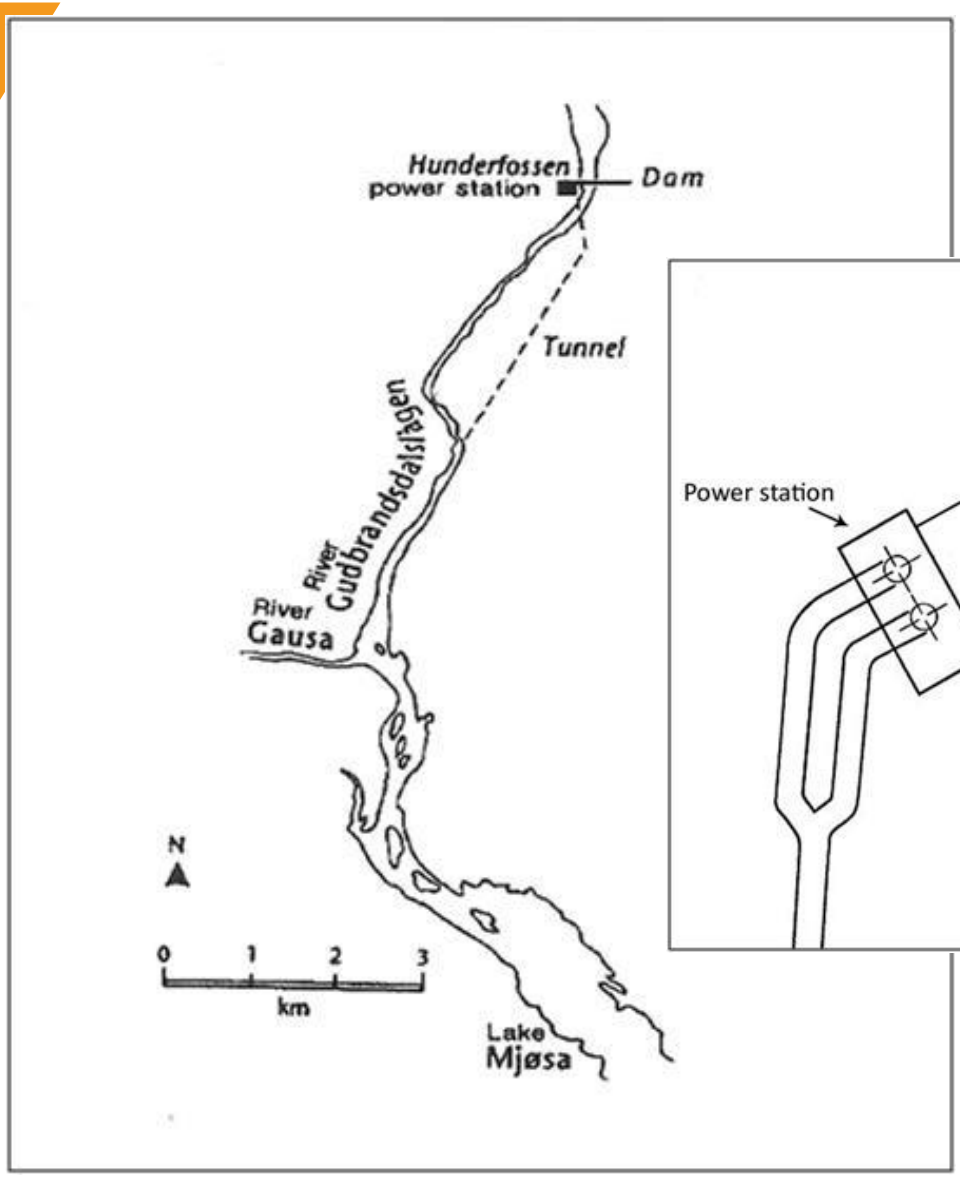
  20 fish species

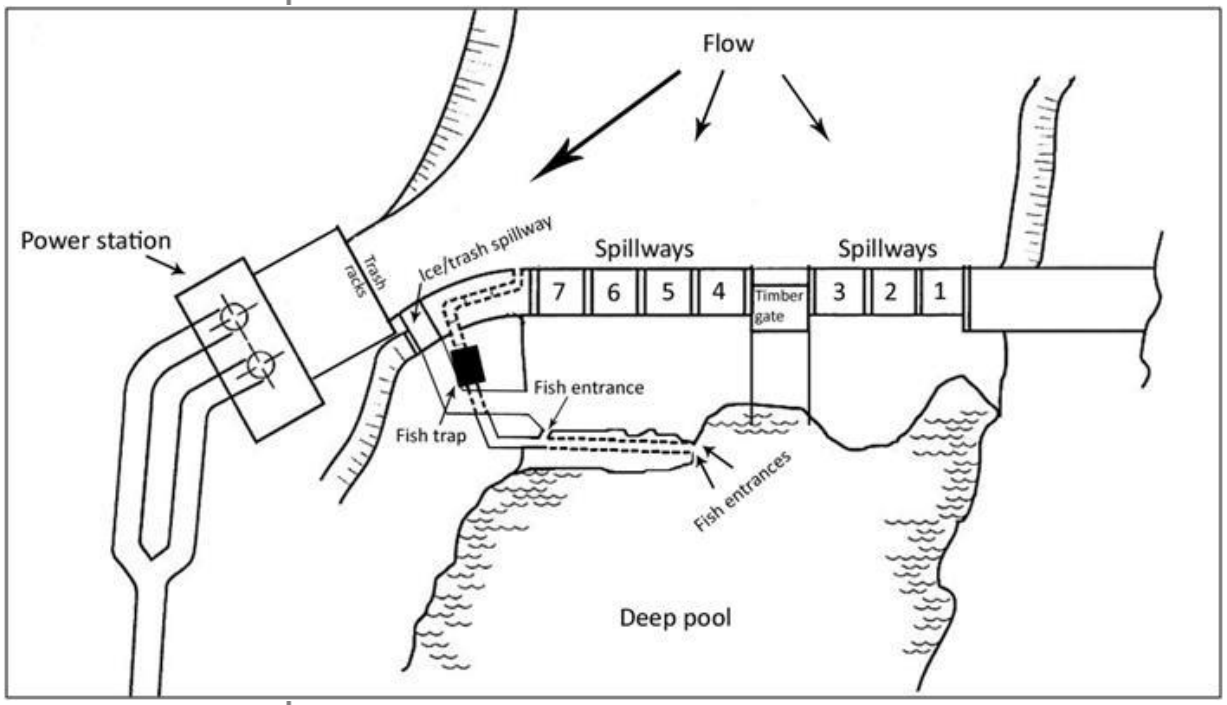
Modifications in the environment of the migrant brown trout

Reduced connectivity

- Hunderfossen power station
  - 2 Kaplan turbines; 2x150 m^3s^{-1}
  - Fish bypass section; 4.4 km
  - Fishway (discharge: 1.3 m^3s^{-1})
  - Spillways for deep water release

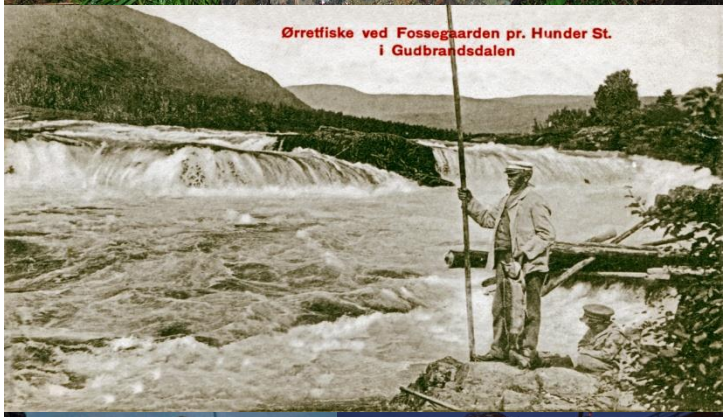




Hunderfossen
power station
Dam
Tunnel
River Gudbrandsdalslågen
River Gausa
N
0 1 2 3
km
Lake Mjøsa


Flow
Power station
Trash racks
Ice/trash spillway
Spillways
Spillways
7
6
5
4
Timber gate
3
2
1
Fish entrance
Fish trap
Fish entrances
Deep pool

The Hunder trout

- Iconic trout population in Norway
  - Private and commercial fishing records dates back to the Middle Age (Huitfeldt-Kaas 1917; Aass & Kraabøl 1999)
- Land-locked trout population, Baltic origin, eastern immigration route (Huitfeldt-Kaas 1918)
- Smoltification is kept intact (Lysfjord 1988)
- Smolt age/size; 4 yr/25 cm (Aass et al. 1989; Aass 1993)
- Fast-growing, large-sized and piscivorous individuals (Dahl 1910; Huitfeldt-Kaas 1917)
- Iteroparous (repeat spawners)
  - Spawns every 2nd yr; > 5 spawning runs/lifetime
  - Body weights up to 18-23 kg (Qvenild et al. 2009)
  - Average body weight of spawners; 3-4 kg

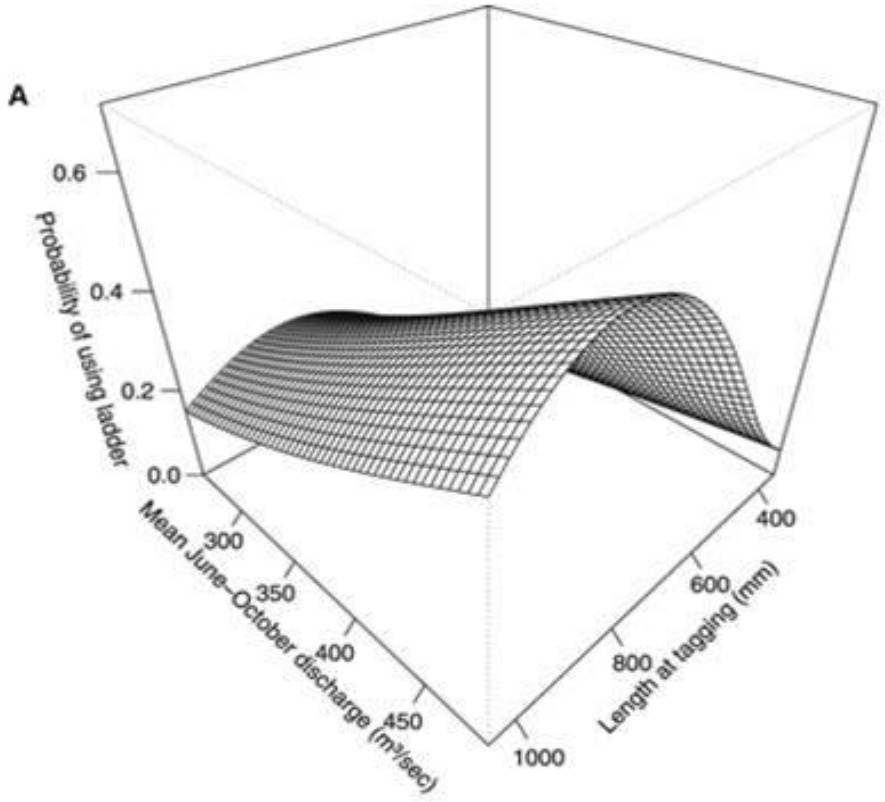


Investigations of fishway efficiency

- **Background**
  - Hydropower dams in rivers inflict fragmentation and reduced connectivity (Jungwirth 1998; Nilsson et al. 2005)
  - Establishment of fishways is a common mitigation feature to facilitate upstream fish passage (i.e. Travade & Larinier 2002; Schilt 2007)
  - Typically, fishway discharges constitute << 10 % of the pre-regulated flow
  - Assessments of efficiency and selectivity are important (Roscoe & Hinch 2010)

The Hunderfossen fishway

- Previous findings; Stabilizing body size selection
  - The fishway attributed as a phenotypic sorting mechanism (Haugen et al. 2008)
- But other problem areas are known (Arnekleiv & Kraabøl 1996)
- A capture-mark-recapture (CMR) experiment was performed to test selectivity

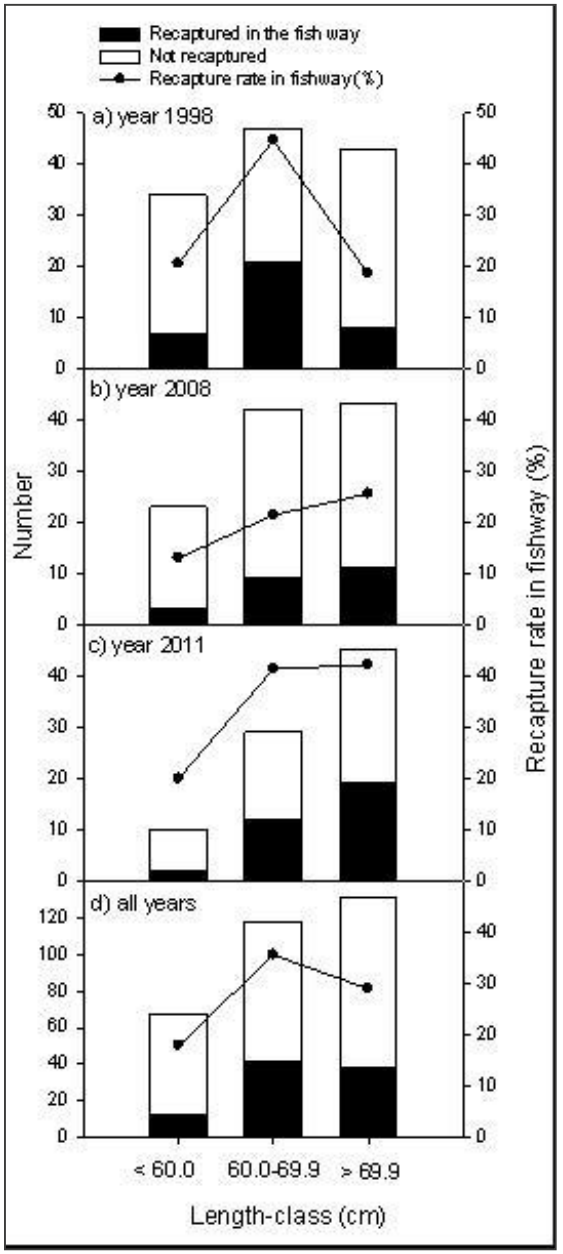


Study design

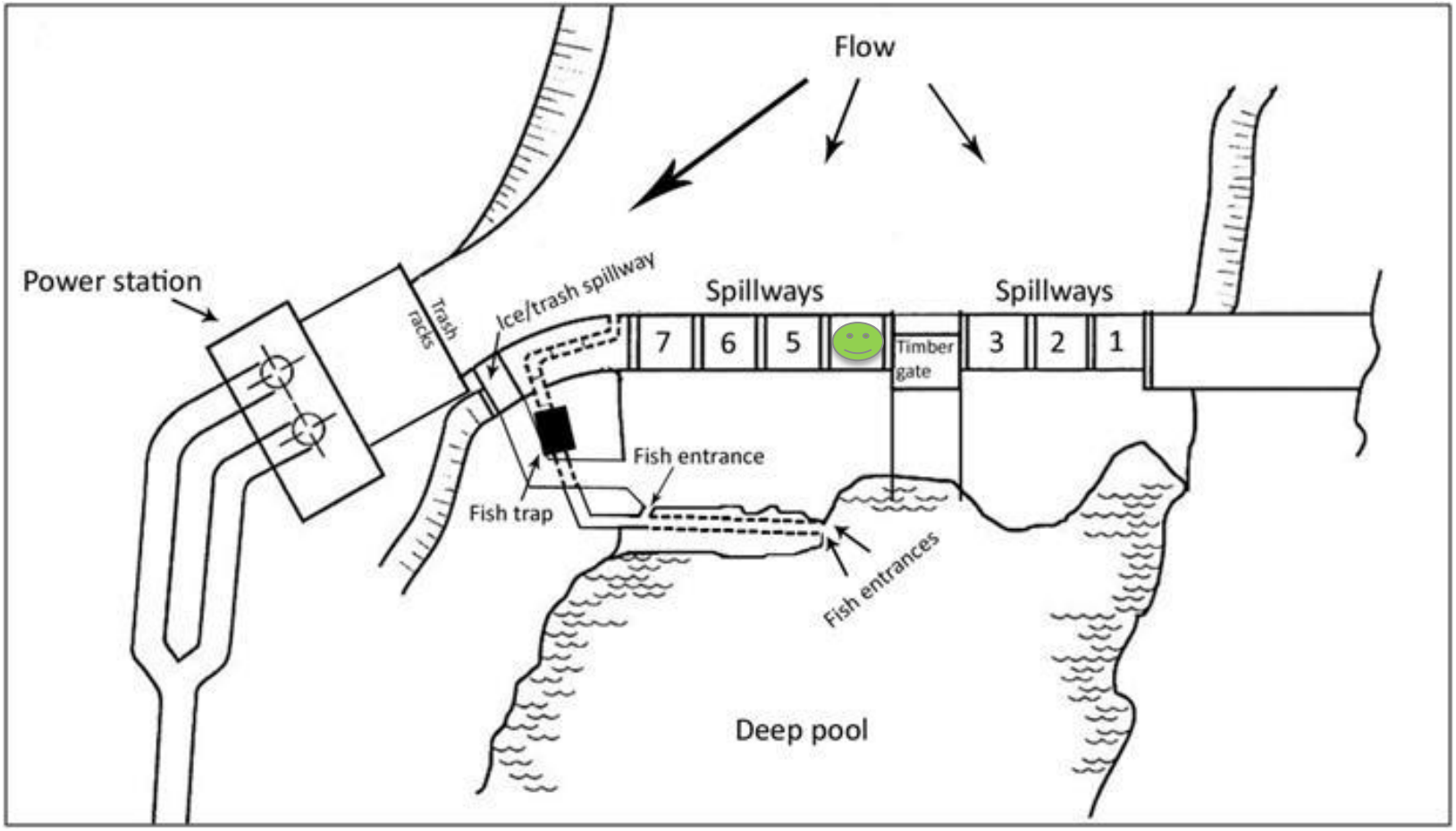
Main results

- 316 Floy-tagged trout; 92 recaptured in the fish trap (3 years), i.e. 29% overall efficiency
- Annual variation: 21%-29%-39%
- Mean annual delay: 20-34-49 days (range: 6 - 77)
- No effect of gender, origin and degree of secondary sexual characters (body coloration)

- Body size selection:
  - Small trout (<60 cm) were significantly less likely to be recaptured in the fishway compared to medium (60-70 cm) and larger (>70 cm) trout
  - Directional rather than stabilizing selection?



Fishway efficiency depends on spillway engagement



Downstream migration and dam passage of brown trout smolts and kelts at Hunderfossen HPP

- **Background**
  - Fish migrations in regulated rivers are well studied, but the emigration phase is by far neglected in Norway (Kraabøl et al. 2009)
  - Preservation of iteroparity requires sufficient two-way passage opportunities at dams (Cada 2001; Keefer et al. 2008; Calles & Greenberg 2009)
  - Surface spillwater release offers the best passage route (Montén 1985; Coutant & Whitney 2000; Schilt 2007; Wertheimer 2007; Wertheimer & Evans 2005; 2007)
  - In Norway, four post-regulation events have impaired dam and spillway passage by reducing surface spill;
    - Cessation of timber floating (1980-1995)
    - Rearmaments and enlargements of turbine capacities
    - Enlargements of trash rack spacing
    - Automation of spillways

Main results

- **Emigration of kelts (n=41) from spawning grounds**
  - 51% of the kelts initiated emigration towards the dam immediately after spawning
  - 49% over-wintered adjacent to spawning grounds
  - Females were 5x more likely to emigrate after spawning in late autumn compared to males