Migratory salmonid fish and dams

Do they mix?

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International seminar on dam removal
24-26 Sep 2018, Hudiksvall, Sweden

Outline

- ✓ Global decrease in river connectivity
- ✓ Migration
- ✓ Anadromous salmonid life history, stock status
- ✓ Do fishways work? Passage up- and downstream
- ✓ Dam removal?
- ✓ Setting goals for restoring anadromous salmonids in regulated rivers

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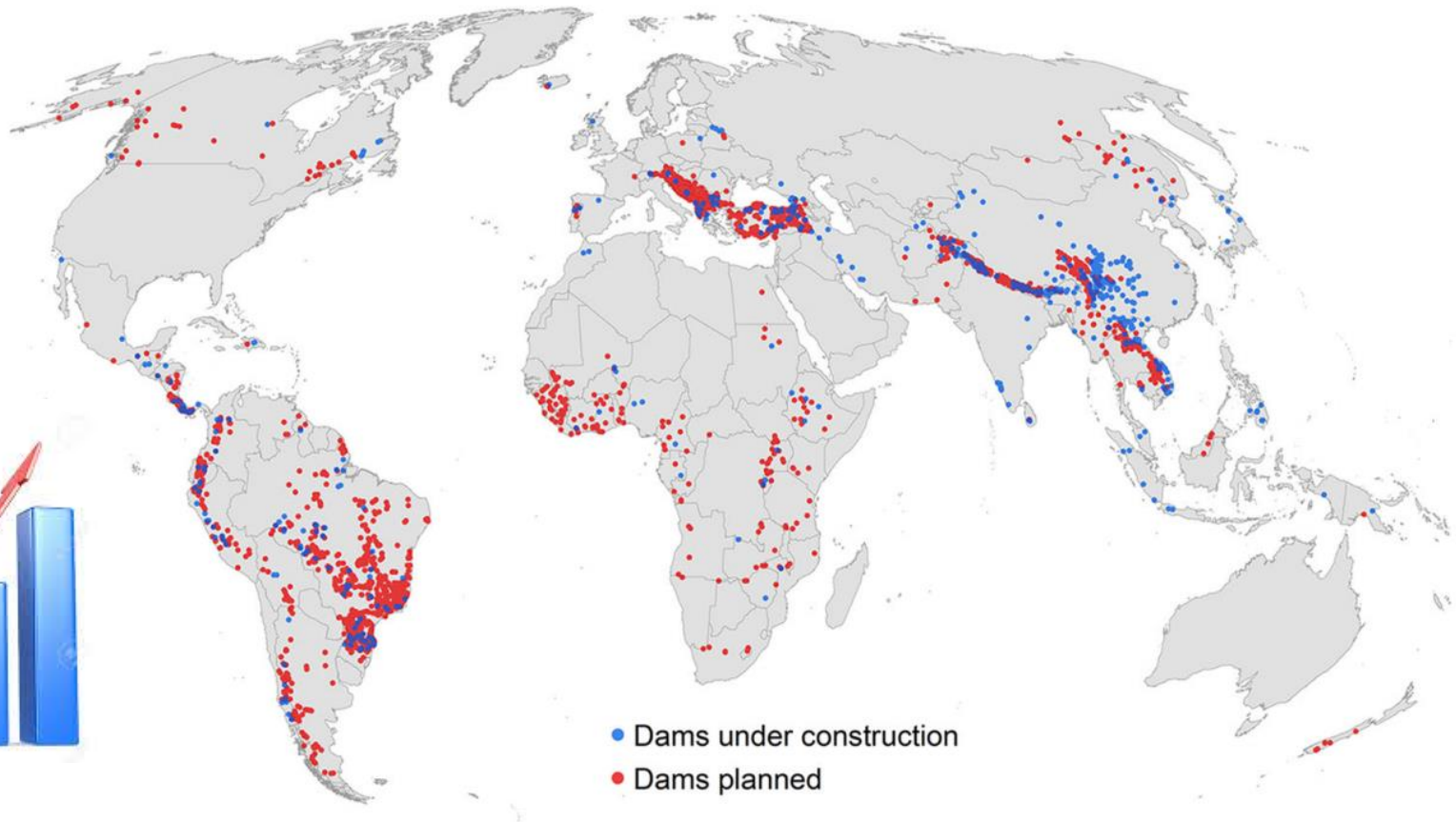
Global boom in hydropower development

- Fueled largely by changes in public perception:
  - **Need to reduce** atmospheric greenhouse-gas **emissions**
  - **Disaster** at the **Fukushima** Daiichi nuclear power plant in Japan in 2011

cf. Lange et al. (2018) Front Ecol Environ

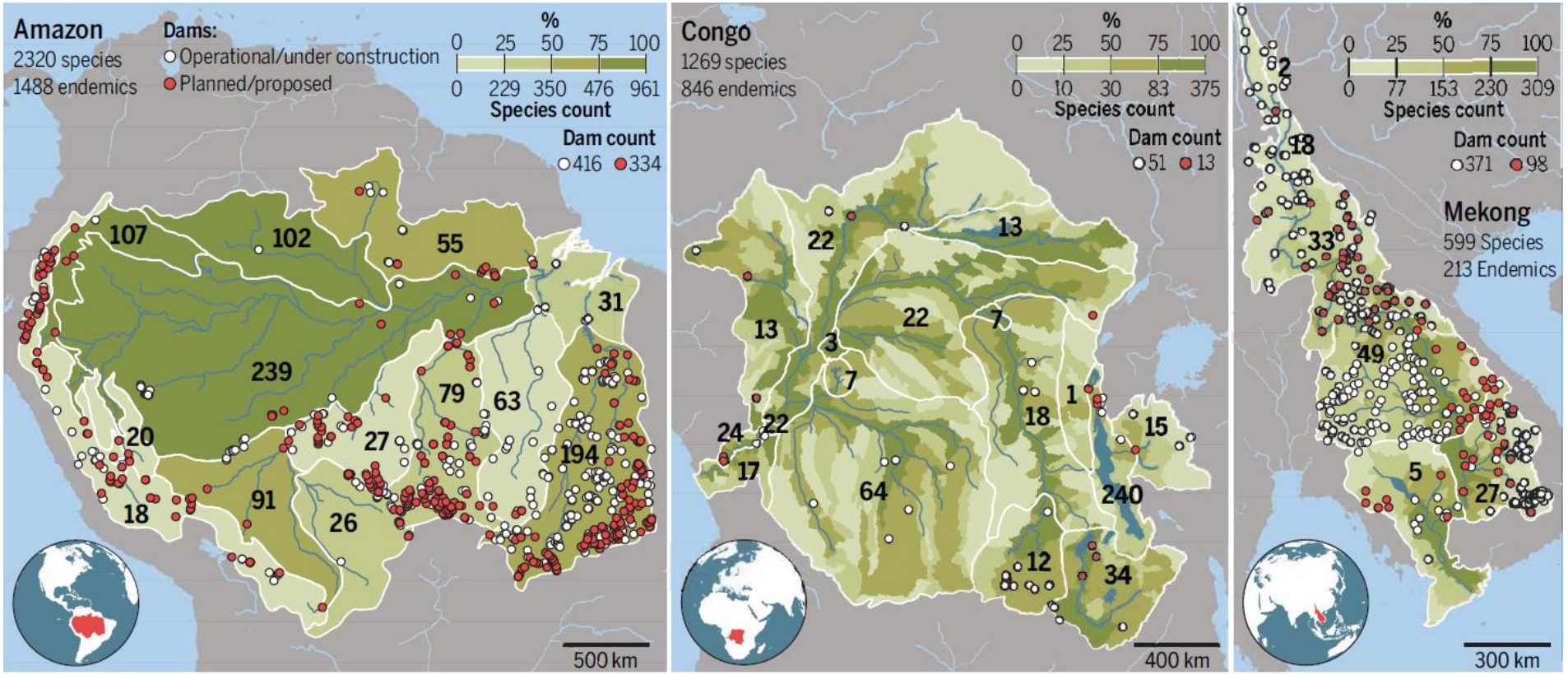
Global boom in hydropower development



- At least 3,700 major hydro dams (>10 MW) are planned or under construction, mostly in countries with emerging economies
- Predicted increase in global hydroelectricity capacity 73 %, to c. 1,700 GW
- Will reduce the number of planet's remaining free-flowing large rivers by > 20 %
- 83,000 small (mostly <10MW) hydropower plants are operating or are under construction in 150 countries

Zarfl et al. (2015) Aquat Sci; Couto & Olden (2018) Front Ecol Environ

Dams in (really) large rivers



Fish diversity (shades of green) and dam locations (dots) in the Amazon, Congo and Mekong basins

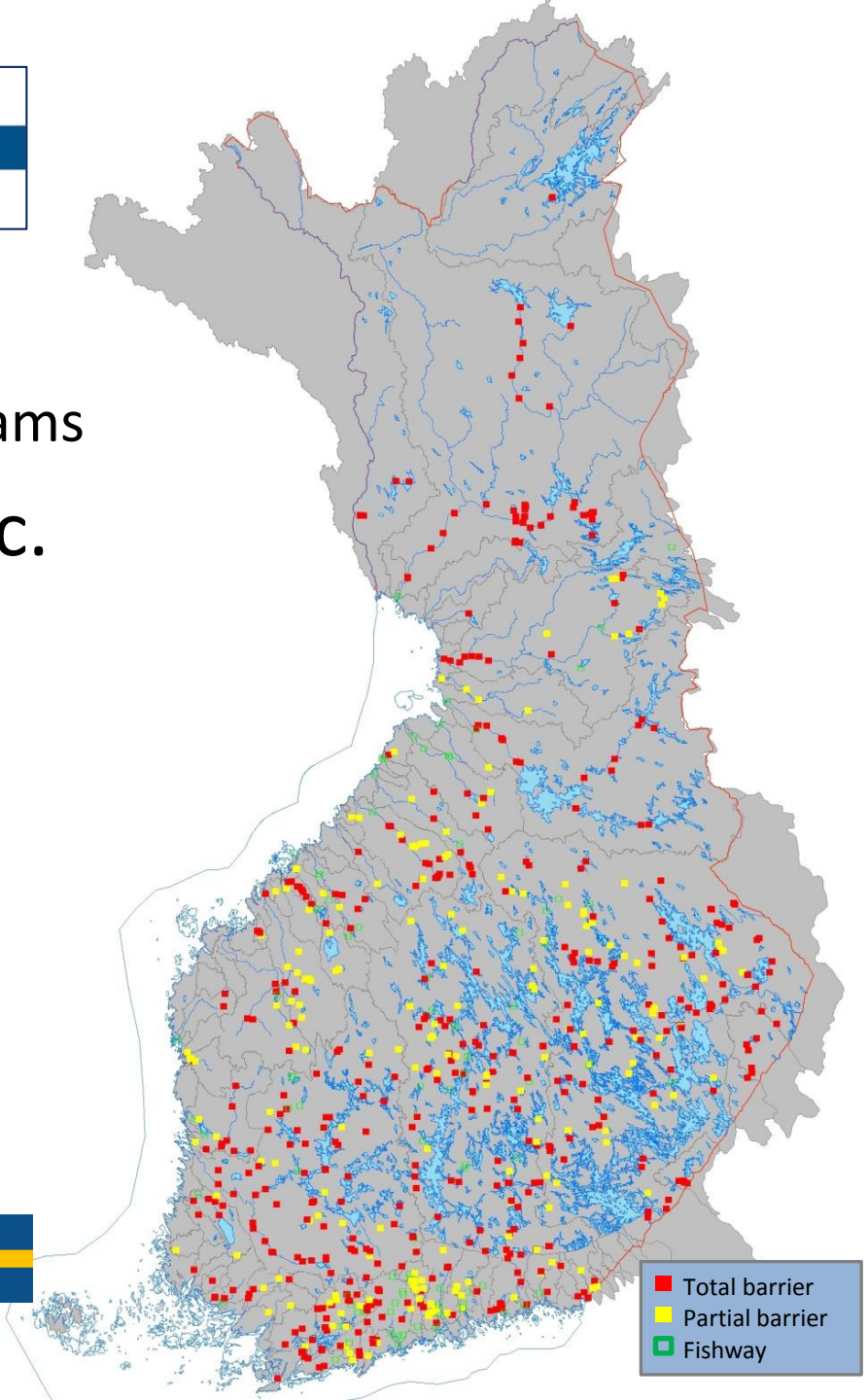
- World's **most biodiverse rivers**: one-third of world's freshwater fish species, most **endemic**
- Most existing dams small, in upland tributaries → 450 additional dams are planned, many large
- Risks and long-term **impacts on biodiversity** in river systems that **support livelihoods of millions** of people?

Winemiller et al. (2016) Science

Finland

- 3224 dams
  - Of which 678 hydropower dams
- 1532 small mill dams etc.
  - c. 25% total barriers for fish migration, c. 25% partial
- 217 fishways
  - **7%** of dams
  - Some mill dams should be included → smaller %

Sweden: **<2%** of c. 2000 hydropower plants have functional passages for fish migration



Migration

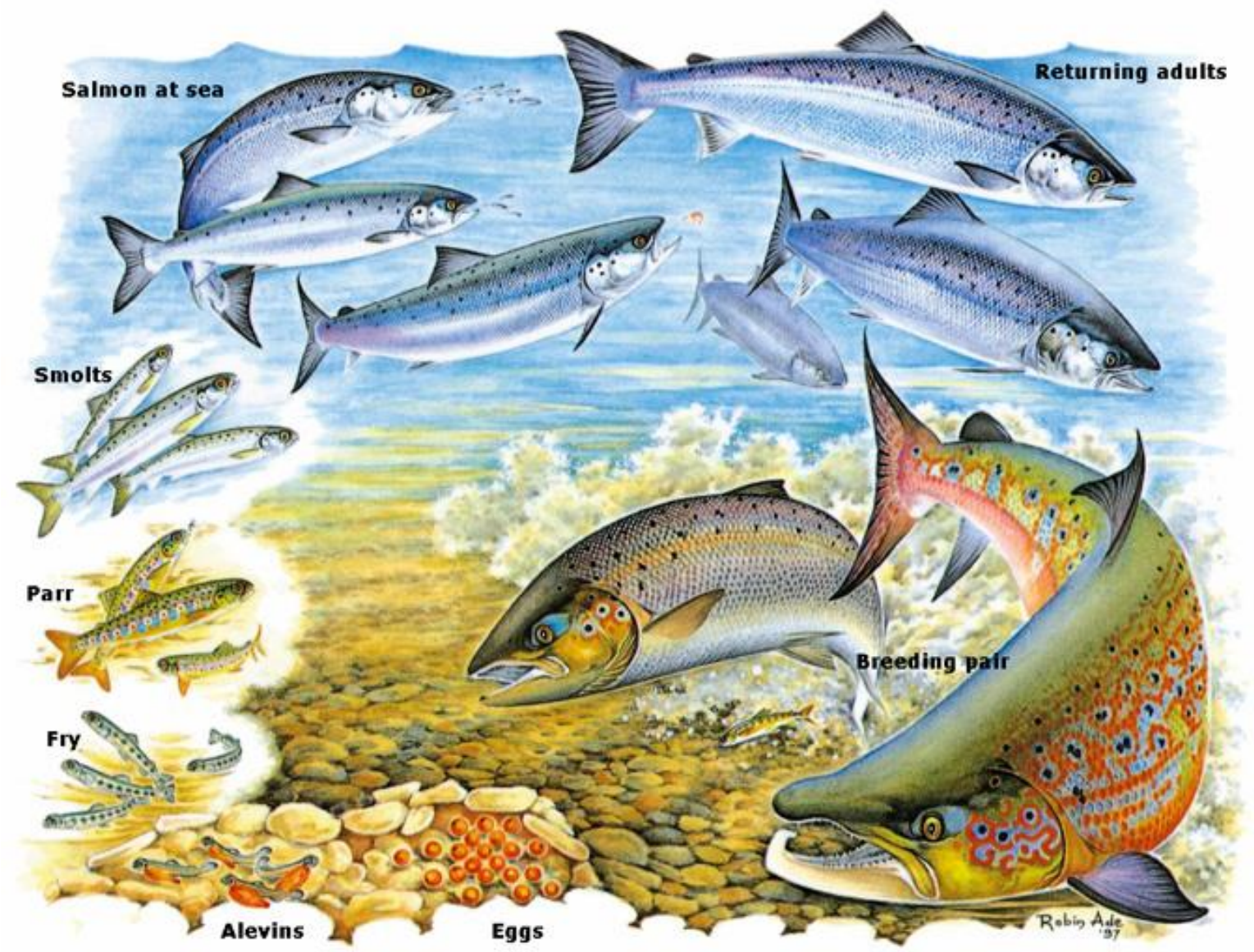
- Definition of migration usually involves a return movement, i.e. ”...to come and go within a lifetime either once or periodically...” (Roff 1988)
- Active, specialized, directed behaviour – excluding random or accidental displacement (Dingle 1980)

Why do animals migrate?

- Obtaining better food resources and growth possibilities
- Achieving better conditions for successful reproduction
- Avoidance of unfavorable environmental conditions

→ Needs of individuals are not being met in the original/present/previous habitat

The wondrous life cycle of an anadromous fish



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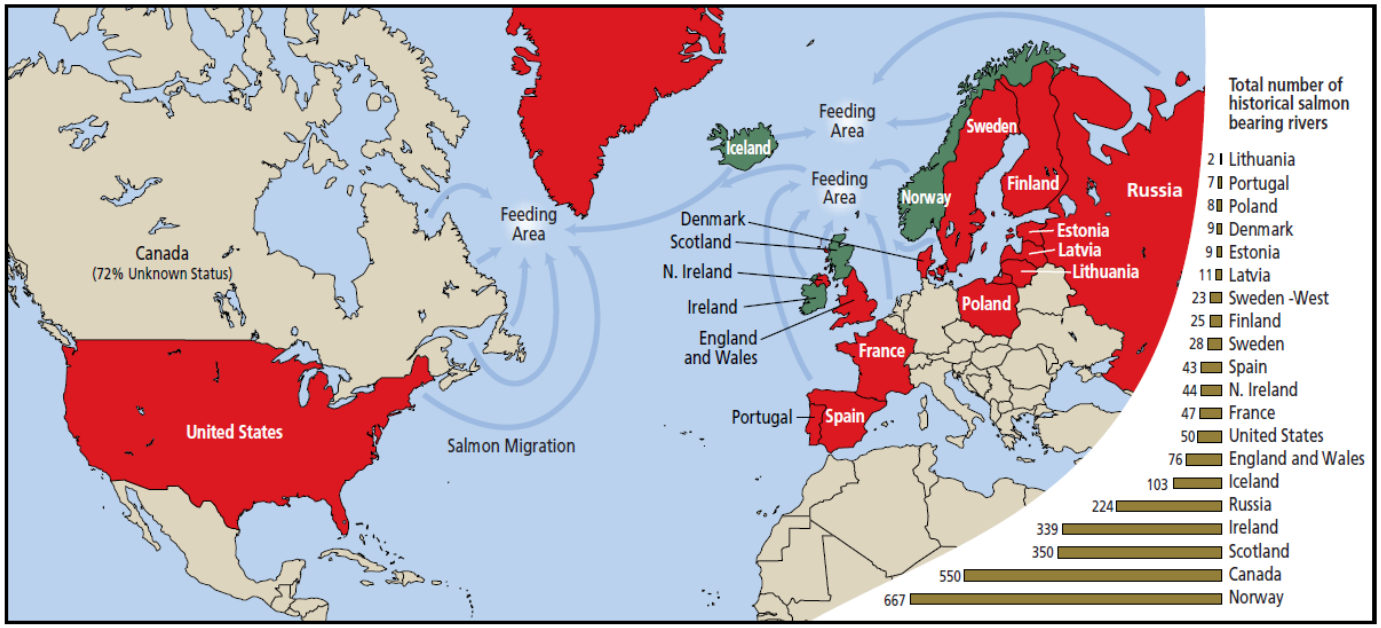
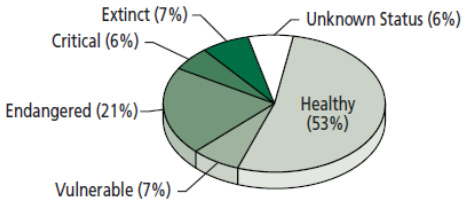
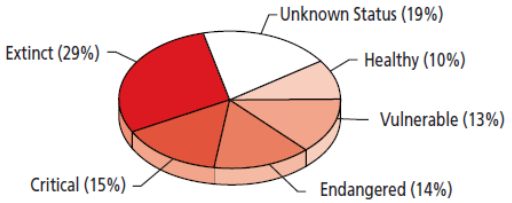
Global overview of **Atlantic salmon** stock status (WWF 2001)



Aggregated categorization of salmon-bearing rivers in the four countries[1] that host the majority (more than 90%) of the remaining healthy rivers

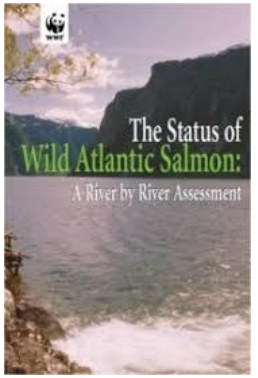


Aggregated categorization of salmon-bearing rivers in 14 countries[2] where the majority of rivers are threatened (vulnerable, endangered and/or extinct)



- Historically c. 2600 Atlantic salmon rivers in the world
- 44% with a status worse than healthy (or unknown)
- Main reasons behind declines:

  Water quality, habitat degradation, overfishing, **dams**



Baltic salmon rivers

Baltic total:

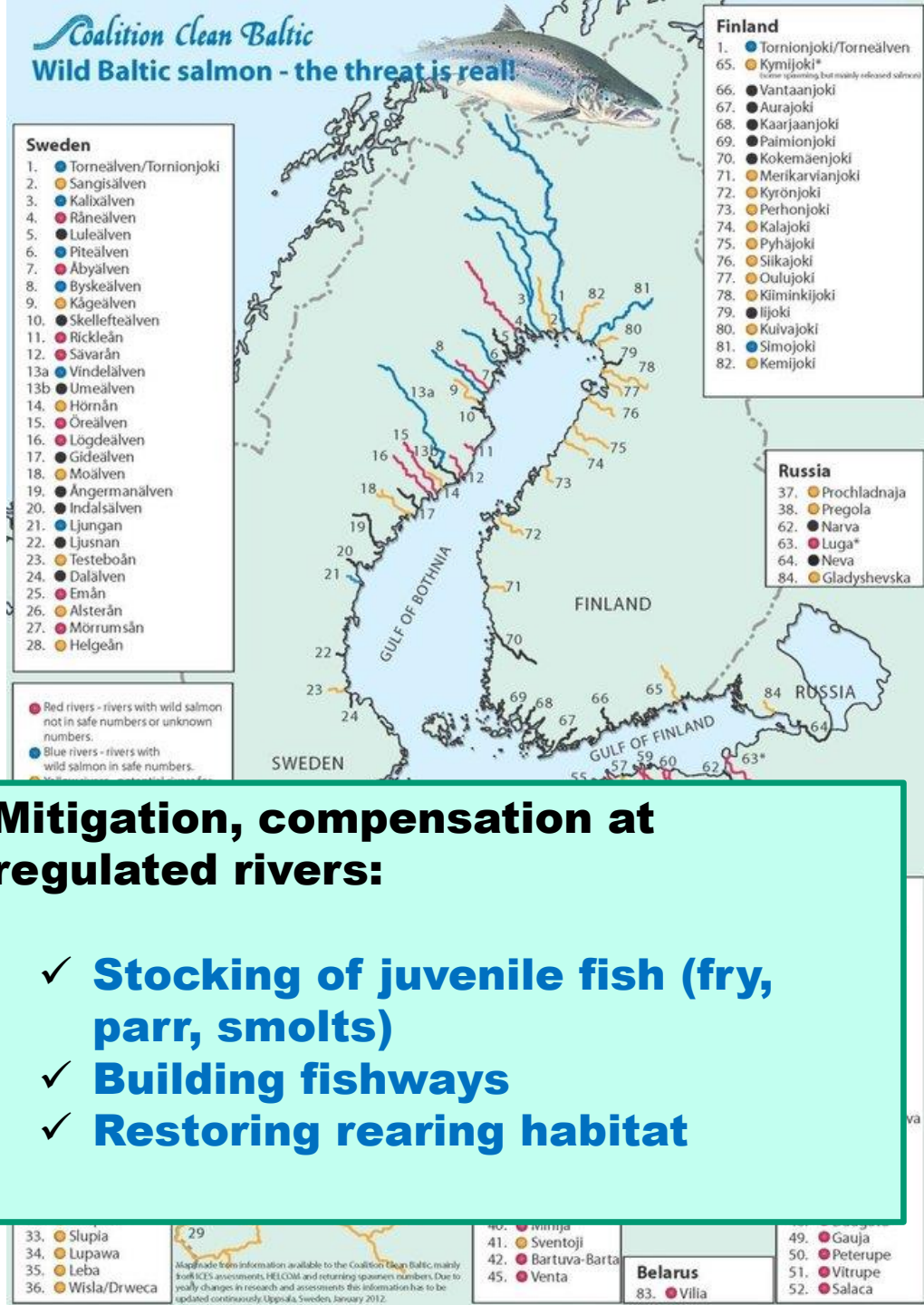
- Historically 100 wild salmon rivers, now 30

Finland:

- Historically 20 rivers, now 2 (+)

Reasons behind the decline:

- Hydrodam construction
- Habitat degradation
  - Water quality, channelization, sedimentation
- Overfishing



Mitigation, compensation at regulated rivers:

- ✓ **Stocking of juvenile fish (fry, parr, smolts)**
- ✓ **Building fishways**
- ✓ **Restoring rearing habitat**

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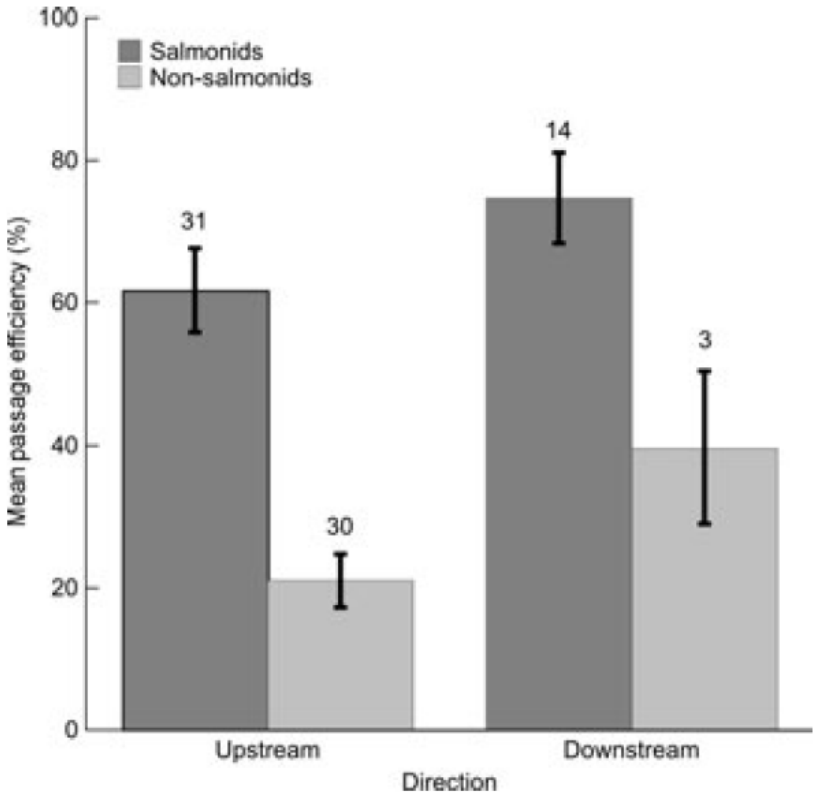
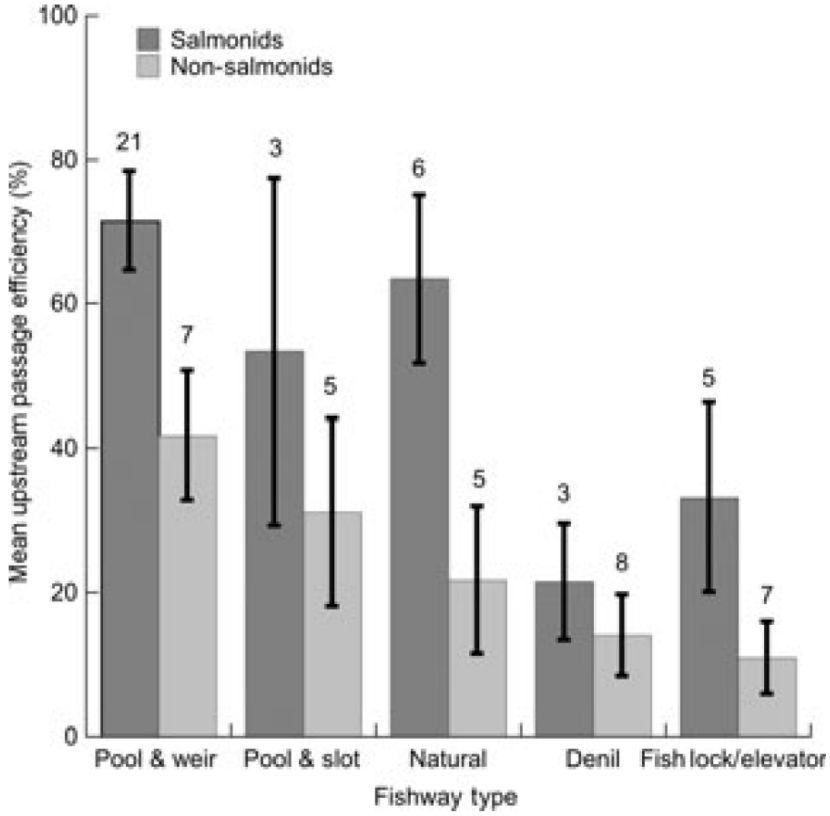
Do fish passages work?

General patterns in passage efficiency

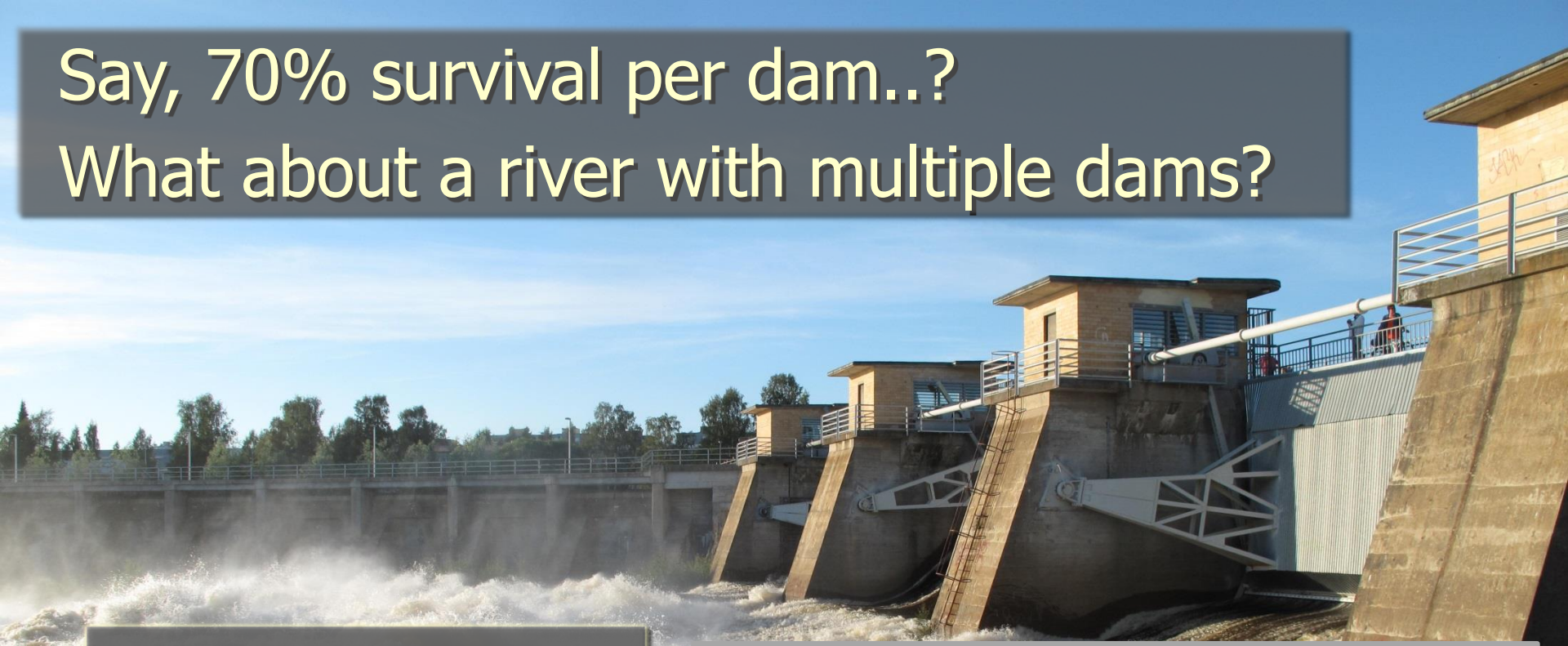




- ✓ Upstream passage efficiency in salmonids is the best across orders; c. 60%
- ✓ Downstream passage efficiency in salmonids c. 75%
- ✓ Marked differences across fishway types

Noonan et al. 2012 FISH and FISHERIES

Say, 70% survival per dam..?
What about a river with multiple dams?



Dams	% fish left
0	100
1	70
2	49
3	34
4	24
5	17

- ✓ Mortality in upstream passage of spawners
- ✓ Mortality in downstream passage of smolts
- ✓ Mortality in downstream passage of spent fish
- ✓ Mortality in upstream passage of repeat spawners
- ✓ etc….

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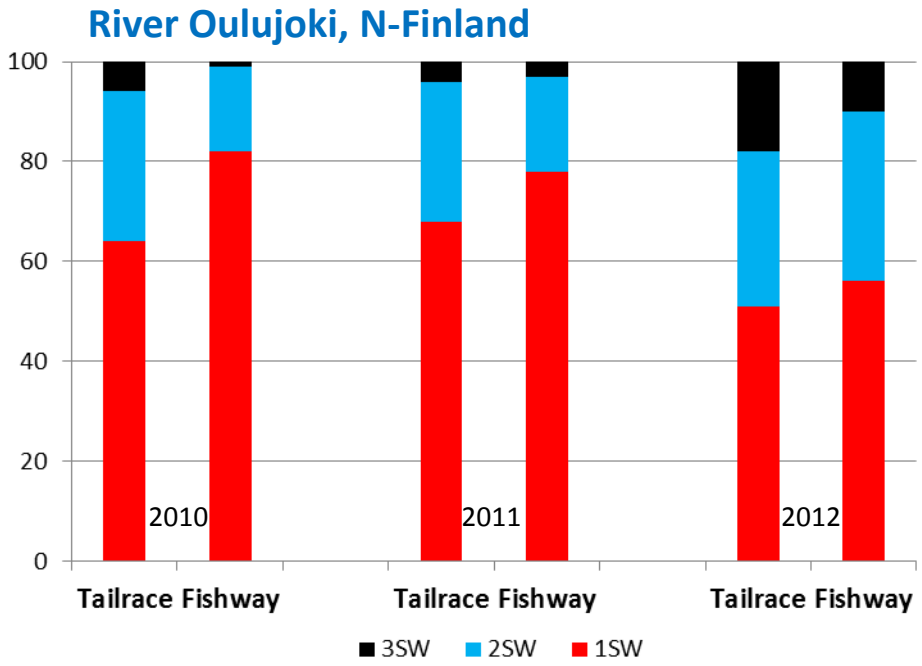
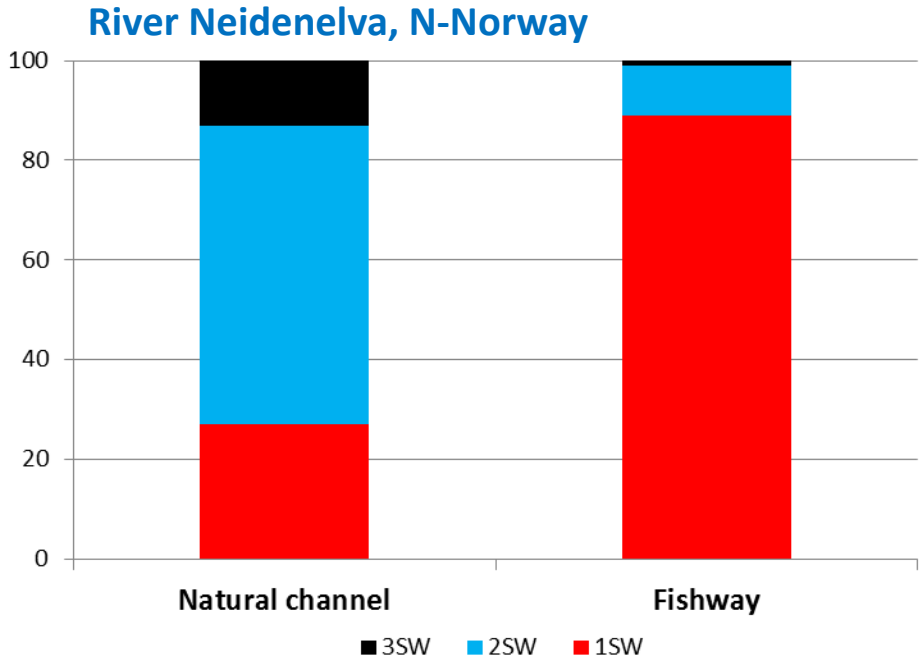
Size-selectivity of fishways?

Marked differences in salmon age structure:

- ✓ Fish passing fishway are younger and smaller than those captured below the dam (River Oulujoki)
- ✓ Fish passing fishway are younger and smaller than those using the natural channel via a waterfall (River Näätämöjoki/Neidenelva)
- ✓ Similar observations from other rivers
- ✓ Are fishways favouring 1SW salmon?
- ✓ How to attract more MSW salmon to fishways?





Orell et al. 2014; unpubl.

Multifaceted problems – interdisciplinary solutions

- Earlier **engineering-focused approach**: attempting to 'fit fish into an equation'
- Fishway design criteria do not adequately account for **natural variation** among individuals, populations and species
- Engineered solutions cannot reinstate the **natural habitat** and **geomorphological properties** of the river
- Currently towards involvement of a **wide range of disciplines:** fish behaviour, socioeconomics, complex modelling …

Silva et al. 2017. Fish and Fisheries
Birnie-Gauvin et al. 2018. Aquatic Conserv: Mar Freshw Ecosyst

Photo: Panu Orell

Downstream passage of smolts

- ✓ **Wide variation in passage efficiency and survival across rivers and dams**
  - **Turbine mortality (*Salmo*): 0 – 35% (Kaplan); 3 – 75% (Francis)**
  - **Guidance efficiency at dams (*Salmo*): 0 – 90%**
- ✓ **Depends on a number of variables**
- ✓ **What do the figures represent – compared to what?**
  - **Survival in a free-flowing river is not 100%**
  - **Experiments: hatchery fish vs. wild fish; tagged fish vs. untagged fish?**

→ Relative figures matter!

Photo: Ville Vähä

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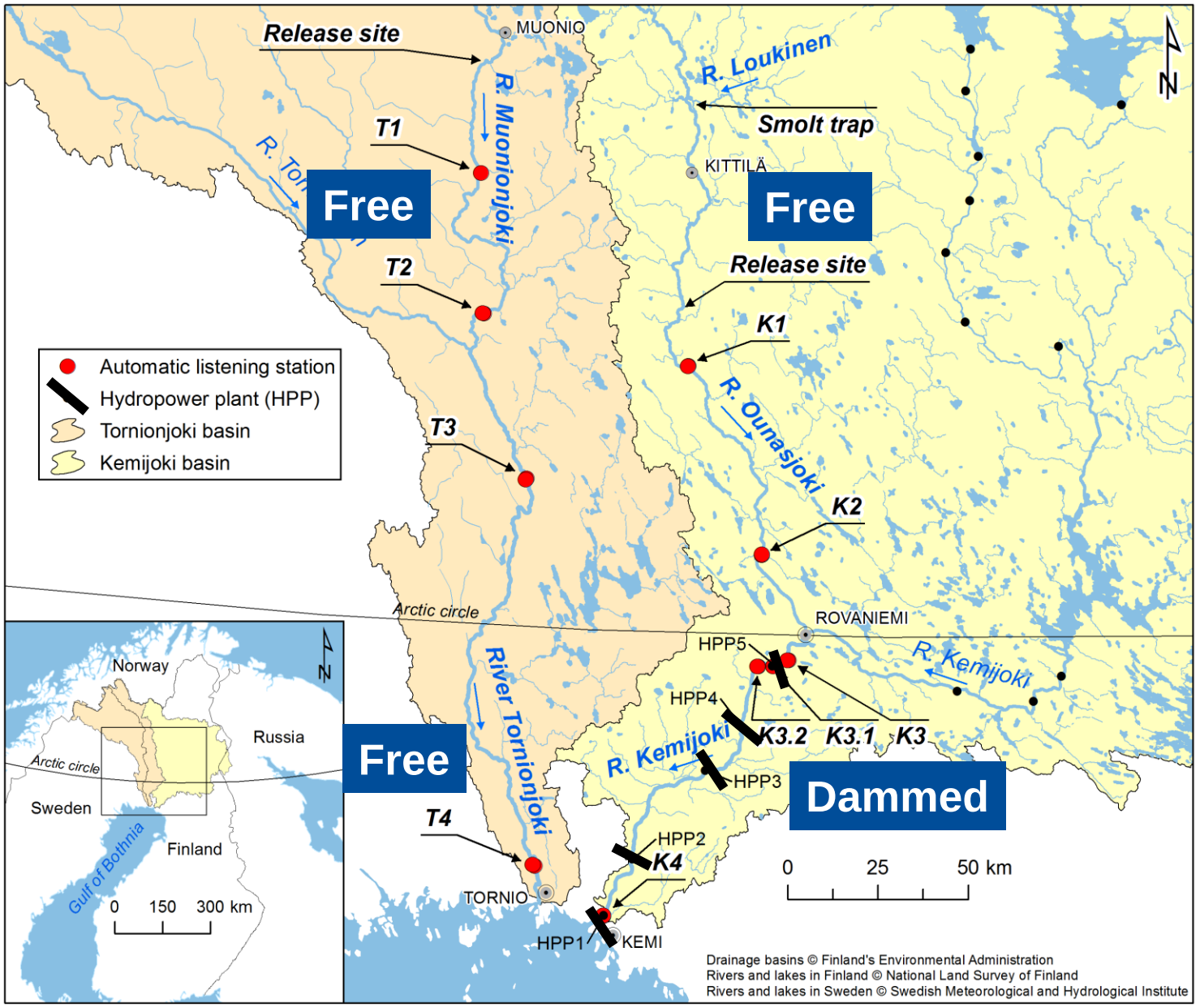
Smolt migration in two large rivers: one with dams, one without

Huusko et al. 2018. Can. J. Fish. Aquat. Sci.



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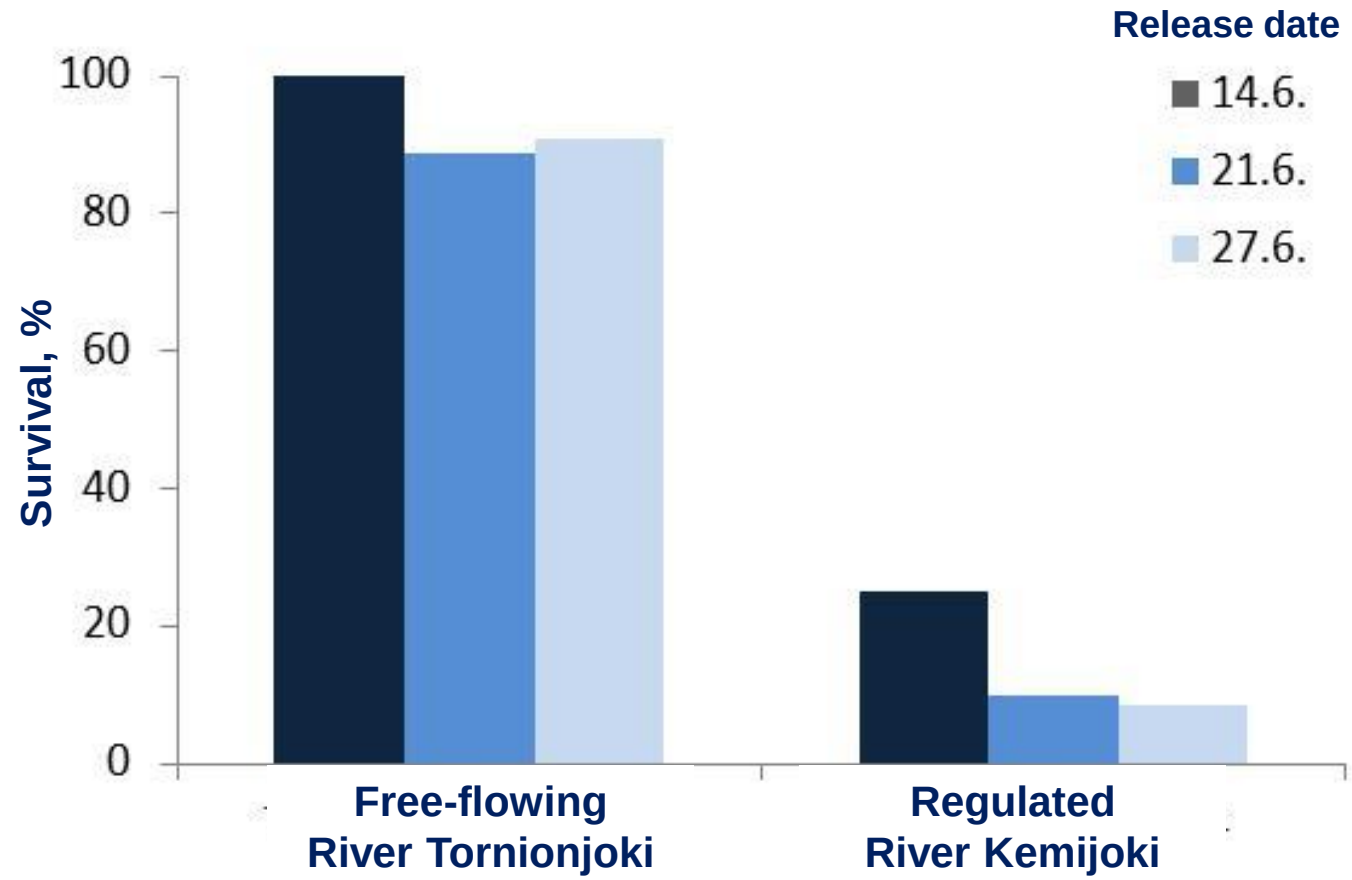
Survival of salmon smolts in lower parts of the rivers

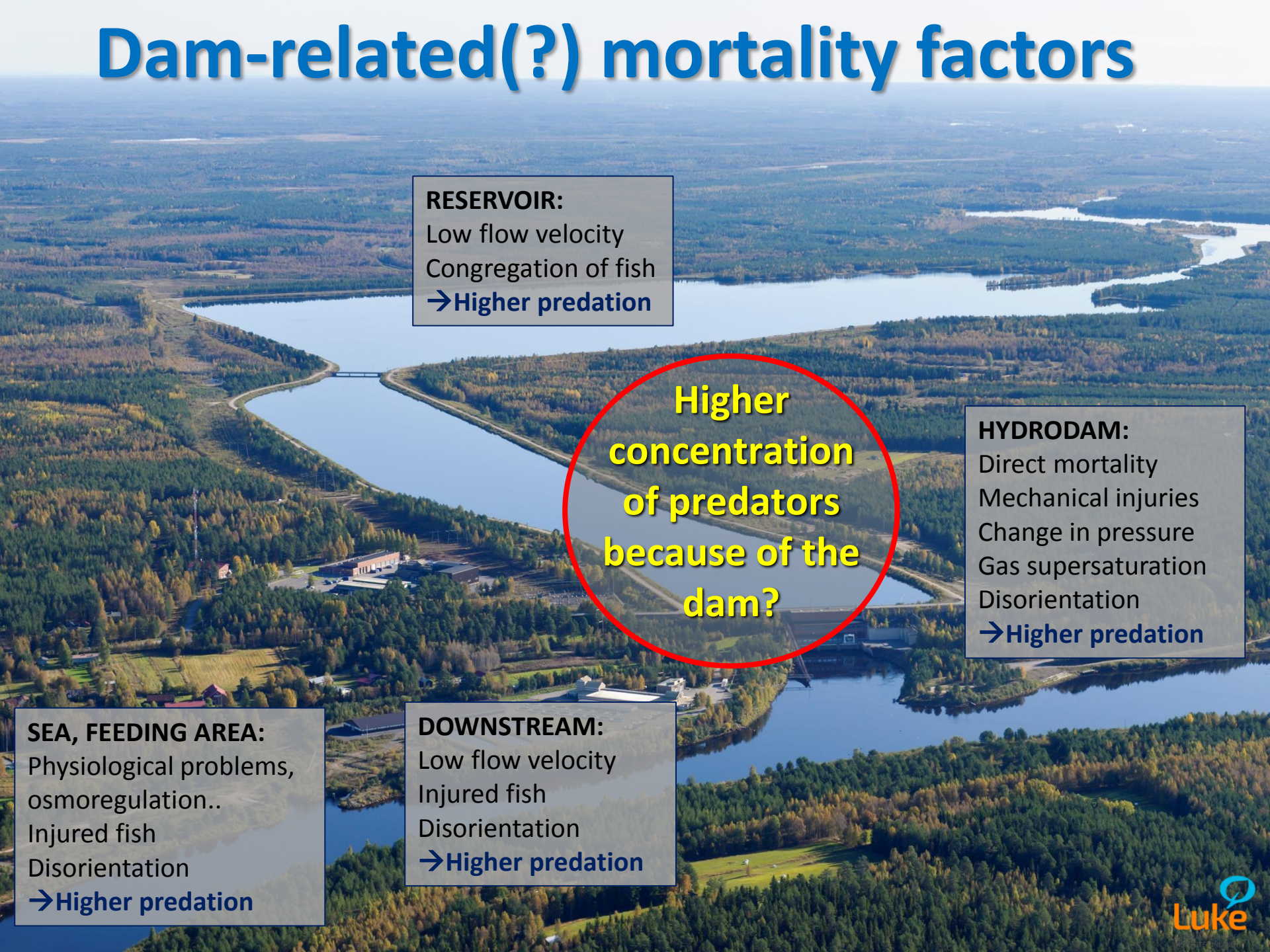


- Smolt survival **six times lower** in the regulated river
- Smolts reluctant to pass multiple dams

→ Solutions for facilitating downstream migration needed!

Huusko et al. 2018 Can. J. Fish. Aquat. Sci.

Dam-related(?) mortality factors



RESERVOIR:
Low flow velocity
Congregation of fish
→**Higher predation**

Higher concentration of predators because of the dam?

HYDRODAM:
Direct mortality
Mechanical injuries
Change in pressure
Gas supersaturation
Disorientation
→**Higher predation**

SEA, FEEDING AREA:
Physiological problems, osmoregulation..
Injured fish
Disorientation
→**Higher predation**

DOWNSTREAM:
Low flow velocity
Injured fish
Disorientation
→**Higher predation**

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Remove a dam?

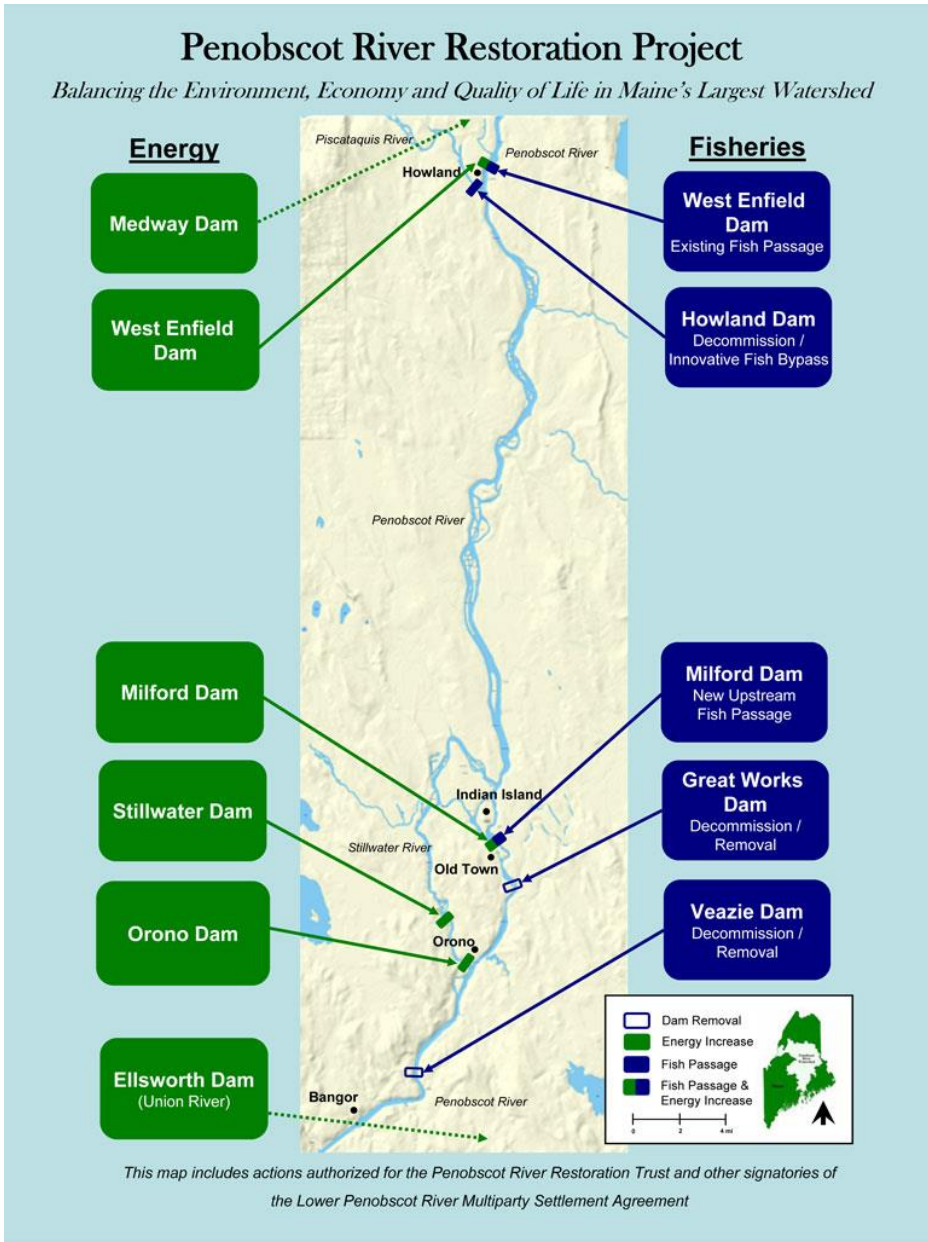
Great Works Dam removal,
Penobscot river, Maine, USA
www.penobscotriver.org

- ✓ **Few studies on recovery responses in migratory salmonid fish populations documented (in primary literature)**
- ✓ **The few existing studies have mostly short monitoring periods**
- ✓ **All indicate or predict positive responses!**

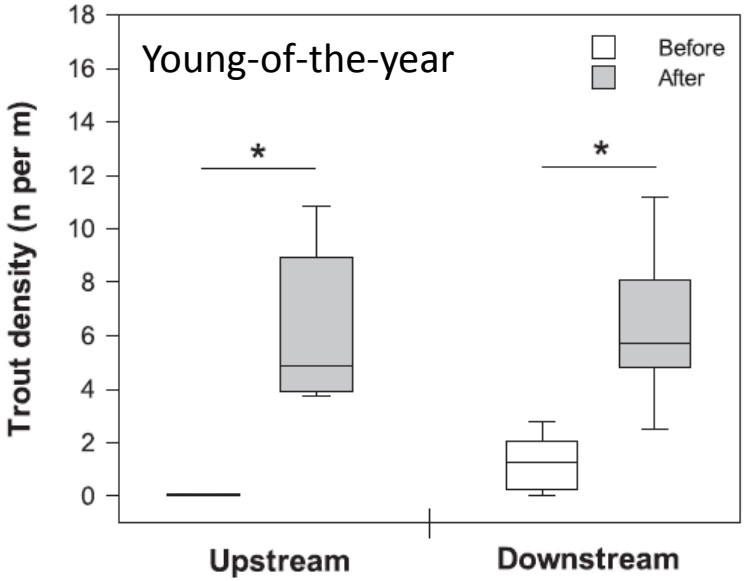
Cf. Birnie-Gauvin et al. 2017

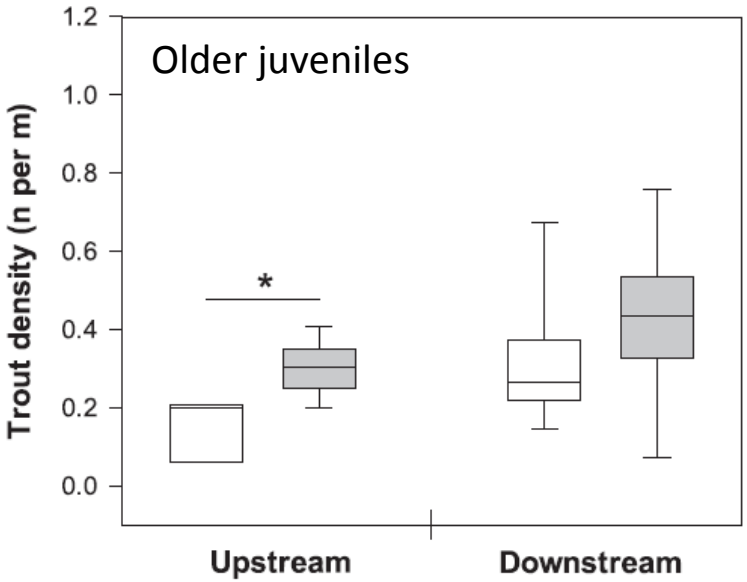
Penobscot River Restoration Project

- ✓ Removal of two major main stem dams 2012-2013
- ✓ Innovative fishways
- ✓ Great success in restoring clupeids: 100 000s river herring, 1000s shad returning
- ✓ Salmon?



Hydrodam removal → increase in brown trout abundance





- ✓ **Trout abundance evaluated for 30 years – 20yr prior to and 10yr following the removal** of a **hydrodam** in Denmark.
- ✓ Trout density **increased dramatically both upstream and downstream** following removal
- ✓ **Barrier removal may be the soundest conservation option** to reinstate fish population productivity

Birnie-Gauvin, Larsen, Nielsen, Aarestrup (2017)
Journal of Environmental Management

Do hydrodams and migratory salmonids mix? – Depends on the goals set

- Self-sustaining population
  - By far the hardest one
- Natural reproduction, enhanced by stocking
  - At some regulated rivers
- Supporting intensive fishery
  - Stocking, sea ranching, terminal fishery areas at estuaries + rivers
- Supporting iconic status, aesthetic value
  - Some fishing, interpretation centers, education, well-being…

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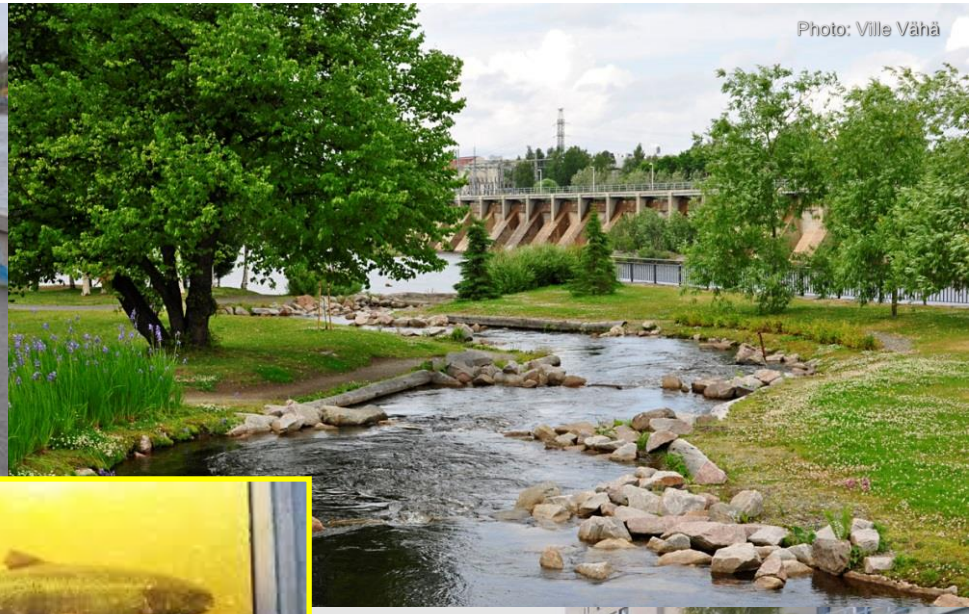
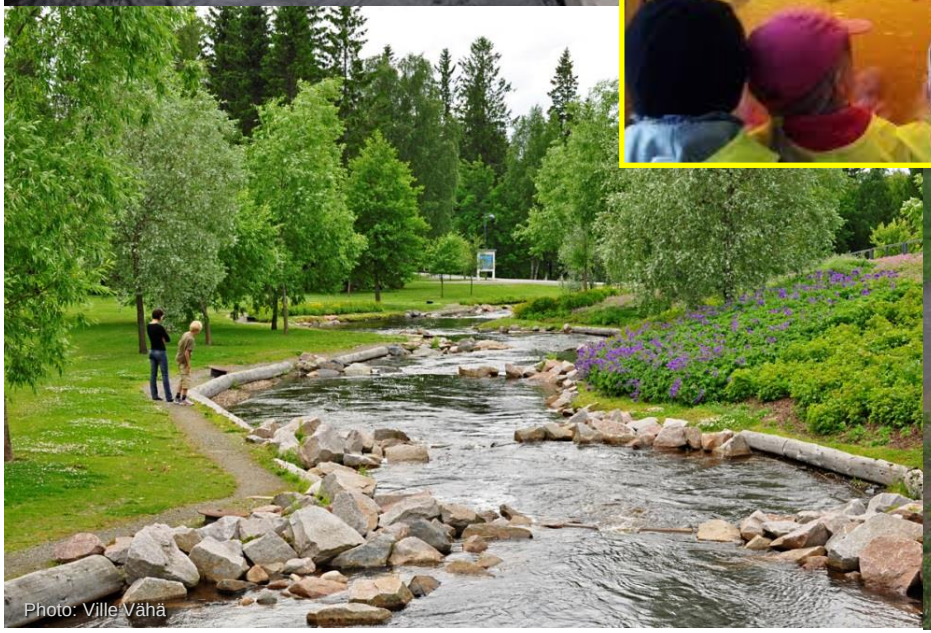
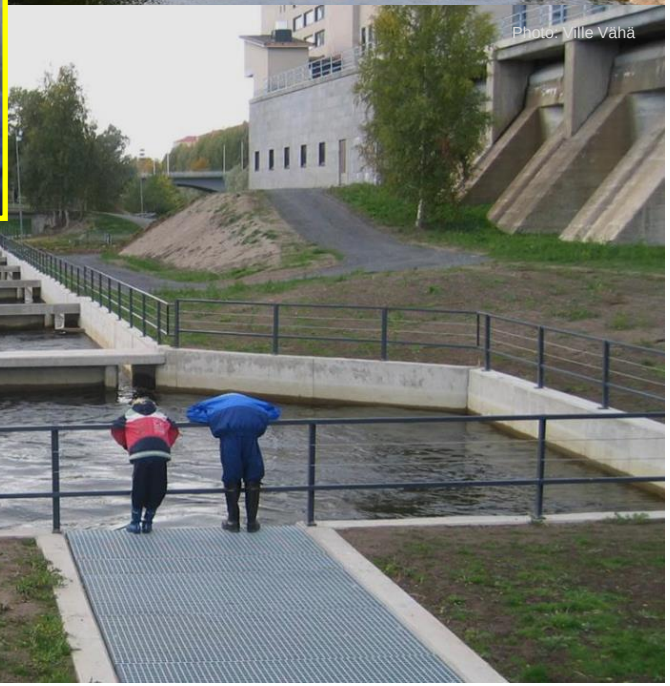
Photo: Panu Orell

Merikoski fishway, River Oulujoki, Oulu, Finland







Merikoski fishway, River Oulujoki, Oulu, Finland
Live web cam: www.oulunenergia.fi