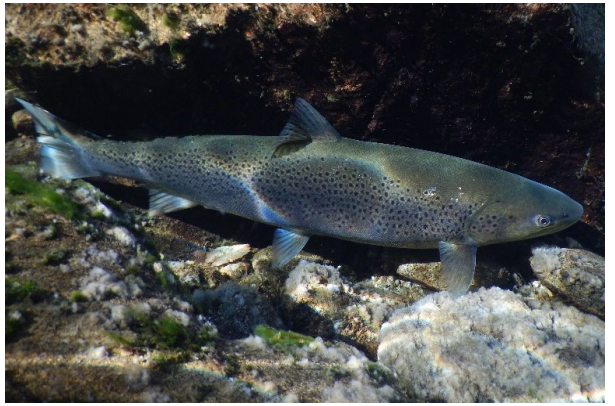
Mitigation measures revisited

– environmental effects, costs and endurance

Ulrich Pulg, Sebastian Stranzl, Christoph Hauer

ulrich.pulg@uni.no



I

(Acts whose publication is obligatory)

DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 23 October 2000

establishing a framework for Community action in the field of water policy

PEAN PARLIAMENT AND THE COUNCIL OF THE UNION,

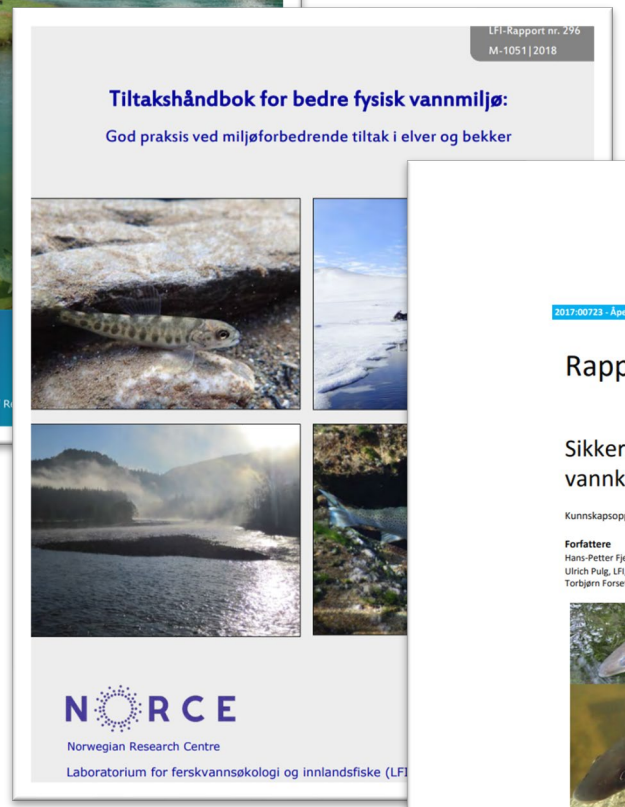
gard to the Treaty establishing the European , and in particular Article 175(1) thereof,

rd to the proposal from the Commission (1),

(3) The declaration of the Ministerial Seminar on groundwater held at The Hague in 1991 recognised the need for action to avoid long-term deterioration of freshwater quality and quantity and called for a programme of actions to be implemented by the year 2000 aiming at sustainable management and protection of freshwater resources. In its resolutions of 25 February 1992 (6), and 20 February 1995 (7), the Council requested an action programme for groundwater and a revision of Council Directive 80/68/EEC of

Water Frame Work Directive 2000

Environmental Design 2013



Handbok mitigation measures 2017

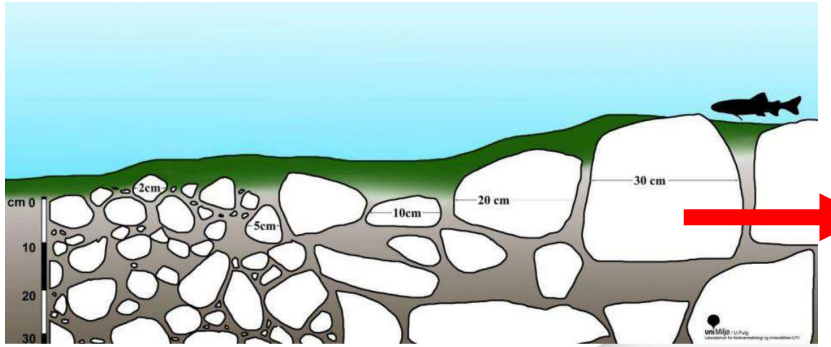
Good practice for fishways 2018

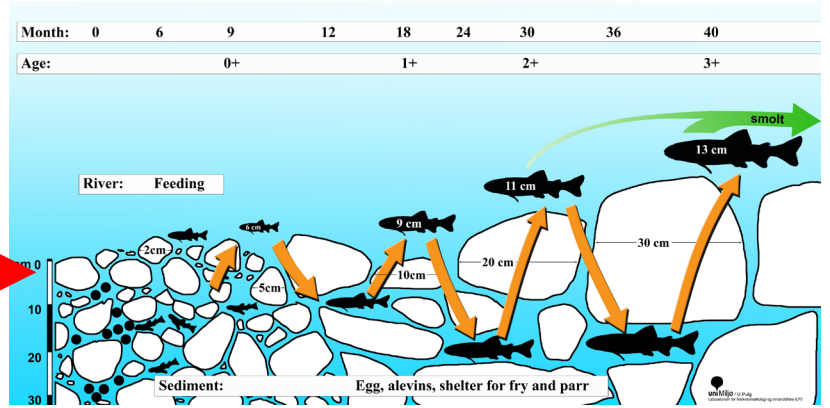
How did it go?

Ripping of armored layers

Endurance: 1-10 år+

Costs : 1-10 NOK/m^2 (2017-NOK)





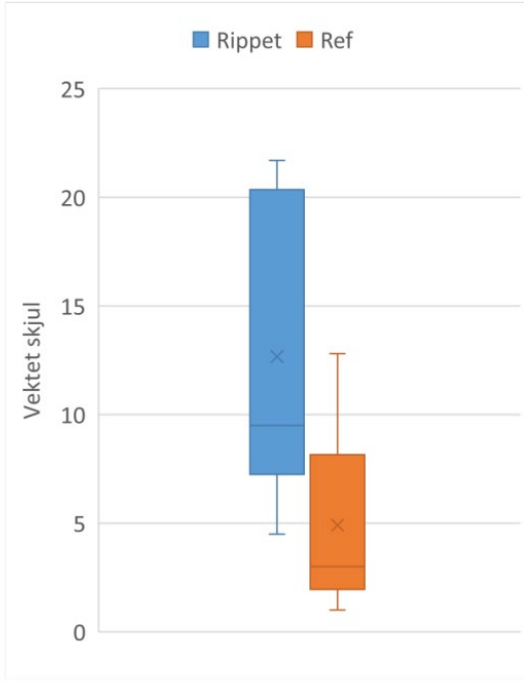
Ripping

Effect: 200 – 350 % increase of parr densities

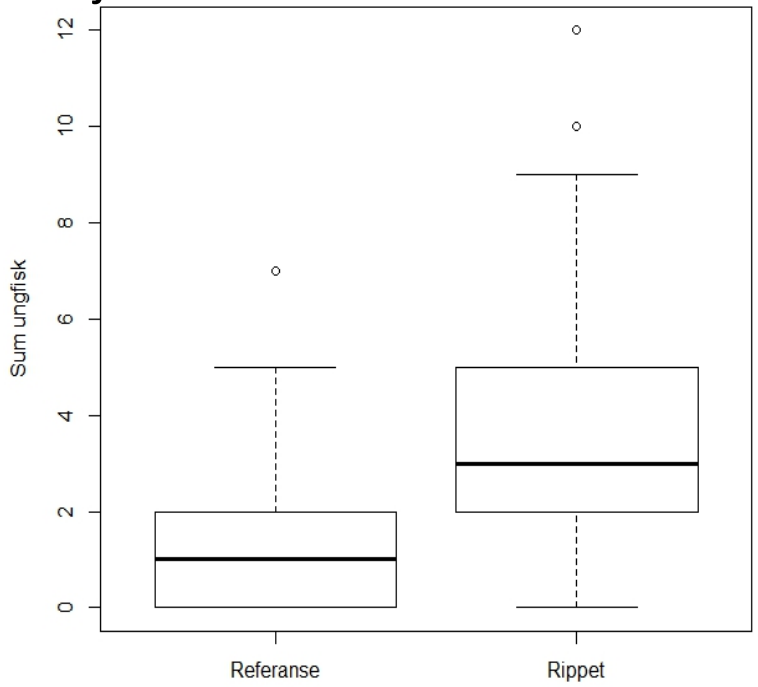
Endurance: 1-10 år+

Costs (2017-NOK) : 1-10 NOK/m^2

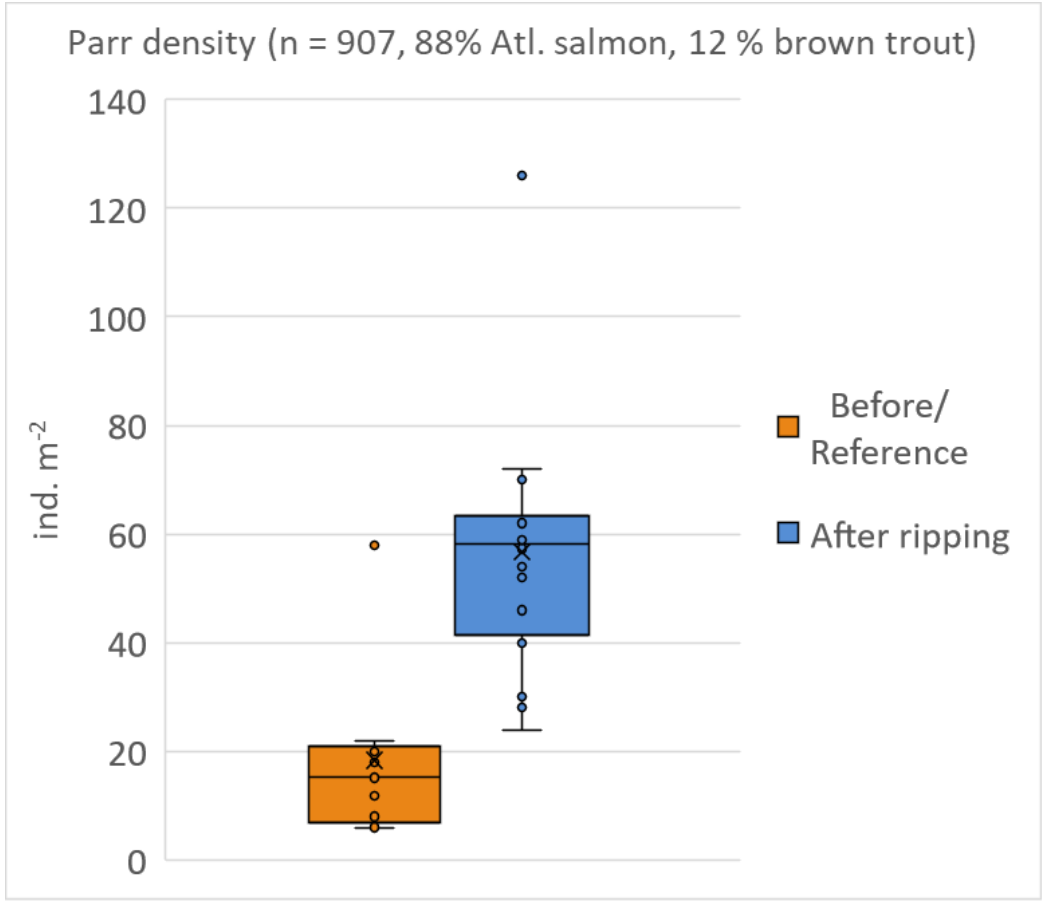
Shelter avialbility



Aurlandselva , juvenile trout and A. salmon



Suldalslågen

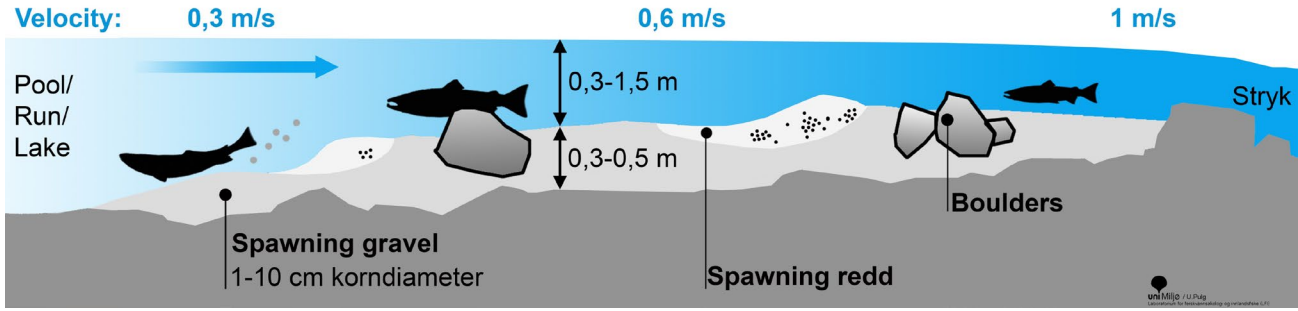


Spawning gravel augmentation

Endurance: 1-21 år+

Typical costs: 180 NOK/m^2 (2017),

4-12 NOK/m^2/year



Spawning gravel augmentation

- Effect: Increase of Atlantic salmon and brown trout fry and parr

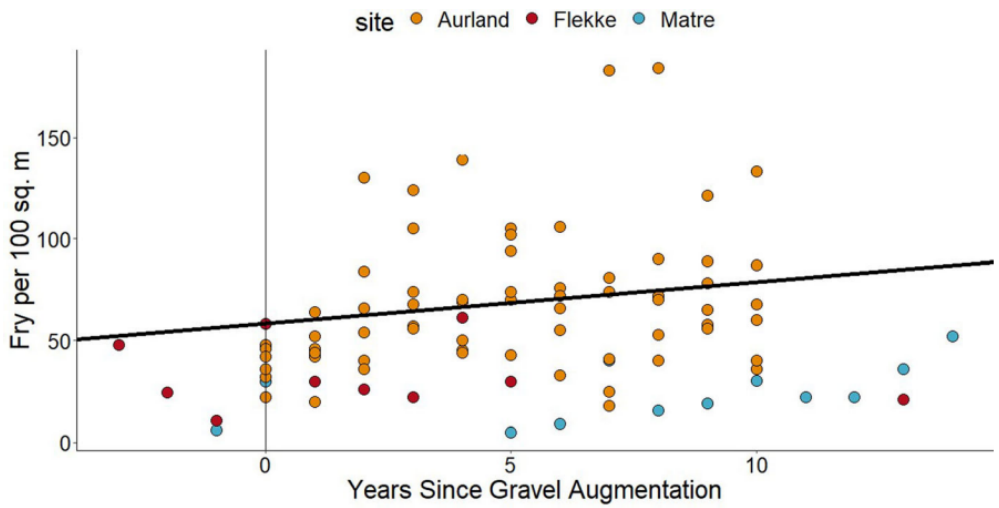


Fig. 13 Atlantic salmon and Brown trout fry densities at the test sites

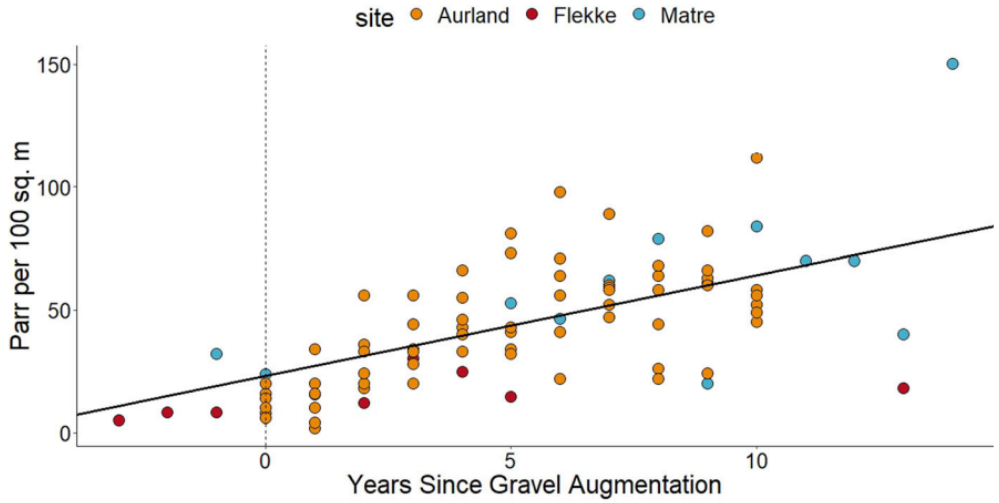
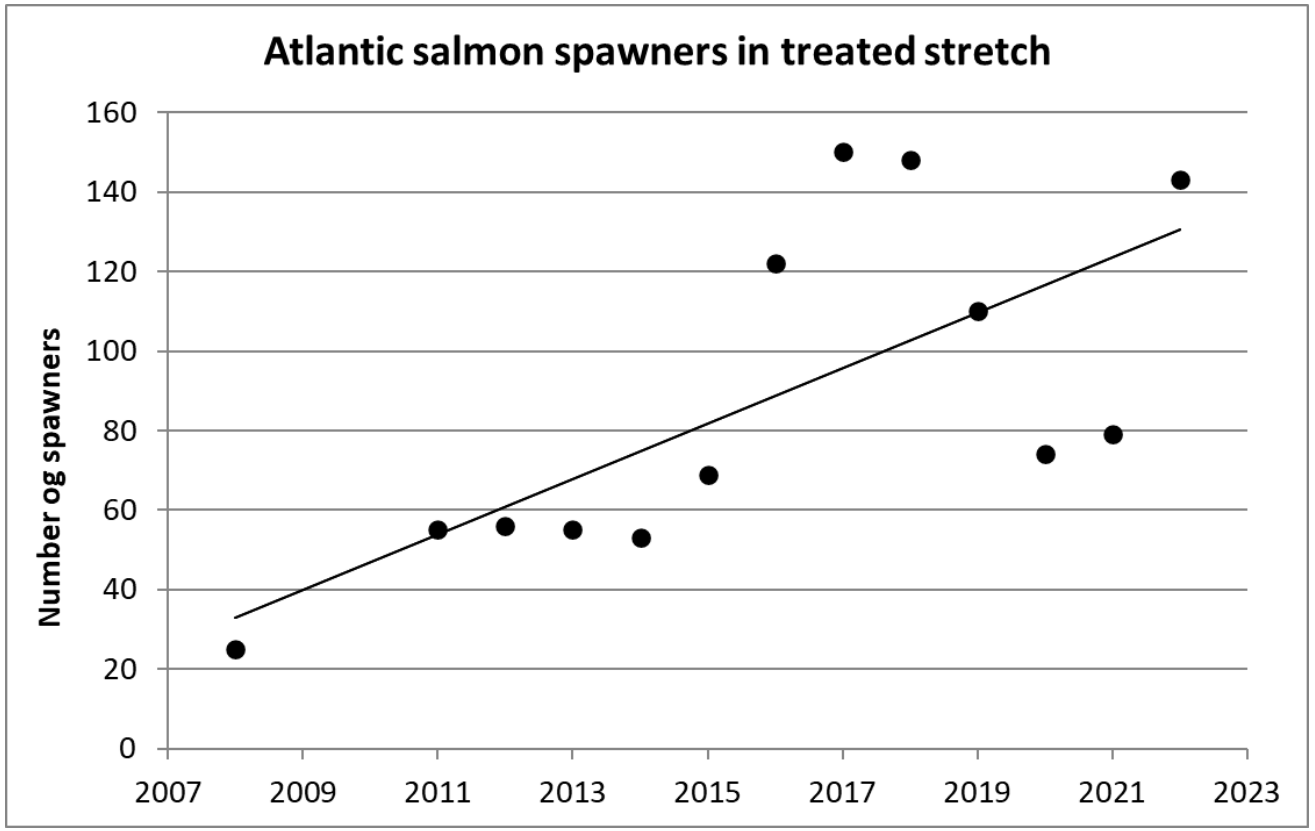


Fig. 14 Atlantic salmon and Brown trout parr densities at the test sites

Pulg, U., Lennox, R.J., Stranzl, S. *et al.* 2021. Long-term effects and cost-benefit analysis of eight spawning gravel augmentations for Atlantic salmon and Brown trout in Norway. *Hydrobiologia* **849**

Boulder placement

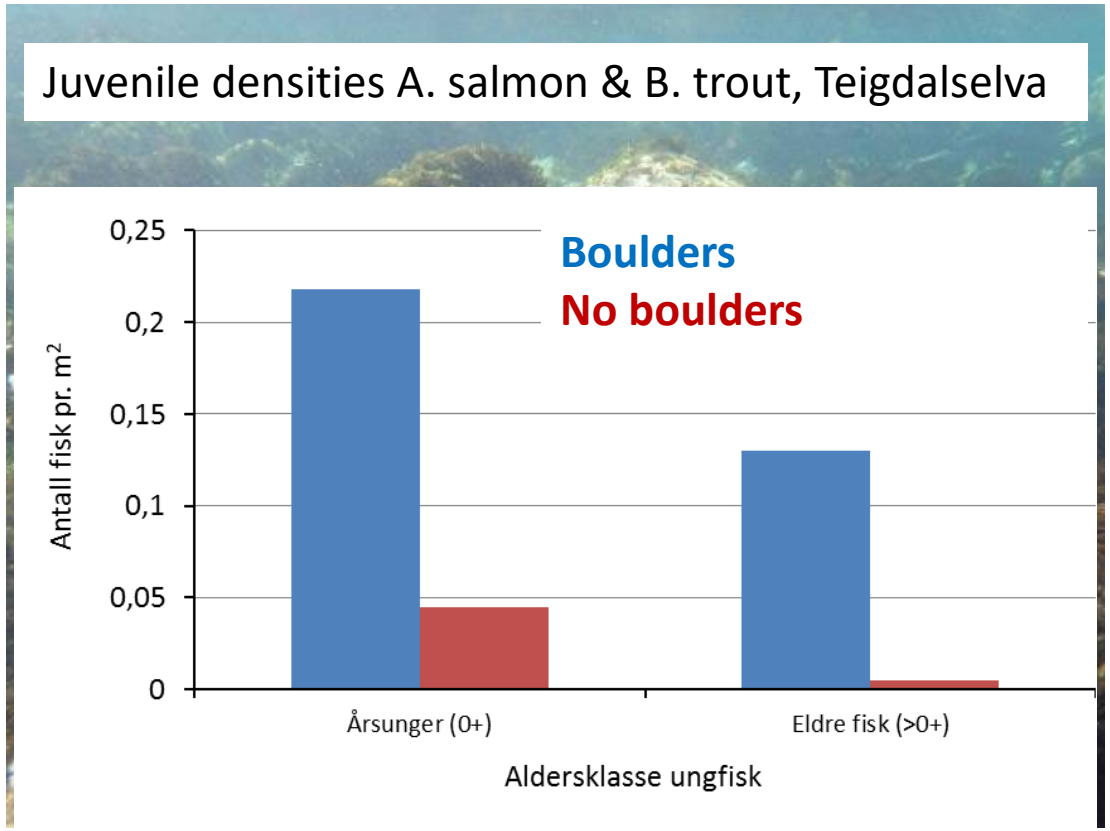
- Endurance: 1-21 år+
- Costs per boulder (2 m) or boulder group (0.5 m): 700 NOK
- Per area: 61 NOK/m^2 (2017-NOK)

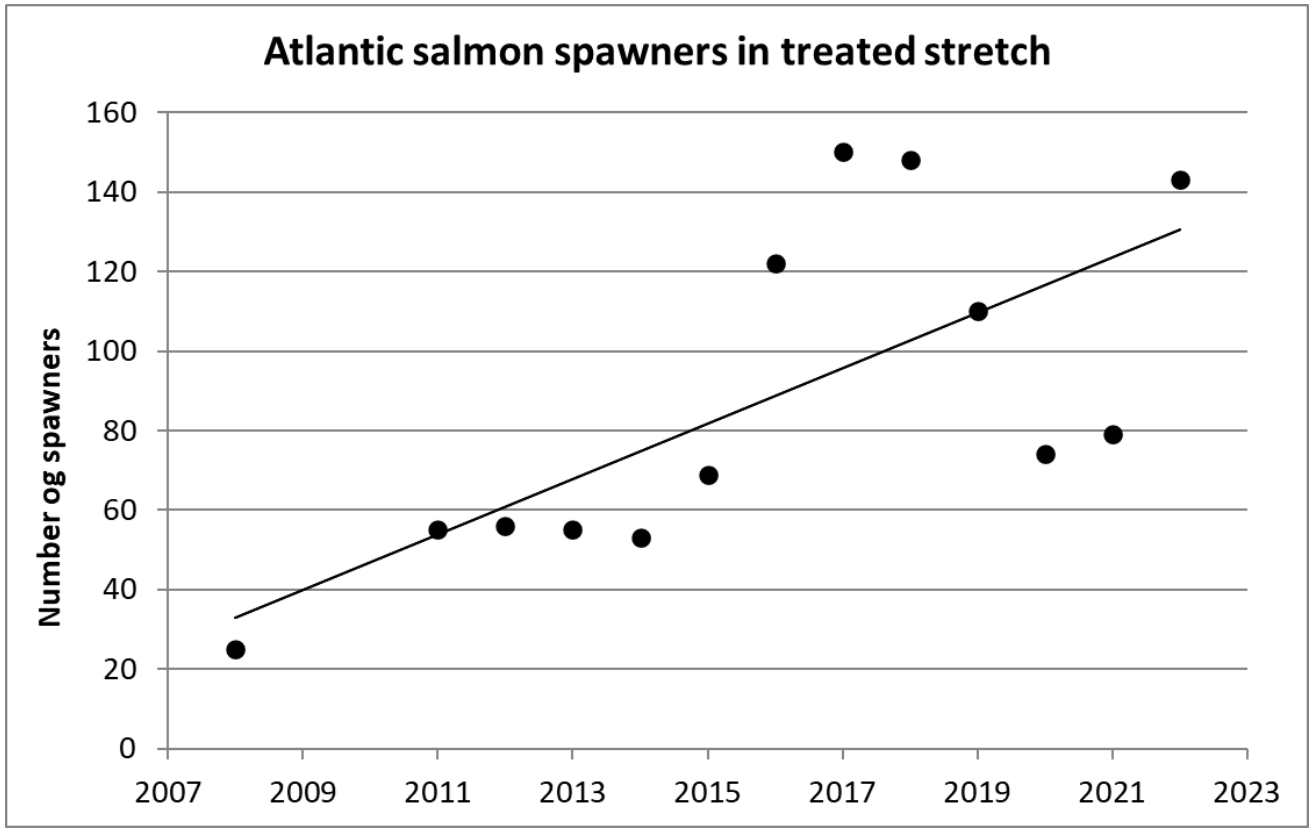


Boulder placement

- Endurance: 1-21 år+
- Costs per boulder (2 m) or boulder group (0.5 m): 700 NOK
- Per area: 61 NOK/m^2 (2017-NOK)

Frafjordelva after boulder placement (2015)





Riparian vegetation

- Endurance: 1- >100 years
- Costs of planting or fencing: 28-98 NOK/m (2023-NOK)
- Effects: Vegetation, birds, insects, fish, bank stability

Large woody debris

- Endurance: 1-4 år
- Typical costs: 25 NOK/m^2
- Effect: Depends on river type. Increased fish abundance in fluvial types

Managment of submersed nuisance vegetation

Endurance: 1-4 years

Costs of mowing or digging: 10.70 NOK /m^2/year

(based on 5 rivers and 13.5 km^2 Navrud 2015)

Managment of submersed nuisance vegetation

Effects: Higher fish and invertebrate densities with «nuisance vegetation» of *Juncus bulbosus*

Hydrobiologia (2022) 849:539–556
https://doi.org/10.1007/s10750-020-04465-x

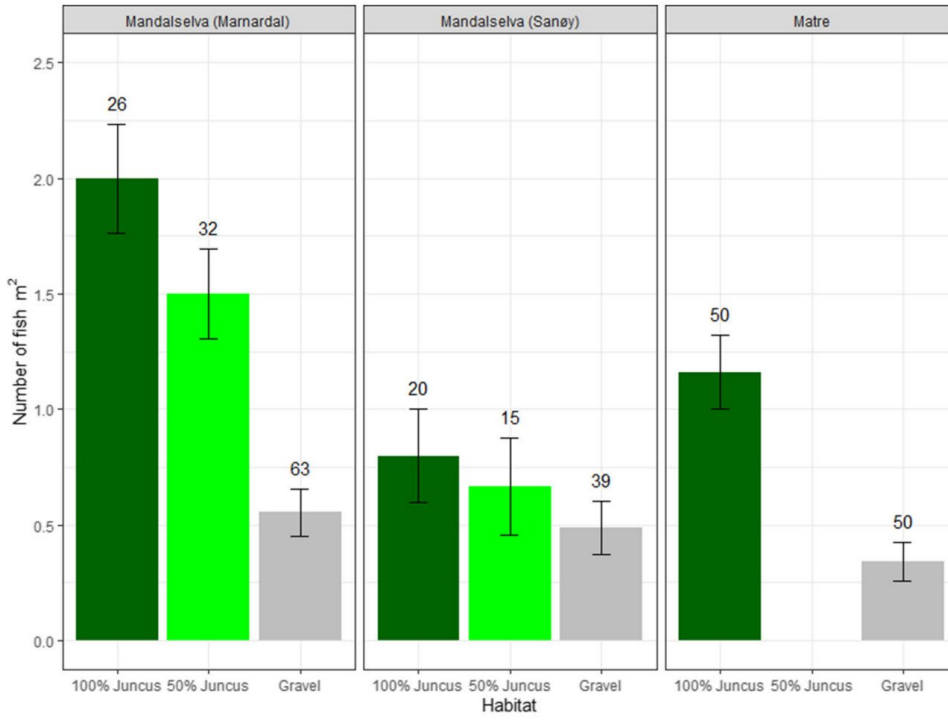
PERSPECTIVES ON SUSTAINABLE HYDRO-POWER

Effects of nuisance submerged vegetation on the fauna in Norwegian rivers

Gaute Velle · Helge Skoglund · Bjørn T. Barlaup

Received: 20 February 2020 / Revised: 23 October 2020 / Accepted: 11 November 2020 / Published online: 18 January 2021

Abstract The abundance of aquatic vegetation is when their spawning grounds are covered by vegeta-



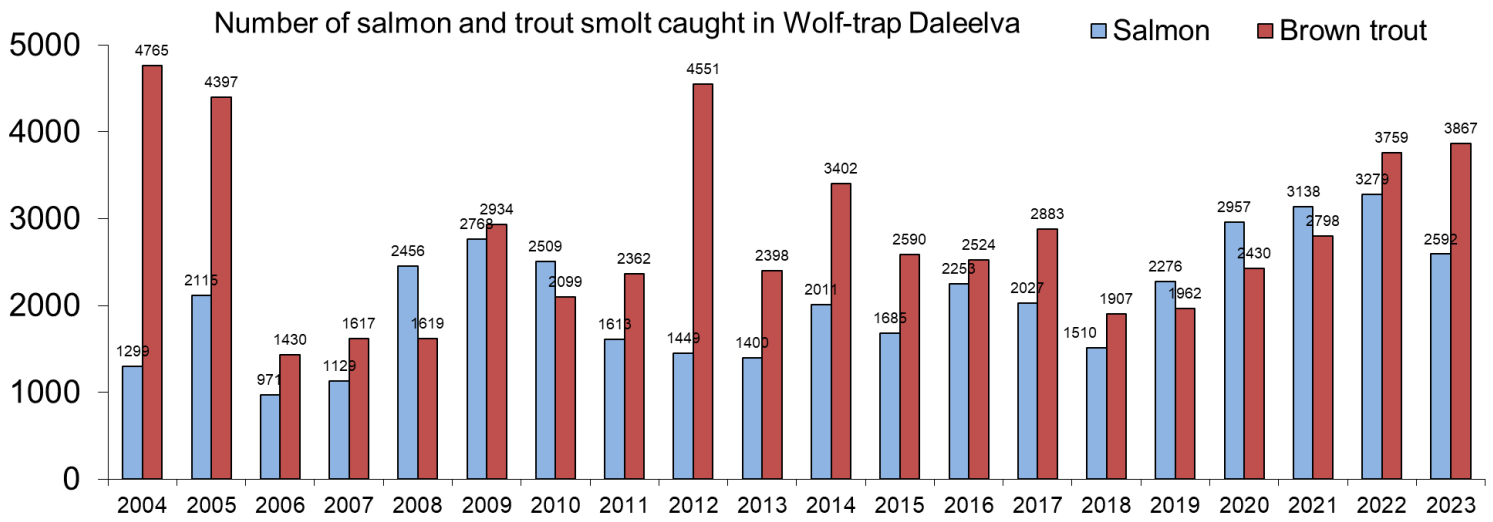
Environmental flow – River Daleelva 300 l/s + residual flow

Costs: 840 000 – 6 590 000 NOK/year (2020,2021)

Salmon smolt production Daleelva: 9000-14000 ind.

8-11 smolts /100 m^2

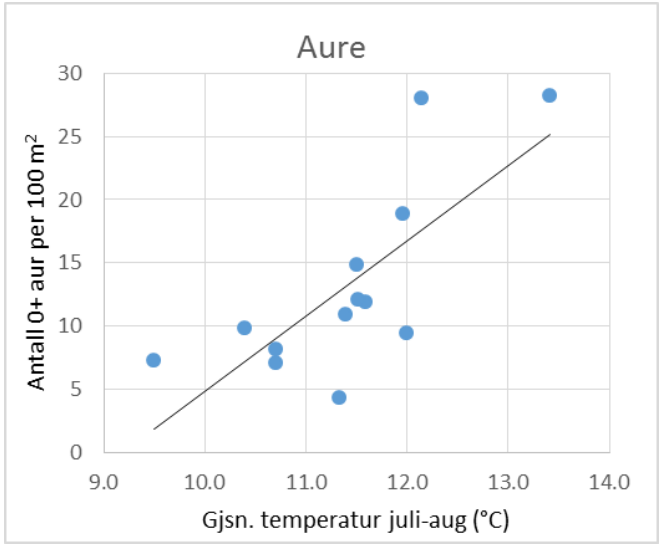
Residual flow stretch counts: 2072 salmon + 2704 trout smolts

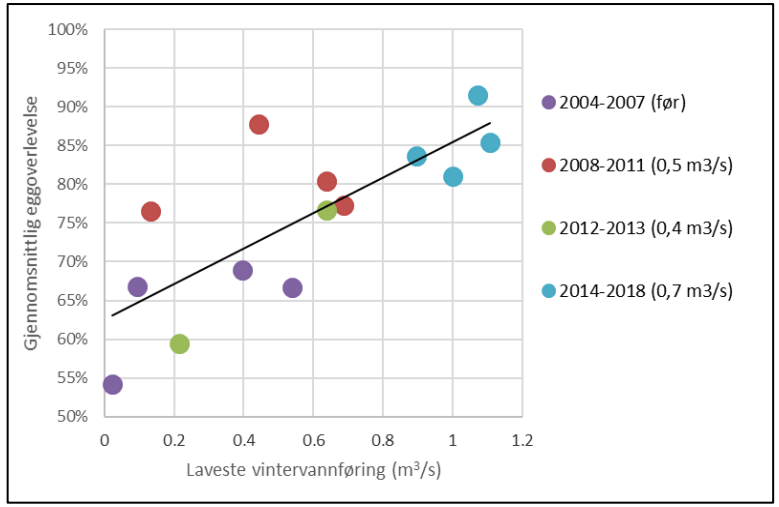


Environmental flow – River Bjoreio temperature & water cover

Q = 1-3 m^3/s + residual flow

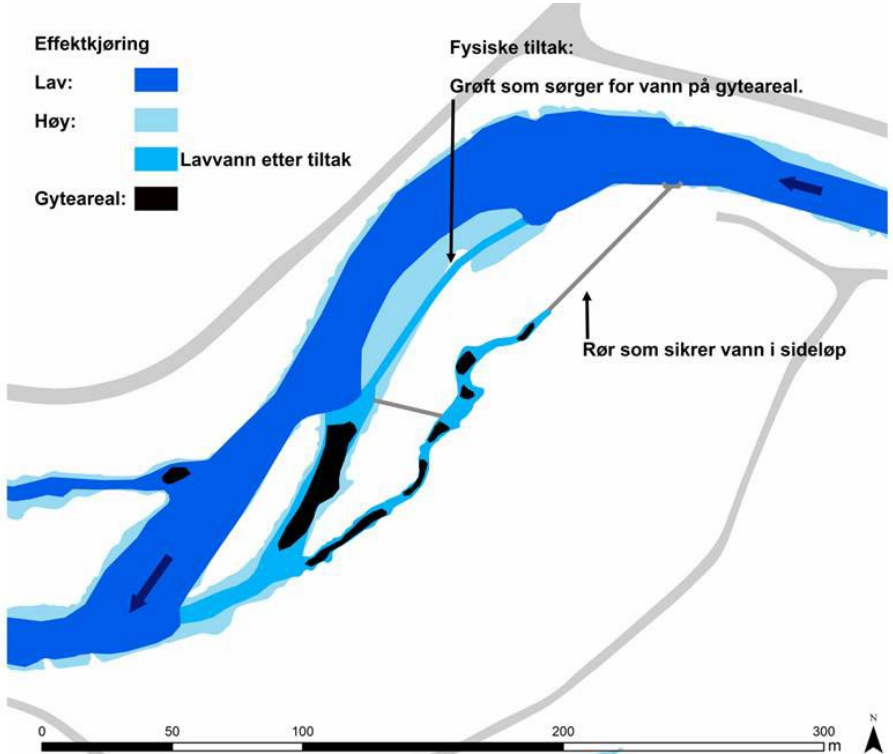
Effects: Higher water temperature and fish densities, (Skoglund 2018)

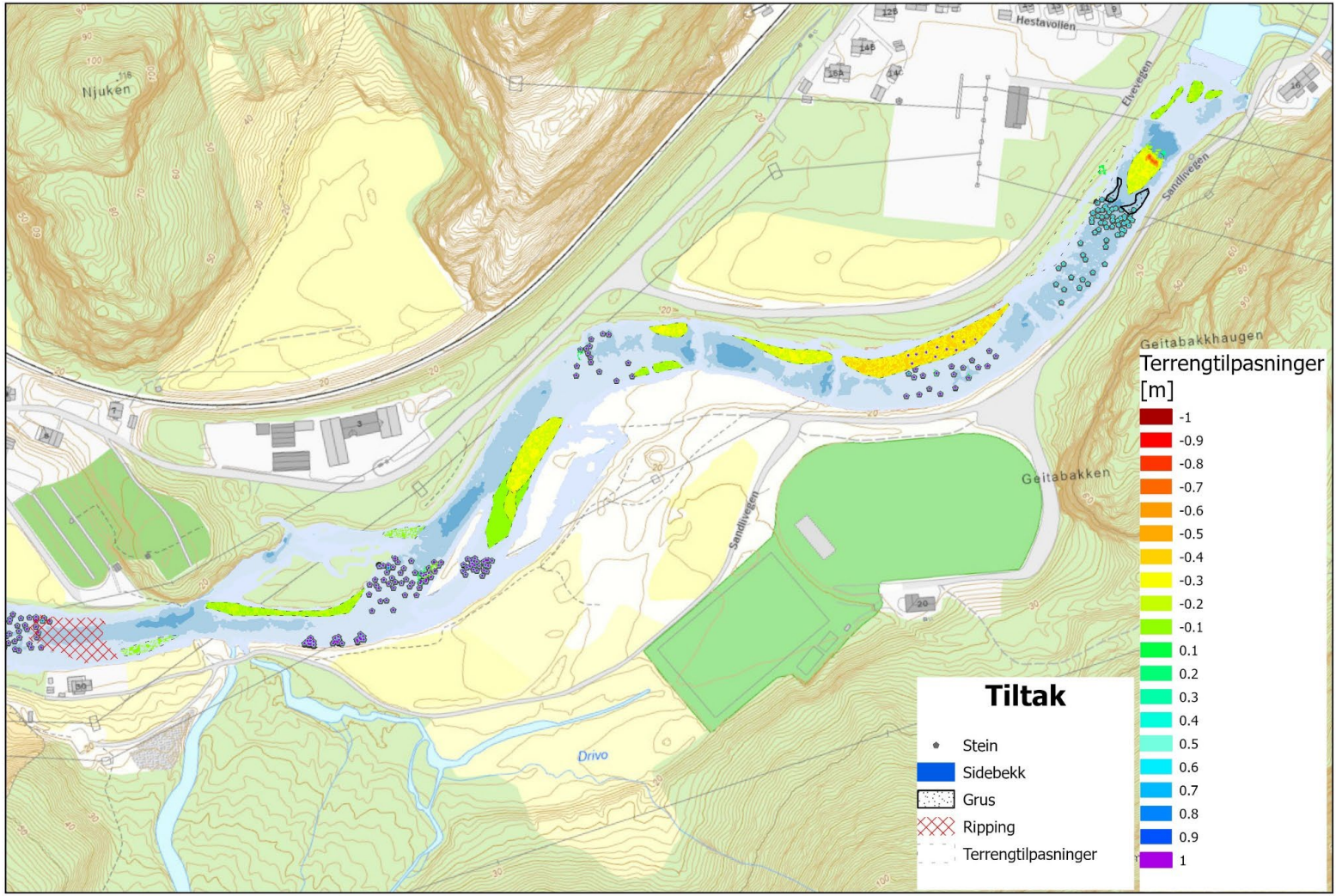




Mitigating hydropeaking by morphological adjustments

- Adjusting bathymetry
- Boulder placement as in diamictic plane beds
- Maintaining habitat quality
- Based on natural river types
- 2D hydraulic modelling





Fishways

- Endurance > 30-60 years
- Costs 10.115 NOK/m^3 construction volume (2017 NOK)

0.04-0.09 NOK/m2/year

14-19 NOK / adult salmon

(Rivers Vestre Jakobselv og Målselv)

- Effect: Fish migration upstream

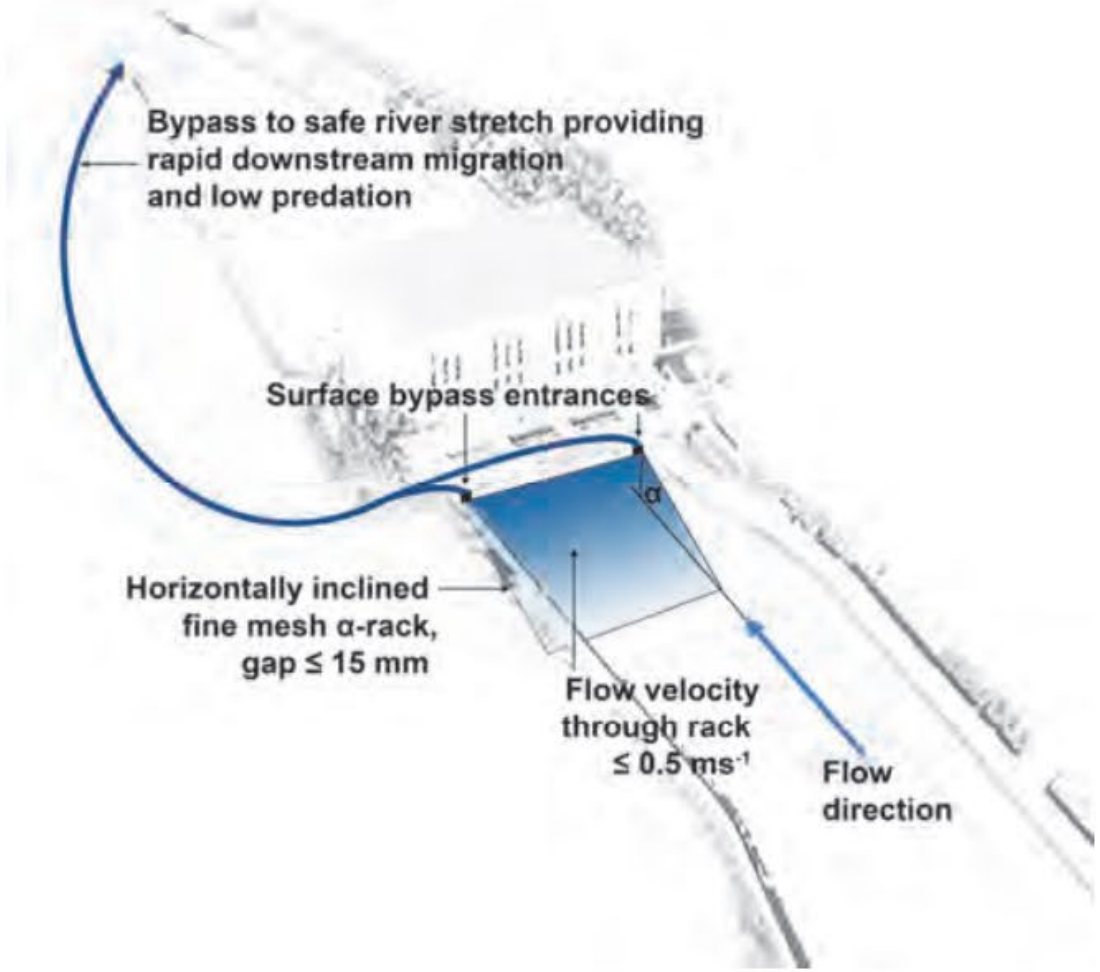
Fishways in culverts of small streams
5-10 m wide,

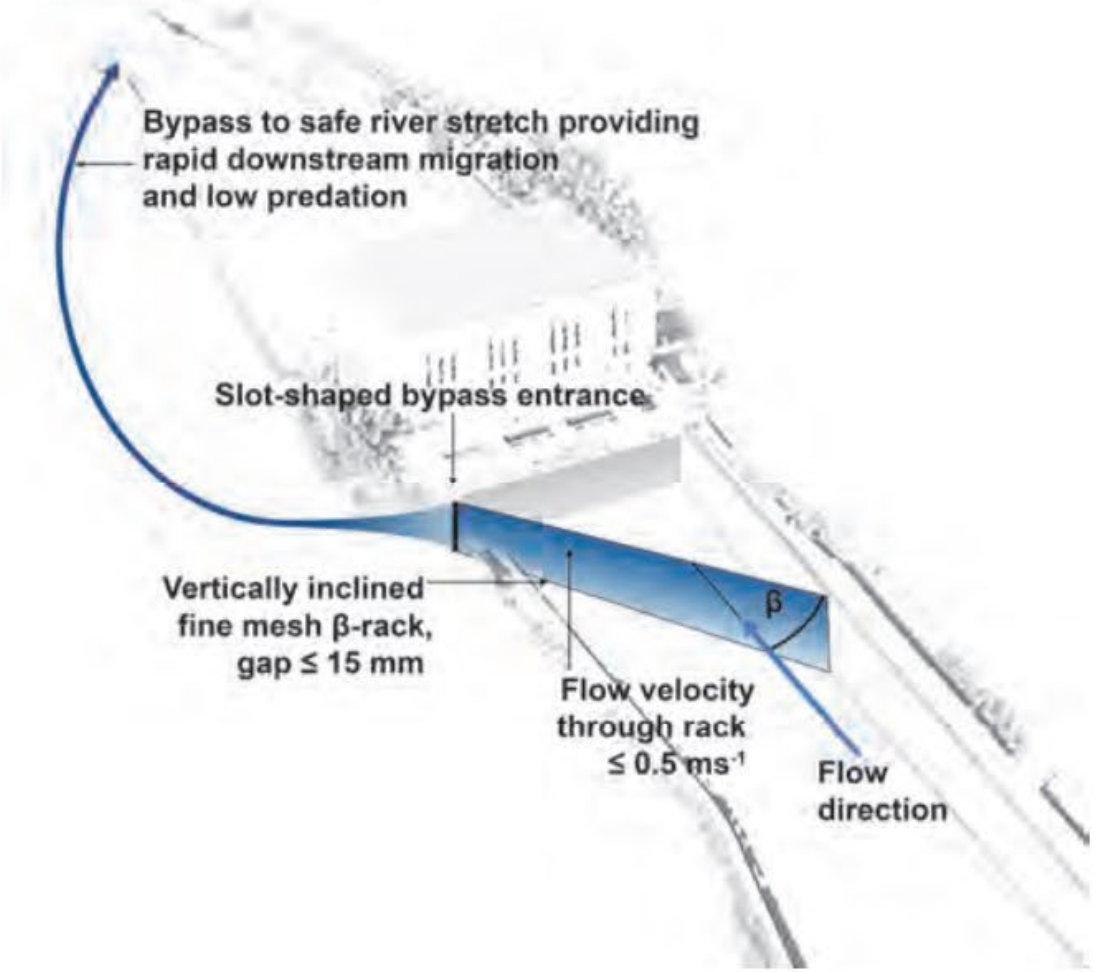
- Endurance: > 30 år +
- Natural river bottom 18.337 NOK/m^2
- Step-pool ramp below 2.371 NOK/m^2 (average)
- Effect: Fish migration

Foto : Statens Veivesen

Fishways

State of the art projects after 2018 – Up- & downstream facilities





Palmafossen (Voss Energi)

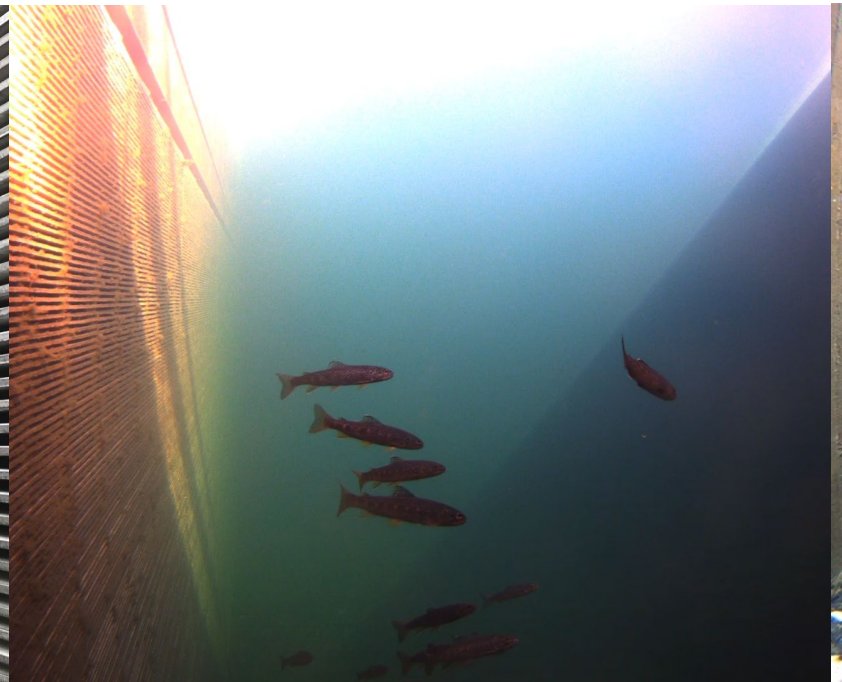
Turbine capacity: 30 m^3/s

Vertical slot pass: 0.8 – 5 m^3/s

Downstream bypass: 2.7 m^3/s

Beta-screen: 12 mm

Costs for fishways: 19.3 MNOK (2021-NOK)



State of the art projects after 2018 – Up- & downstream facilities

Boenfoss (Boen Foss AS)

Rafoss (Sira-Kvina kraftselskap)

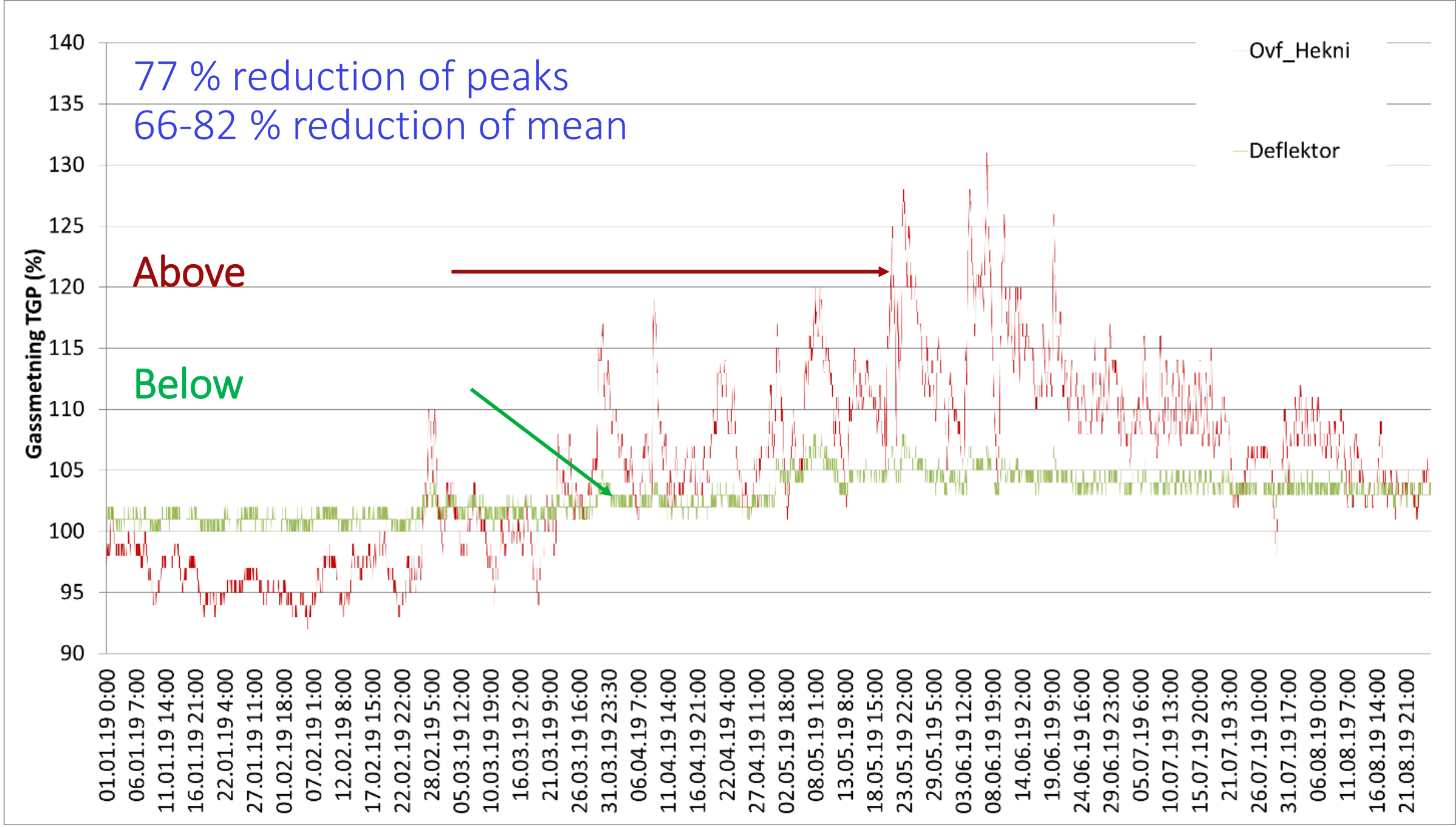
Tolga kraftverk (Hafslund Eco)

Nye Dalsfoss kraftverk (Skagerak Kraft AS)

(Foto: Lars Bendixby)

Reduction of TDGS - Total dissolved gas supersaturation

- Flow adjustments in secondary intakes
- Vacuum intakes
- Screen cleaners
- Alert systems
- Dilution
- Deflektor aereation


77 % reduction of peaks
66-82 % reduction of mean
Above
Below
Ovf_Hekni
Deflektor
Gassmetning TGP (%)
140
135
130
125
120
115
110
105
100
95
90
01.01.19 0:00
06.01.19 7:00
11.01.19 14:00
16.01.19 21:00
22.01.19 4:00
27.01.19 11:00
01.02.19 18:00
07.02.19 1:00
12.02.19 8:00
17.02.19 15:00
22.02.19 22:00
28.02.19 5:00
05.03.19 12:00
10.03.19 19:00
16.03.19 2:00
21.03.19 9:00
26.03.19 16:00
31.03.19 23:30
06.04.19 7:00
11.04.19 14:00
16.04.19 21:00
22.04.19 4:00
27.04.19 11:00
02.05.19 18:00
08.05.19 1:00
13.05.19 8:00
18.05.19 15:00
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03.06.19 12:00
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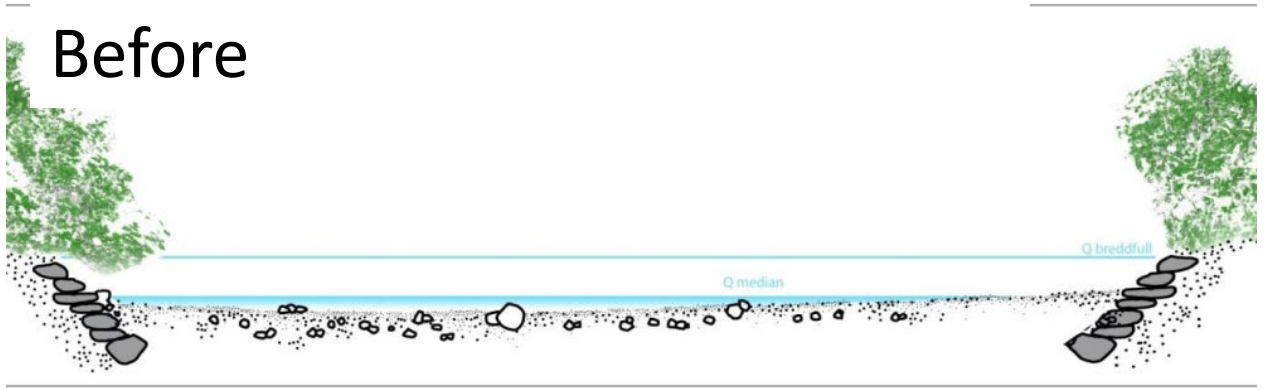
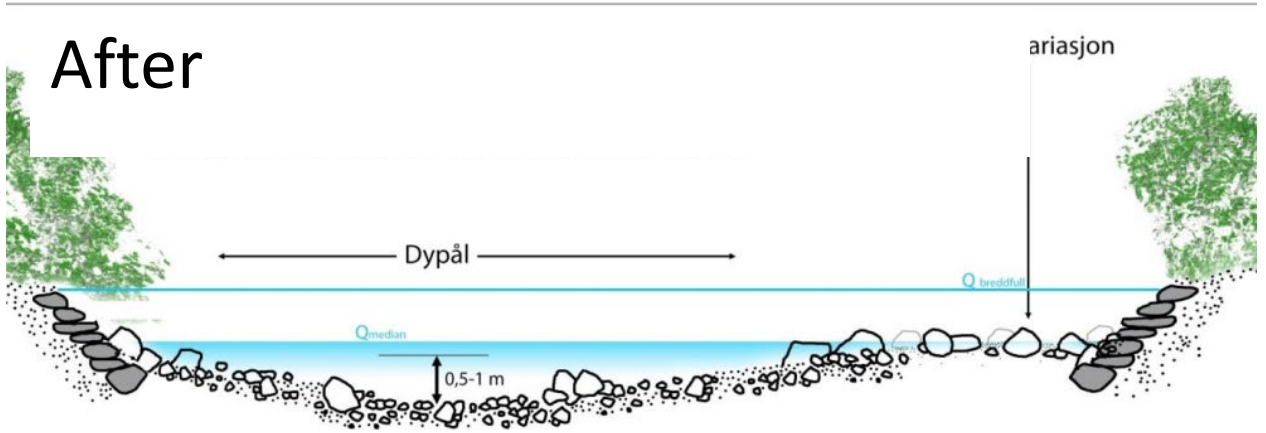
14.06.19 2:00
19.06.19 9:00
24.06.19 16:00
29.06.19 23:00
05.07.19 6:00
10.07.19 13:00
15.07.19 20:00
21.07.19 3:00
26.07.19 10:00
31.07.19 17:00
06.08.19 0:00
11.08.19 7:00
16.08.19 14:00
21.08.19 21:00

Sediment management

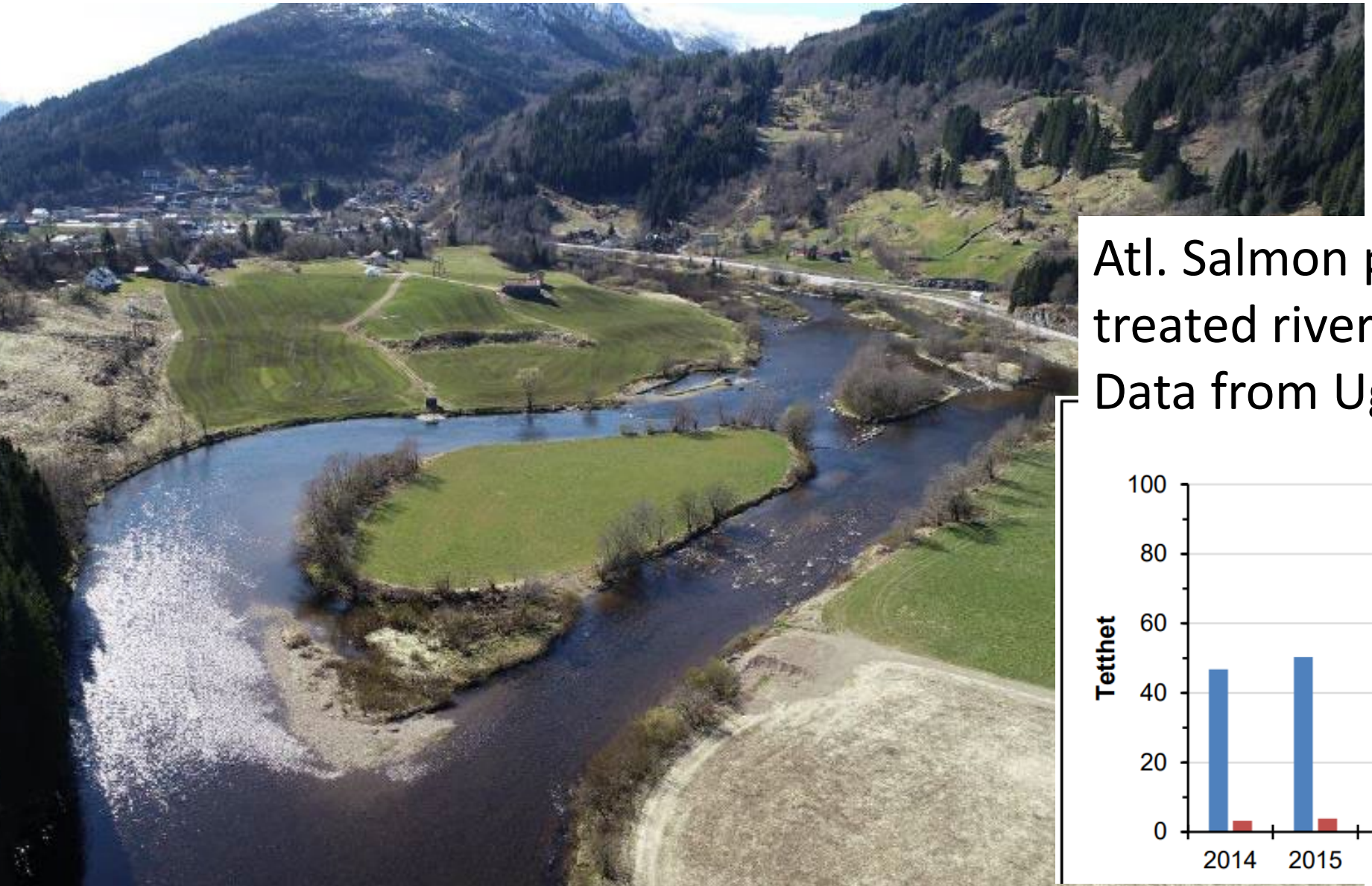
- **Removing fines in River Nausta,**
- **Maintaining coarse sediments,**
- **Reestablishing natural river morphology**
- **Based on natural river types**



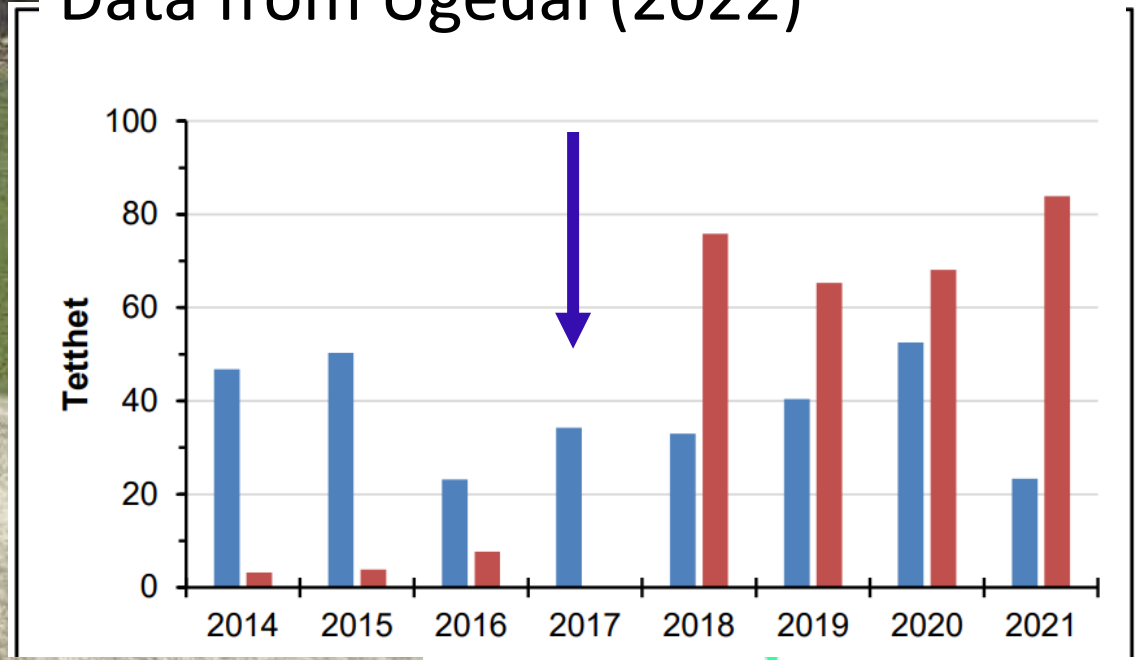


- Endurance: 6 years +
- Costs: 31 NOK/m2
- Effects:
  - Significant increase in parr densities
  - Less inundation (Q<Q10)

Sediment management in River Nausta

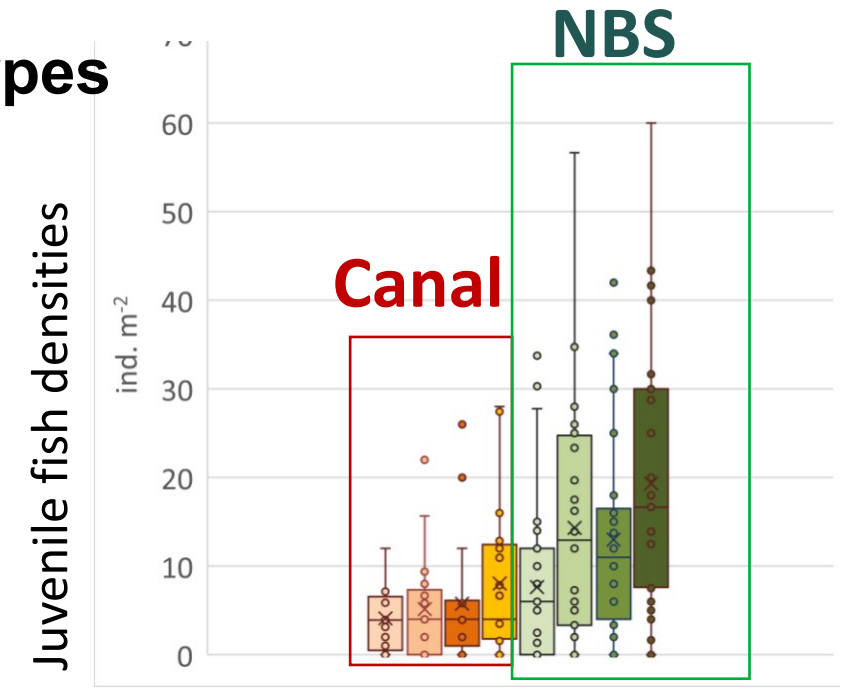


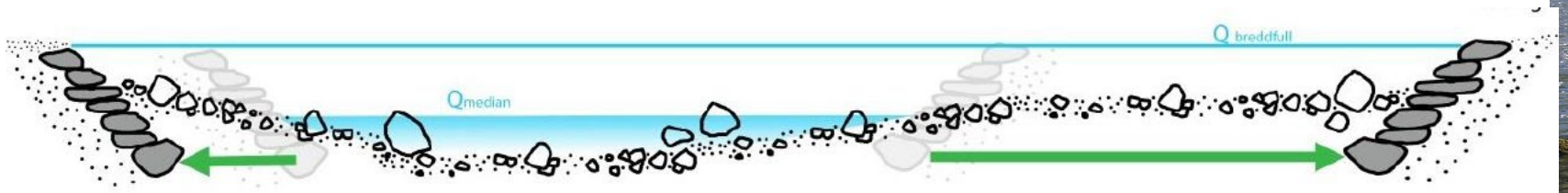
Atl. Salmon parr densities in treated river stretch (2017). Data from Ugedal (2022)



Nature based solutions (NBS)

- No bank protection
- Nature like boulder layer and vegetation on rip-rap.
- Based on natural river types
- Channel widening





Restoration - dam & weir removal – Tromsa dam (head 7 m)

Endurance: permanent

Costs: 2.9 MNOK (2022-NOK)

Effects: Fish migration upstream Lågen tributary

(bilder: Tore Solbakken GSFF)

Restoring rivers

by removing ground sills

- Endurance: permanent
- Costs: 4-65 NOK/m^2
- Effect: increase in juvenile densities
  improved connectivity

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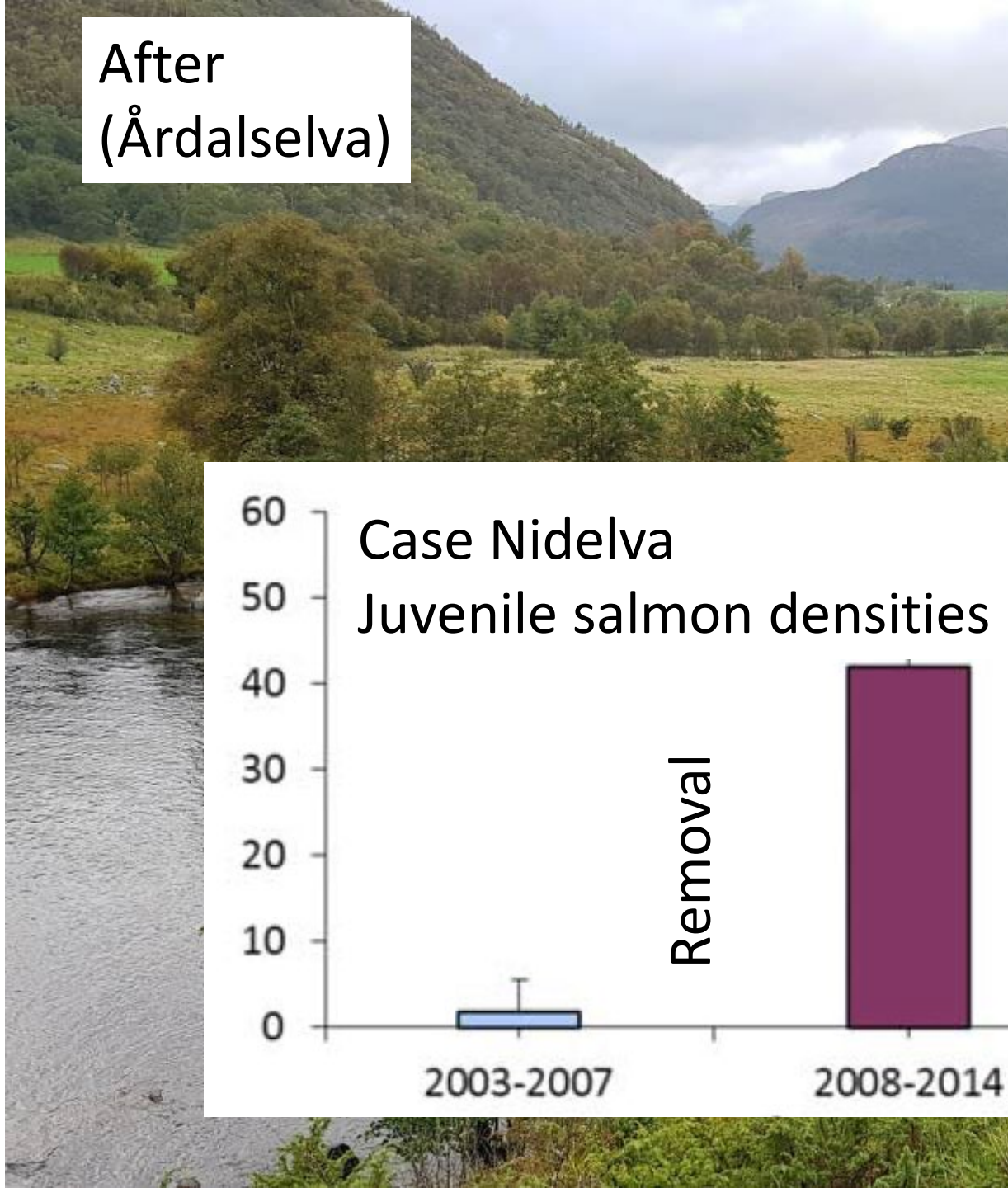
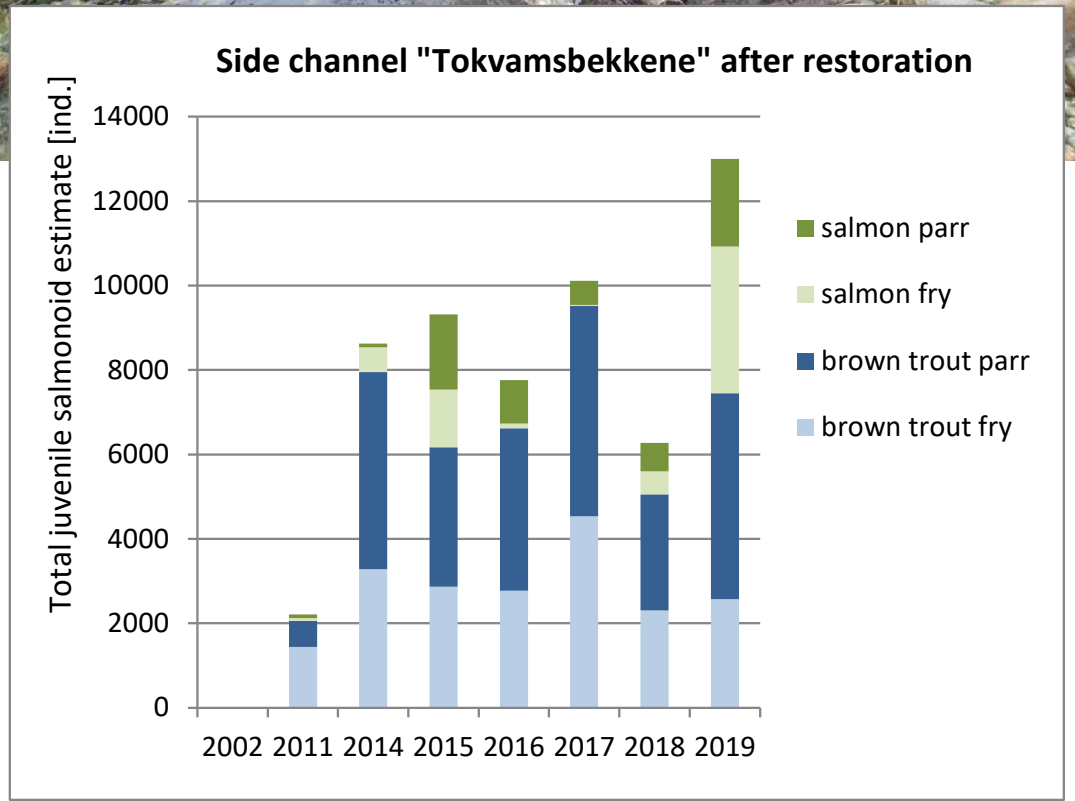


Restoring side channels

- **Reconnecting cut off side channels**
- **Nature like river morphology based on river typology**
- **Dynamics and riparian vegetation**

- Endurance: permanent
- Typical costs: 200 NOK/m^2

- Effects:
  - Increasing aquatic habitat
  - Significant increase in juvenile fish production



Restoring rivers, side channels and active flood plan

- «More room for the river»
- More room for inundation and morphodynamics during floods

JOURNAL OF FLOOD RISK MANAGEMENT CIWEM Open Access

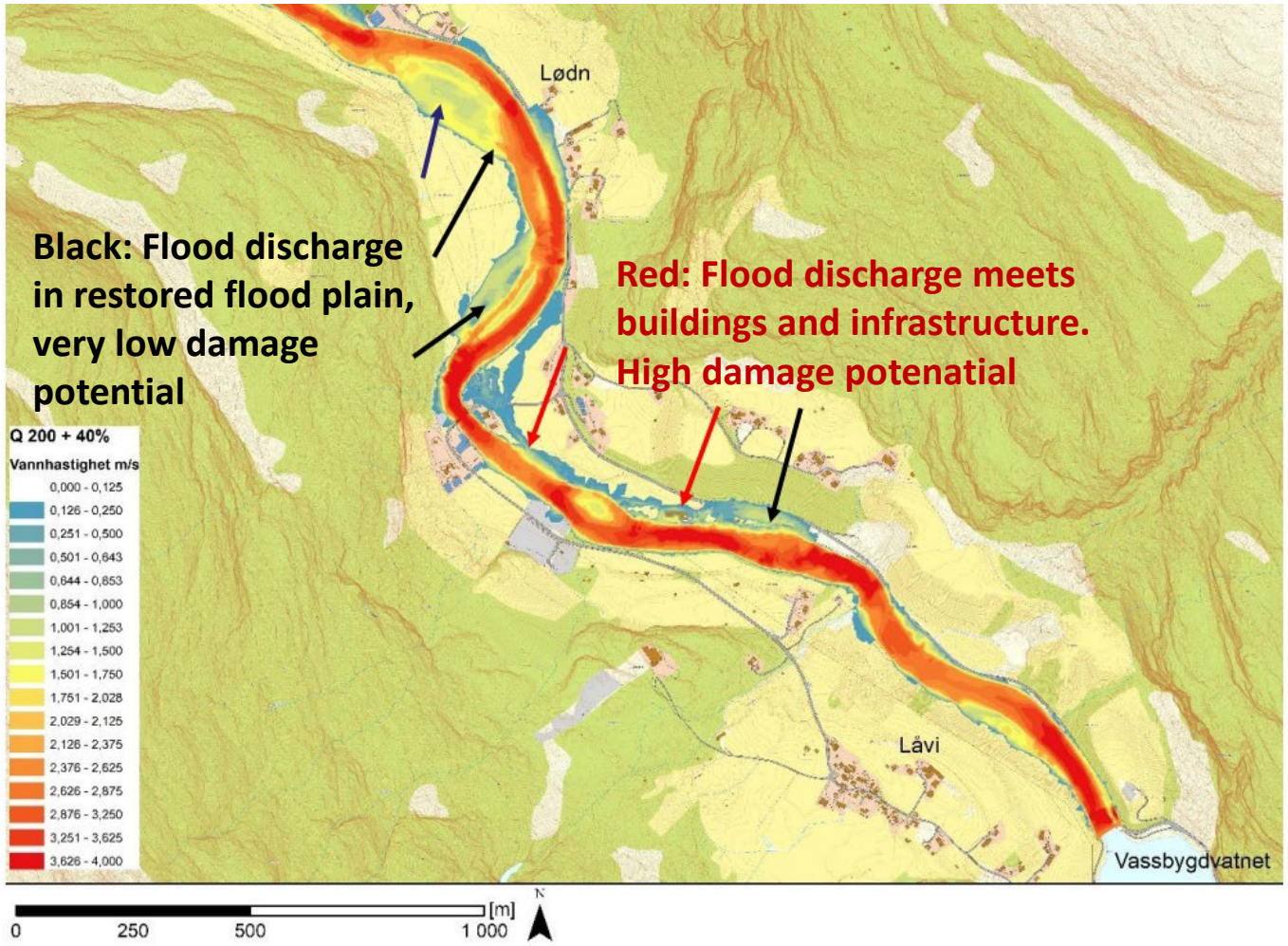
ORIGINAL ARTICLE | Open Access

Critical flows in semi-alluvial channels during extraordinarily high discharges: Implications for flood risk management

Christoph Hauer, Peter Flödl, Helmut Habersack, Ulrich Pulg

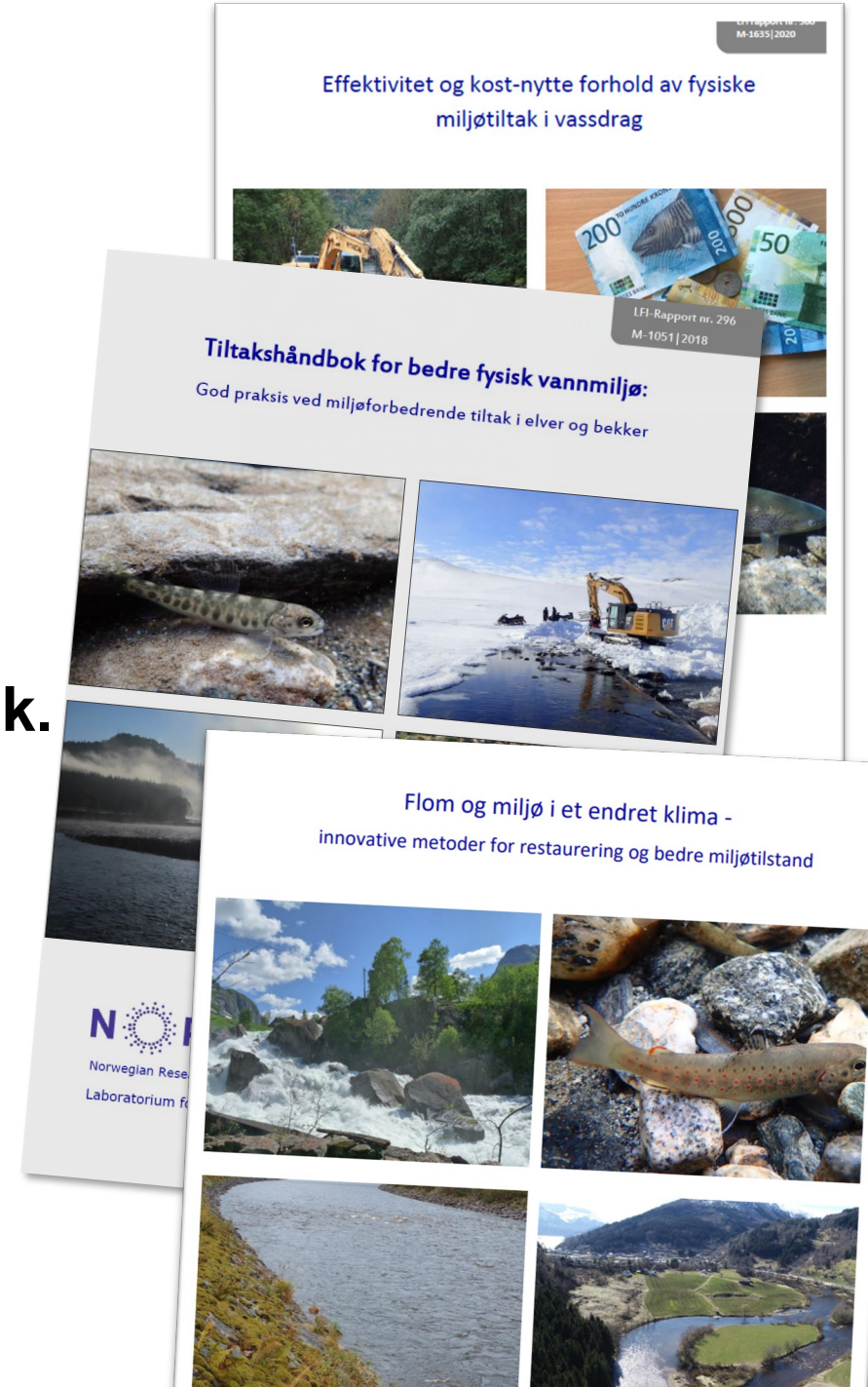
First published: 20 July 2021 | https://doi.org/10.1111/jfr3.12741 | Citations: 1

Funding information: Norwegian Water Authorities (NVE); Federal Ministry of Economy, Family and Youth and the National Foundation of Research, Technology and Development of Austria



Discussion & summary

- There are many good pratice solutions
- WFD, relicensing, EU taxonomy …
- They do cost money ! But they don’t break the bank.
- Often «Good ecological status» is posssible
- Big difference in performance - Why?

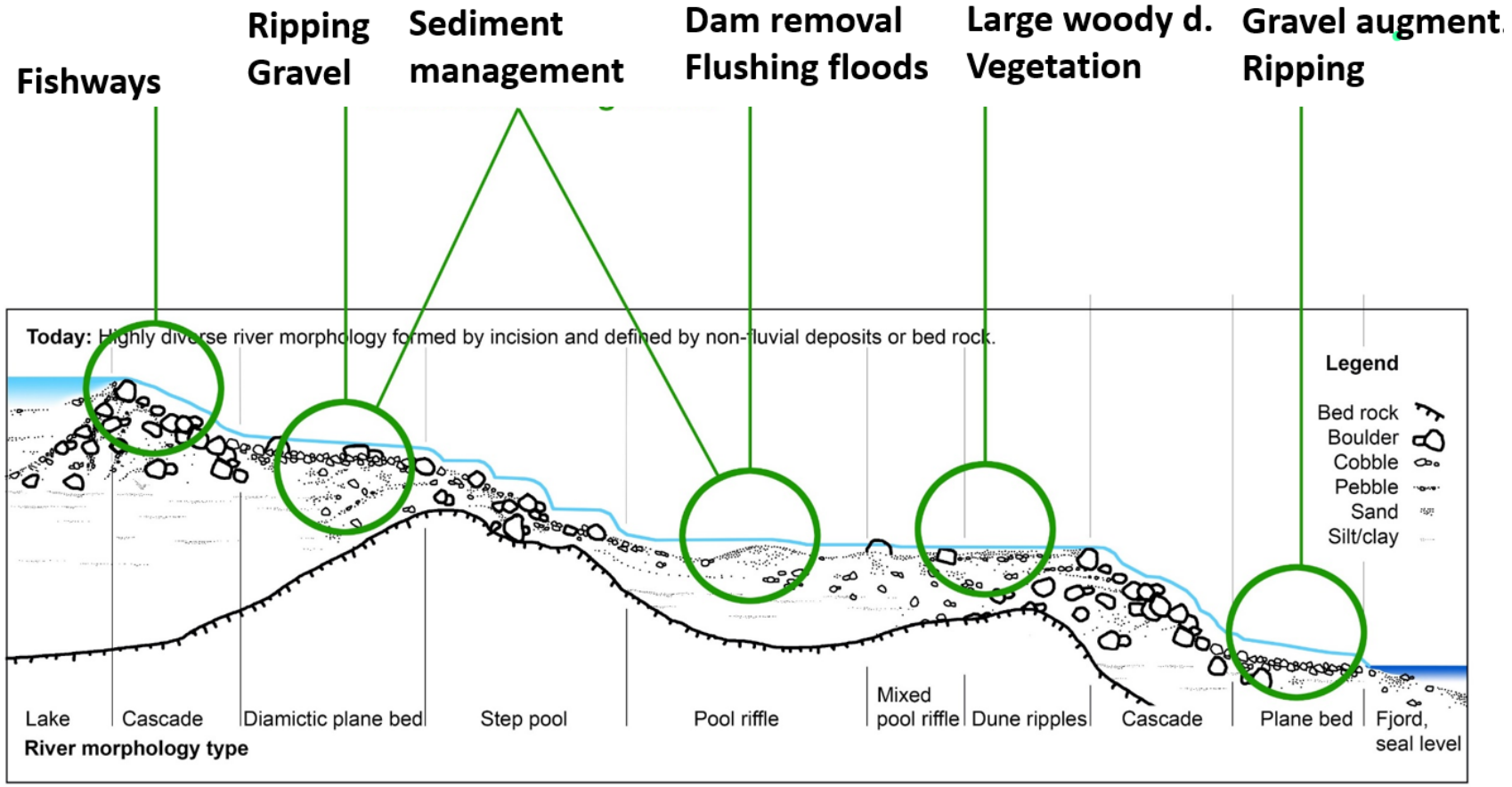


Discussion & summary

- **Solutions must fit to the rivers' hydromorphology.**
- **River typology.**

Hauer & Pulg 2018: The non-fluvial nature of Western Norwegian rivers. Catena 171.

Hauer & Pulg 2021: Buried and forgotten – the non-fluvial characteristics of postglcial rivers. RRA

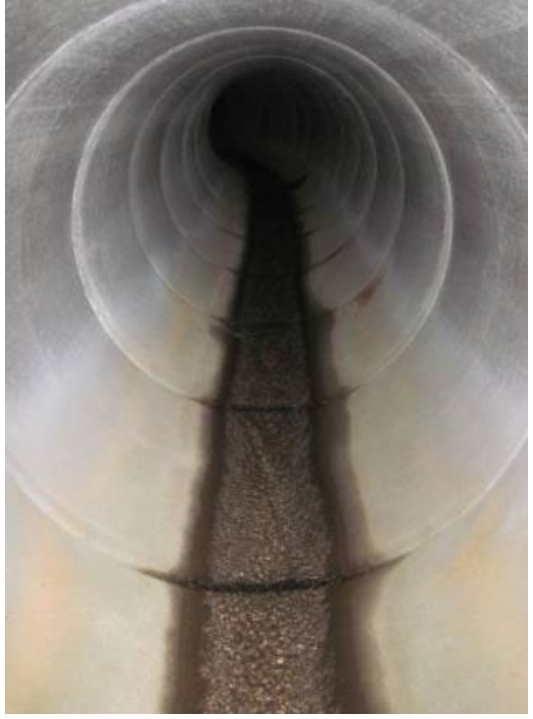


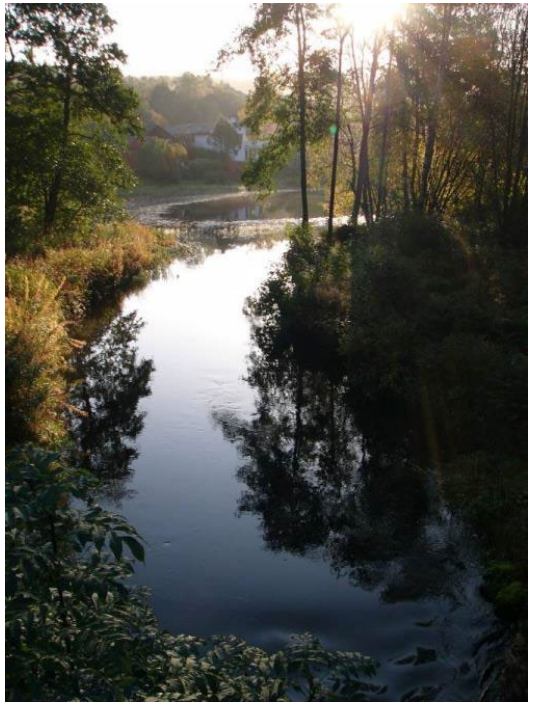
Discussion & summary

- Swedish- Norwegian initiative for a common nordic river typology

Discussion & summary

- If «good ecolocical status» can be reached without compromising the river use…
- … the water body is not defined as «heavily modified»
- Due in the rest of Europe – and relevant for Norway
- What if regulated rivers would achieve «God ecological status» not just potential ?





Discussion

- Measures and their performance depend on hydromorphological conditions
- Natural references, «Målbilde»

1. Restoration of processes, natural habitats, self-sustaining
2. Mitigation measures, including maintenance

Environmental design versus ecological restoration

- Different scientific traditions
- For many species, comunities and natural processes the restoration concept makes more sense

Thanks!

Projects financed by and in cooperation with:

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Hafslund E-Co, Statkraft, Eviny, Å Energi, Lyse, GSFF, Nausta elveeierlag, Voss Energi, Statens Veivesen, NJFF, Sabima

BOKU Wien, NINA, NIVA, NTNU, SINTEF