Extended environmental design

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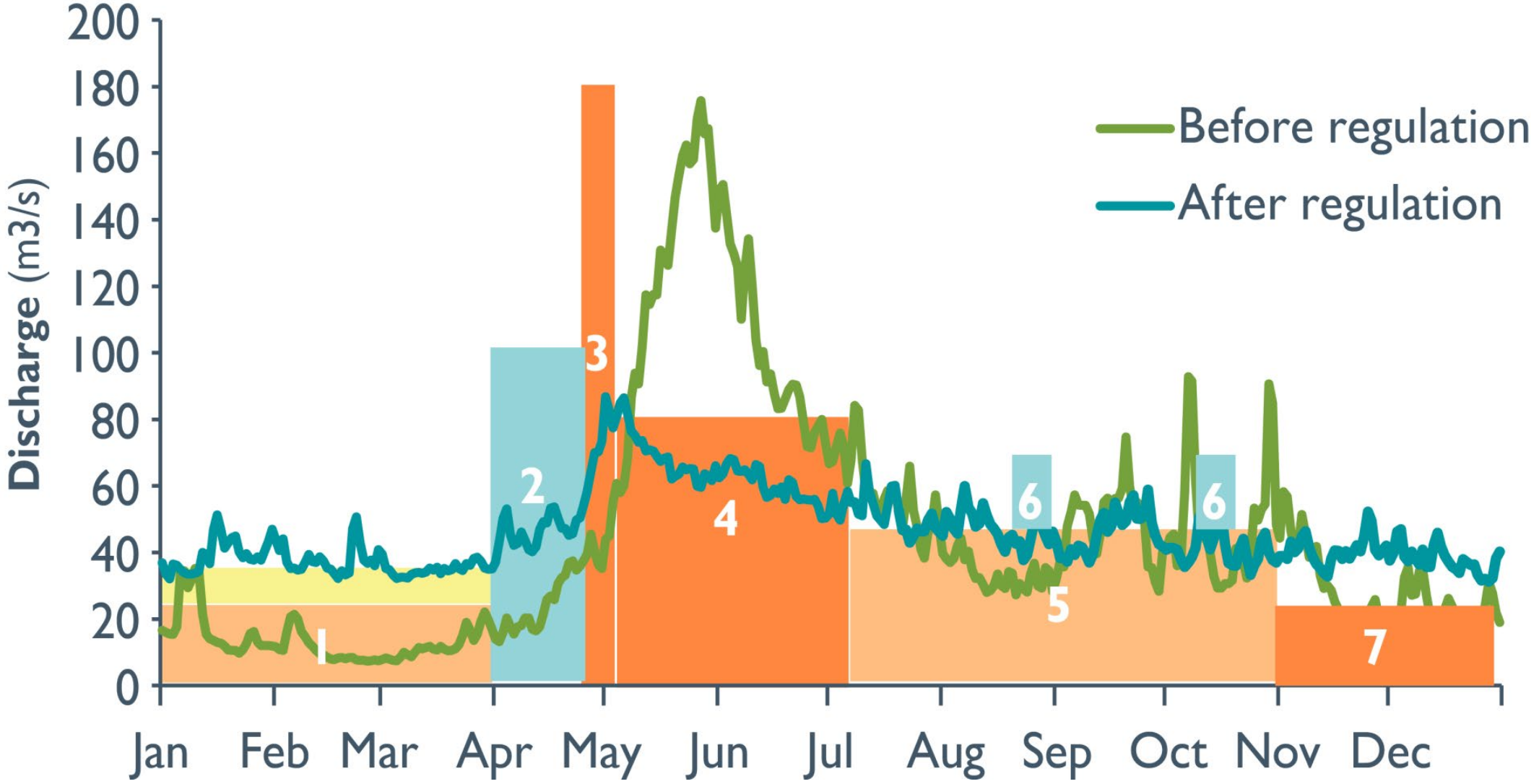
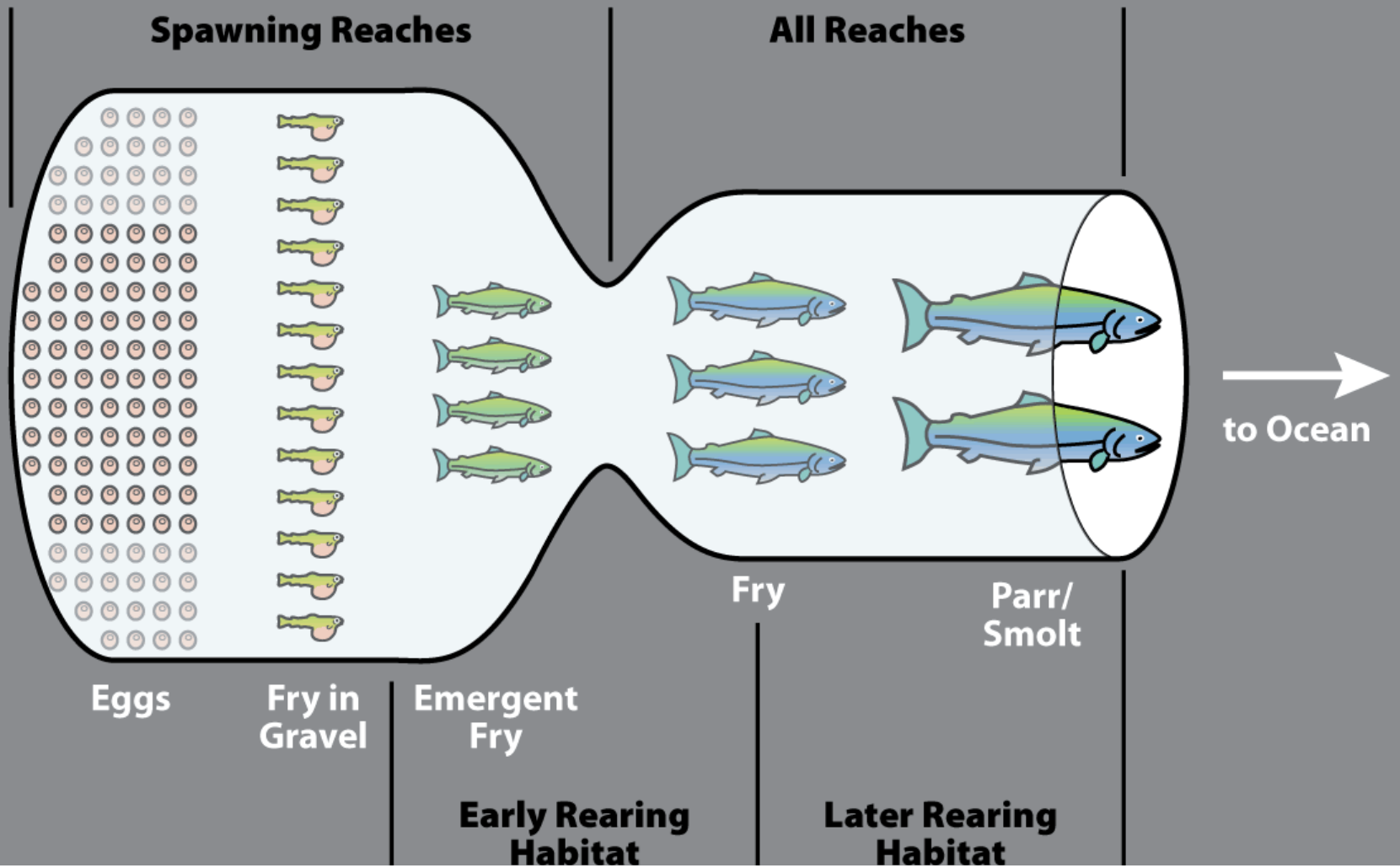
Line Sundt-Hansen, T. Forseth, T. Bongard, T. Forseth, F. Fossøy, R. Sivertsgård, M. Majaneva, B. Köhler, I.J. Hagen, S. karlsson, (NINA)
H. Skoglund (NORCE),H. Sundt (SINTEF/NTNU)

Teknologi for et bedre samfunn

Design solutions – how to use water?



HABITAT BOTTLENECK



Fish dies only once!

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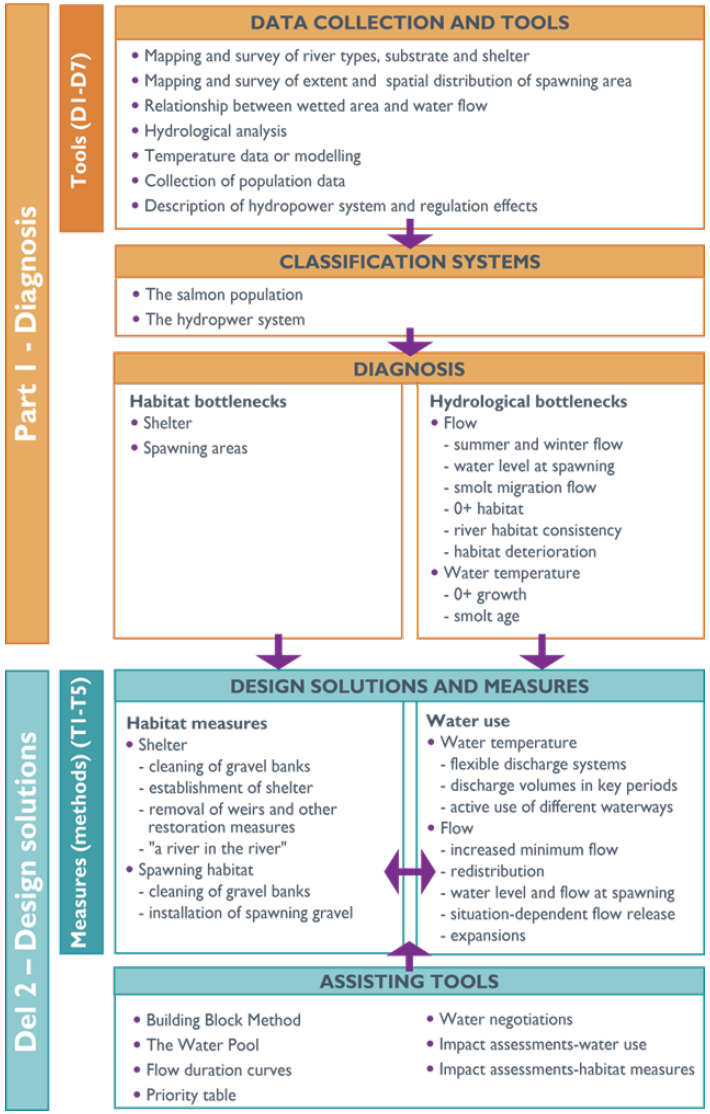
Environmental design – what is it?

- A **method** to consider power production, societal needs and the environment
- A **systematic approach** combining recognized and new knowledge
- **Handbook**, course and a set of tables and graphs for hydropower and salmon
- Method for salmon is established, include other species, biodiversity and ecosystem services



- Method for Atlantic salmon

Free download at:
www.cedren.no

SINTEF

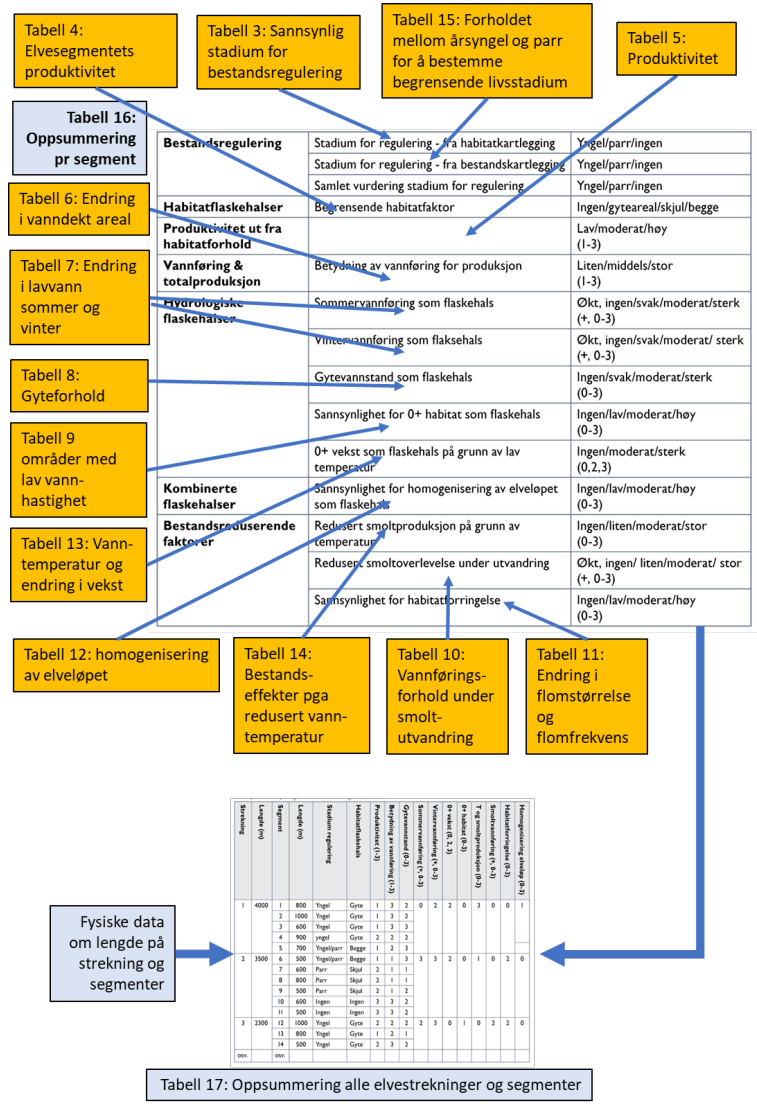
CEDREN

Guidance

Example: Impacts of peaking

Factor	Indicator	Vulnerable fish pop.	Robust fish pop.
Dewatering	Ramping rate [cm/t]	< 5	5-13
Dewatered area	Percentage of total	< 5 %	5-10 %
Ratio	Q_{max} / Q_{min}	< 1,5	1,5-3
Frequency	# days with hydro-peaking	< 10 % < 37 days	10-25 % 37-91 days
Peaking operation	Semi-quantative	Daily in < 2 periods	Daily > 2 periods
Timing	Peaking in sensible seasons	Spring	Summer & fall

Systematic sequence



Extended environmental design

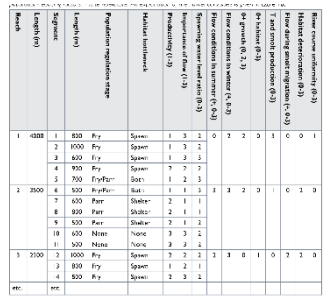
Other species and habitats

Flood protection

Energy services

Recreation and tourism

		Extent of spawning habitat as a percentage of river area.		
		Small (<1%)	Moderate (1-10%)	Large (>10%)
Distance between spawning habitats (across all segments)	Large (>500 m)	Small	Small	Moderate
	Medium (200-500 m)	Small	Moderate	Large
	Small (<200 m)	Moderate	Large	Large



Guidance, methods and tools

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Step 1: Diagnosis – what is the status?

	Indicator	Metric	Data source
 Arctic charr	• Fish density • Fish growth • Fish population	• 0^+ to 1^+ ratio • Number of 0^+ pr m^2 • Number of > 0^+ pr m^2	• Electro-fishing • Databases
 Boating/paddling	• Suitability for boating	• Suitability index	• Interviews • Controlled water release • Modelling hydraulics
 Energy services	• Water storage • Water transfer • Response time	• Storage volume • % of total flow • MW/minute	• Data bases • Power station data

Step 2: Impacts and bottlenecks

	Topic	Indicators	Metrics
 Arctic charr	• Hydrology • Temperature • Habitat • Fragmentation	• Low flow • Degree days • Wetted area • Barriers	• 7-day low flow • # days to 50% hatching • Ration low/normal wetted area • Shelter index
 Boating/paddling	• Hydrology • Habitat • Barriers	• Acceptable flow • Flood conditions • Water depth • Water velocity • Weirs	• # days between thresholds • Changes in return period • Changes in depth @thalweg • Maximum velocity m^3/s • # of weirs
 Energy services	• Generation • Reservoir • Flexibility	• Annual generation • Installed capacity • Capacity factor • Storage volume • Ramping rates	• Change in GWh • Change in MW • Change in % • Change in % • MW/min

Mitigation measures – design solutions

Environmental flow release

Stable temperature and ice cover

Introduce "a river in the river" when water is withdrawn

Two-way migration solutions

Improving habitats

"Water bank"

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Norwegian Institute for Nature Research

Line Elisabeth Sundt-Hansen (PhD)

Senior scientist Norwegian Institute for Nature research (NINA)

WP leader WP4c HydroCen

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NORWEGIAN RESEARCH CENTRE FOR HYDRO POWER TECHNOLOGY

FME
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway

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NORWEGIAN RESEARCH CENTRE FOR HYDROPOWER TECHNOLOGY

HydroCen is a research centre for environmentally friendly energy. Our main objective is to enable hydropower to meet complex challenges and exploit new opportunities through innovative technological solutions.

Research partners

NTNU SINTEF NINA Norwegian Institute for Nature Research

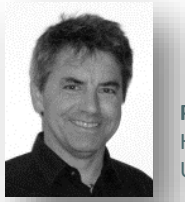
Status June 2024

- 43 partners
- 8 years (2017-2024)
- 40 mill. EUR
- 25 active projects
- >40 associated projects (~40 mill. EUR)
- ~90 Scientists
- 36 PhD & Post doc.
- >400 MSc. (estim.)
- >3000 m^2 laboratories

THE HYDROCEN ORGANISATION
per May 2024

EXECUTIVE DIRECTOR
Liv Randi Hultgreen

SCIENTIFIC COMMITTEE



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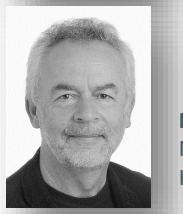
Hydraulic engineering
University of Innsbruck



Prof. Thomas Staubli
Mechanical engineering
Hochschule Luzern

Prof. Juan Ignacio Pérez-Díaz
Power systems and -scheduling
Technical University of Madrid

Sr. Researcher Dr. Niels Jepsen
Aquatic ecology
Technical University of Denmark

Research leader Emma Hagner
Cross disciplinary HP projects
Energiforsk in Sweden

INDUSTRY REP.
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Prof. Leif Lia

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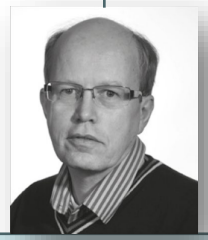
Prof. Arne Nysveen



WP 3
MARKET AND SERVICES
Dr. Birger Mo

WP 4
ENVIRONMENTAL DESIGN
Line E. Sundt-Hansen

MORE THAN 100 SCIENTISTS, PHD, POST DOC AND TECHNICAL PERSONNEL

MORE THAN 100 INDUSTRIAL MEMBERS
PARTICIPATING IN TECHNICAL COMMITTEES & PROJECTS

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CENTRE COORDINATOR
Berit G Hagen

COMMUNICATIONS OFFICER
Juliet Landrø

FINANCE OFFICER
Birk Fiveltun

INNOVATION MANAGER
Jonas Bergmann-Paulsen

INNOVATION FORUM

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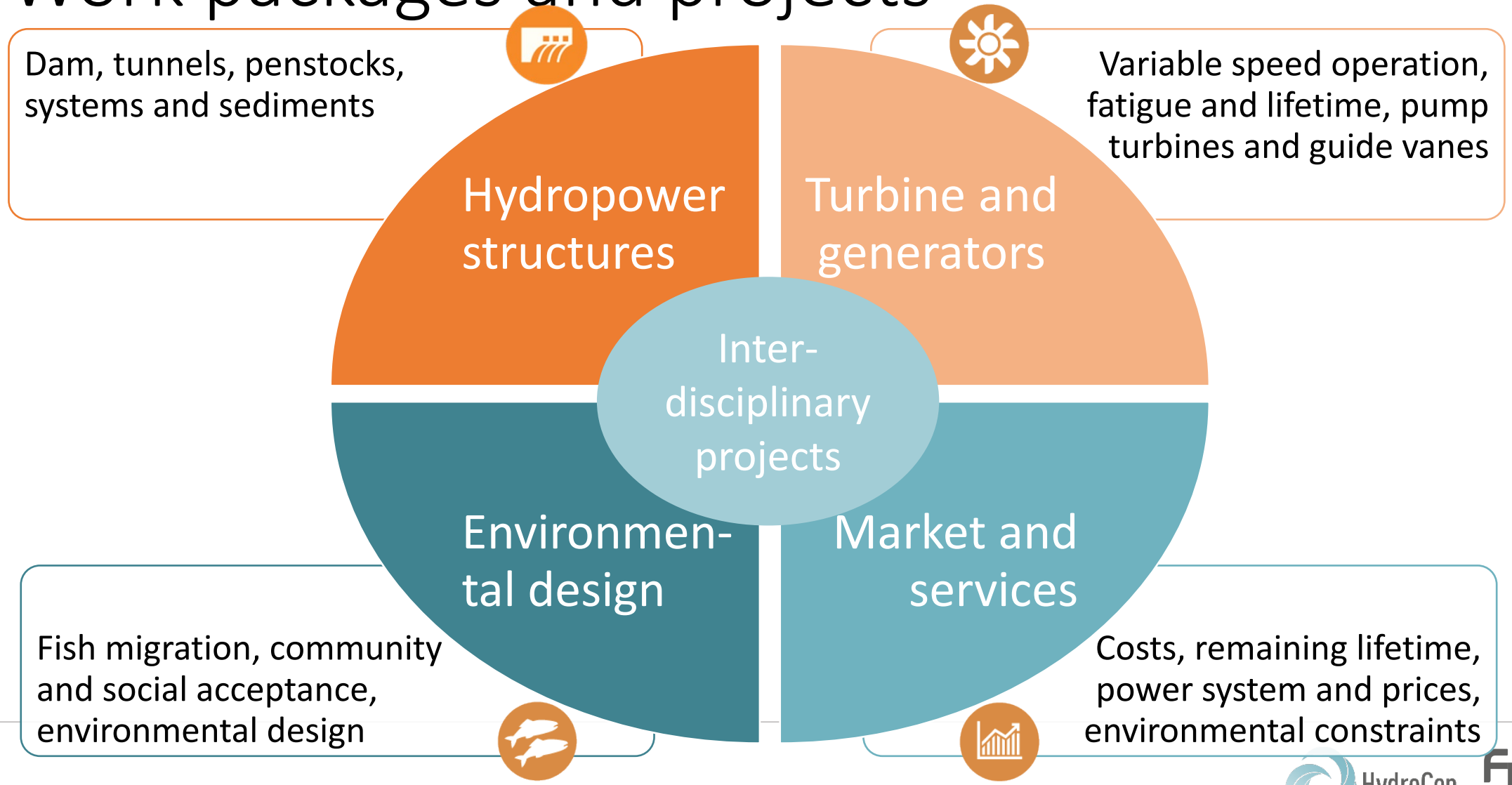
Work packages and projects



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Demonstrating expanded environmental design in Demo case River Nea

Line Elisabeth Sundt-Hansen (PhD)

(Senior research scientist)

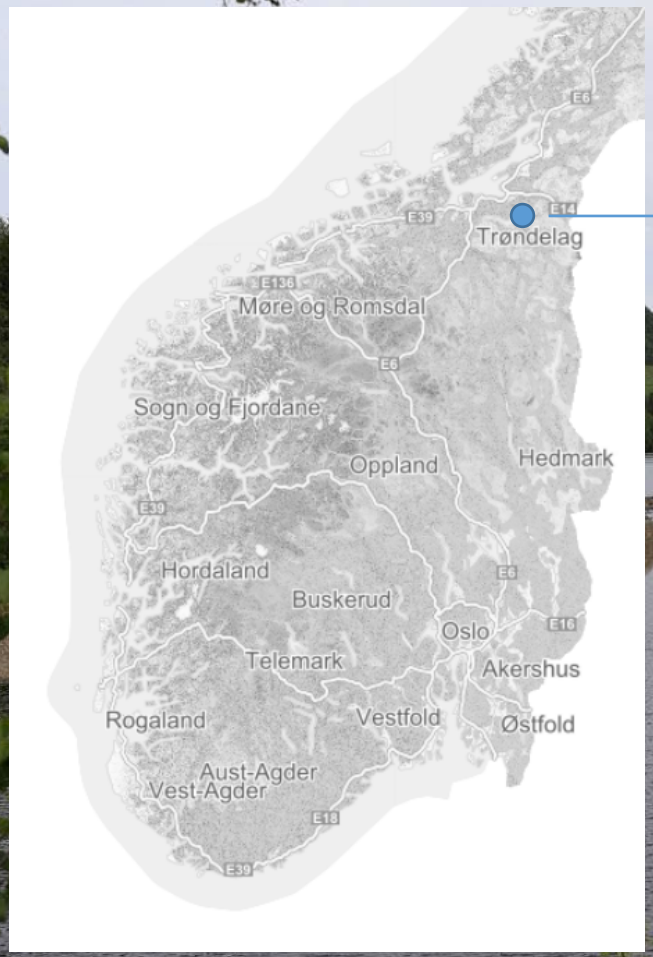
T. Forseth, T. Bongard, T. Forseth, F. Fossøy, R. Sivertsgård, M. Majaneva, B. Köhler, I.J. Hagen, S. karlsson, (NINA), H. Skoglund (NORCE),H. Sundt (SINTEF/NTNU), A. Harby (Sintef Energi AS)

Environmental design expanded

- In Hydrocen, centre for environmentally friendly hydropower
- Expanding the concept to new river systems
  - Inland rivers, other fish species
- Adding more ecological elements and people
  - biodiversity, recreational use, landscape perception

Test case:River Nea

Nea

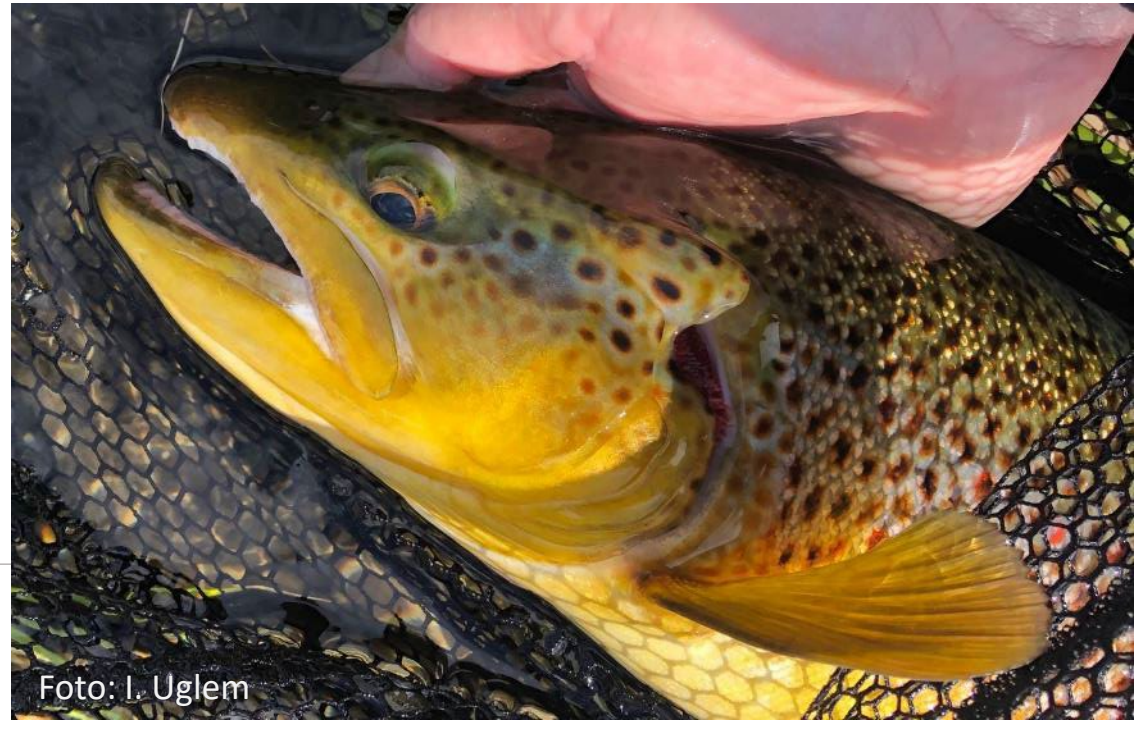


Nea river

Background River Nea

- Historically important spawning river for large Brown trout from the Selbu Lake
- Nea is known for sports fishing
- Population reduced in the last decades
- Changes in ecosystem

- Water shed is regulated for hydropower production by Statkraft
- Water deferred in tunnel, no minimum discharge in winter
- 32 weirs in 20 km
- Introduction of non-native species such as European minnow and pike



Research questions

- Are the weirs barriers for spawning migration and juvenile movement?
- Are the weirs impacting the ecosystem; invertebrates?
- How do people view the weirs?

Aim: Develop methods to provide answers to these questions

Foto: H.M. Berger

Foto: I. Uglem

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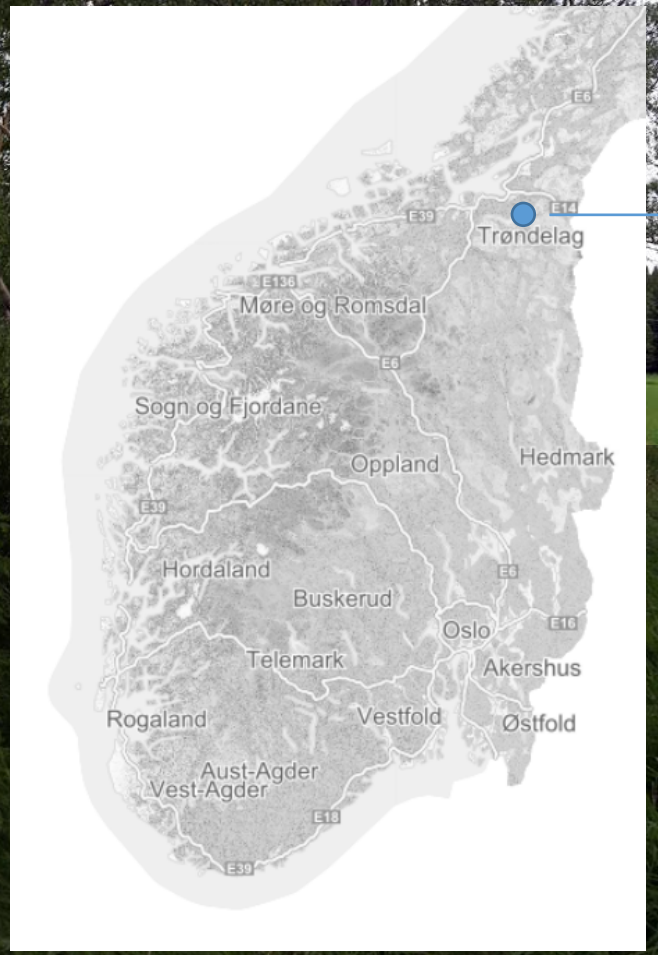
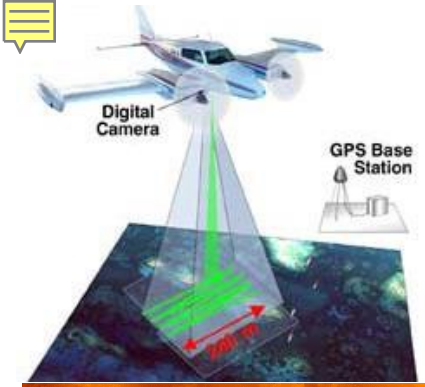
Case studies: River Nea 32 weirs (20 km stretch)

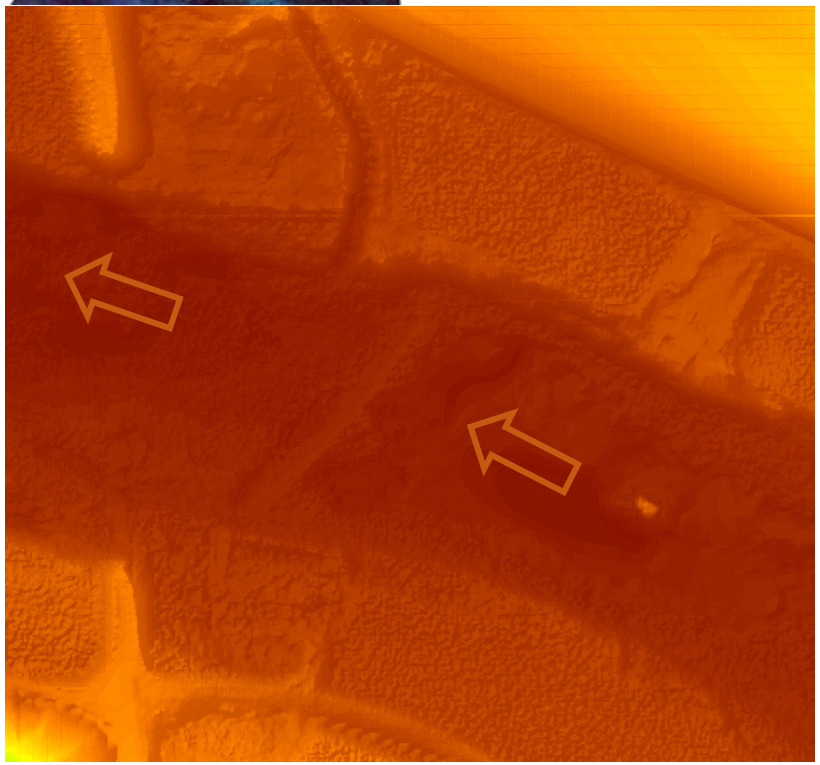
- The River Nea case
  - Genetical analysis of Brown Trout (pike & minnow)
  - Green LiDAR (mapping)
  - Biodiversity (eDNA & conventional methods)
  - Recreational use (quantitative & qualitative methods)
  - Weirs, aesthetics and landscape perception



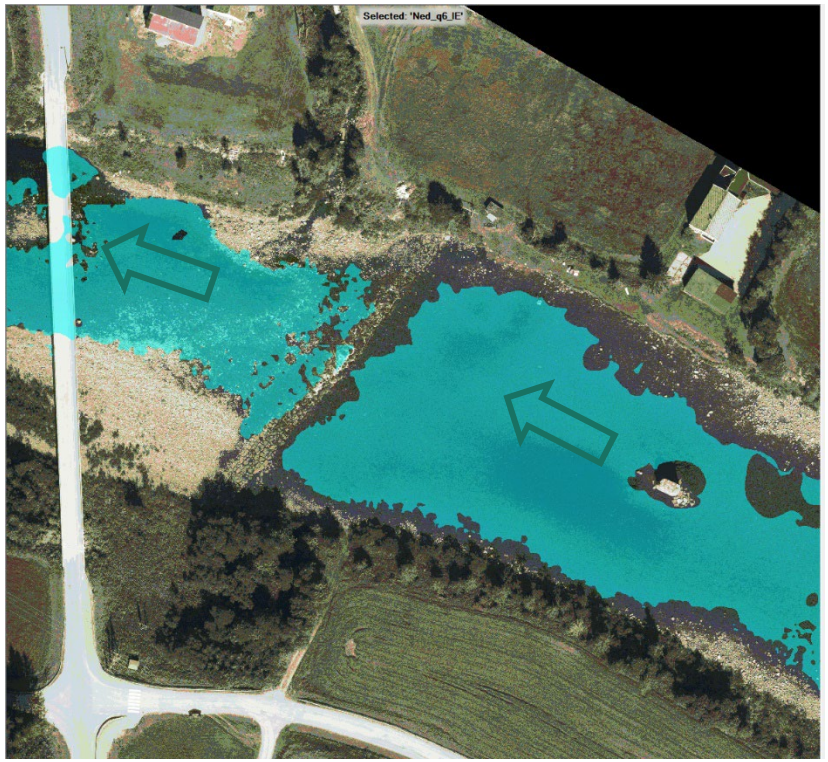


Bird perspective

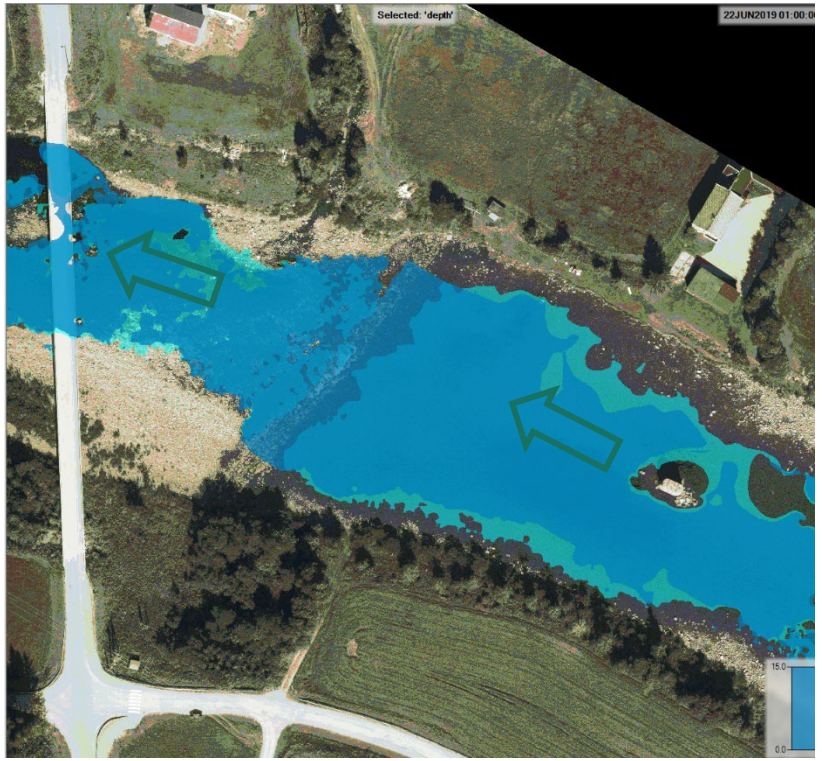
River Nea case



Green lidar based terrain



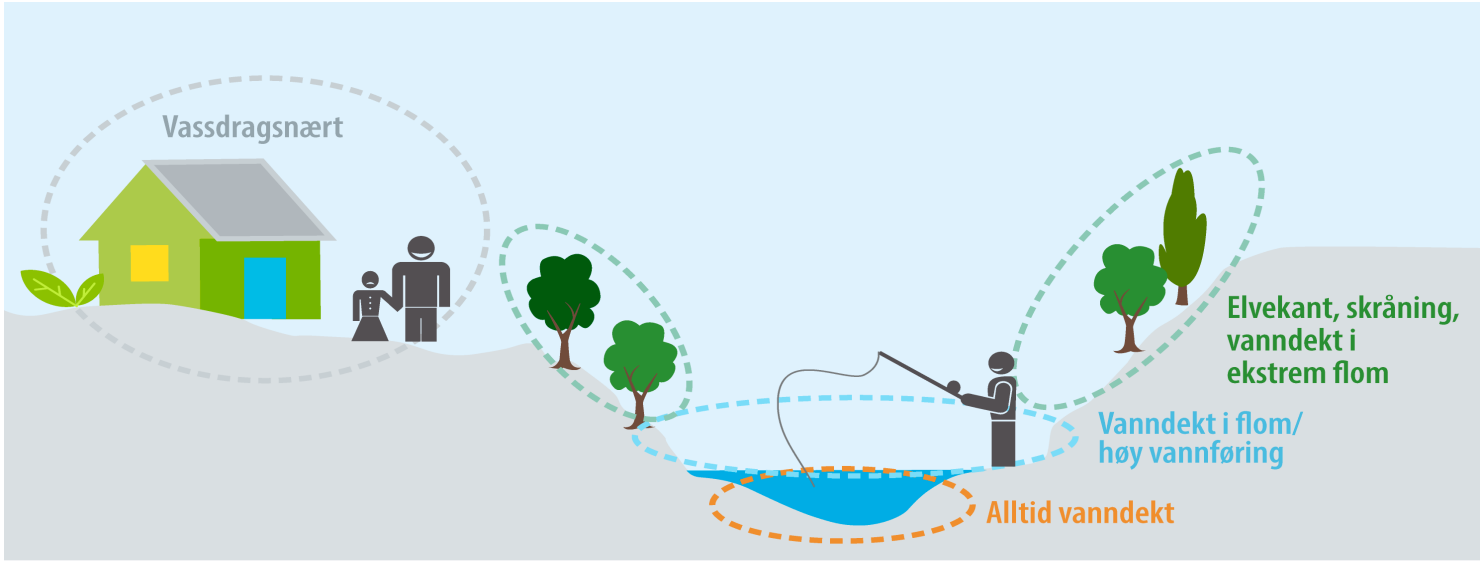
3 m^3/s – no weir changes



3 m^3/s – weir removed

(Figures from Håkon Sundt)

The river and the landscape



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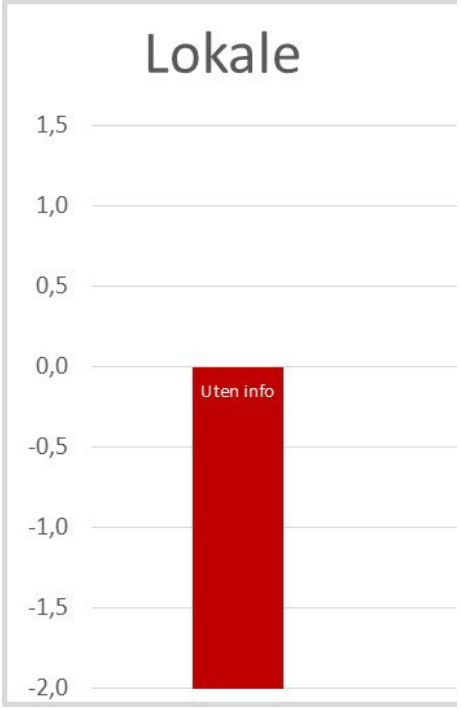
River Nea and weirs as landscape elements

Junker-Köhler & Sundt 2021

Peoples attitude toward restoration measures

-3	-2	-1	0	+1	+2	+3

Vet ikke ☐



Fishing for answers…

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Genetics

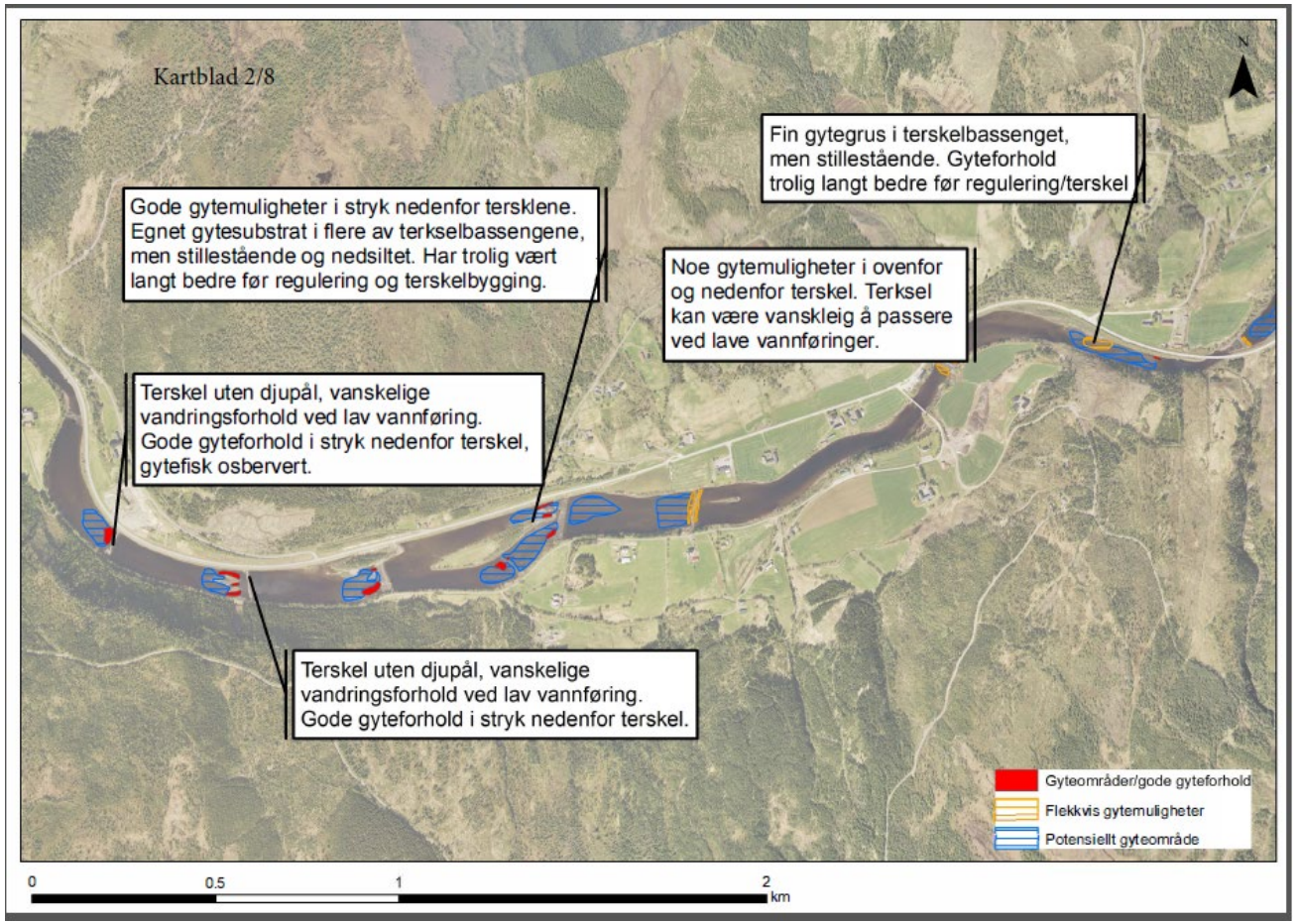
Most family groups were within same cohort and within a geographic area

Some full sibling groups in different cohorts

Family groups were rarely spread across barriers (weirs)

	N_e	Lower CI	Upper CI
Age 0+	**156**	125	197
Age 1+	**139**	110	178

The spawning habitat



Several weirs placed on old spawning grounds
(Potential spawning areas, marked in blue)

Red and yellow marks presently used spawning areas

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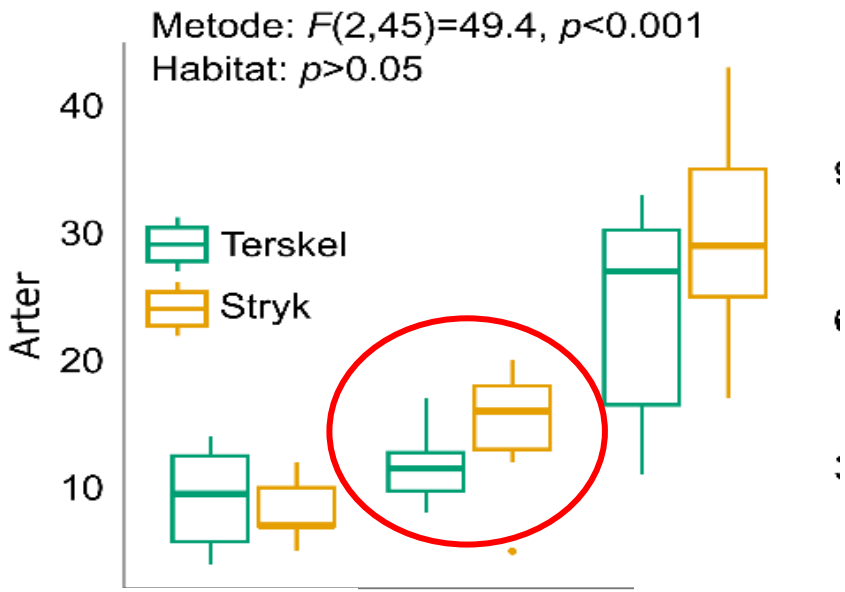
Biodiversity in weir pools and rapids

Invertebrates



Conventional Method

Meta-barcoding ethanol

DNA water

All methods:

We found less species than expected:

- 62 % of expected invertebrate species
- Less biodiversity in pools compared to rapids

Majaneva, Sundt-Hansen, Brandsegg, Sivertsgård, Bongard & Fossøy 2024, Hydrobiologia

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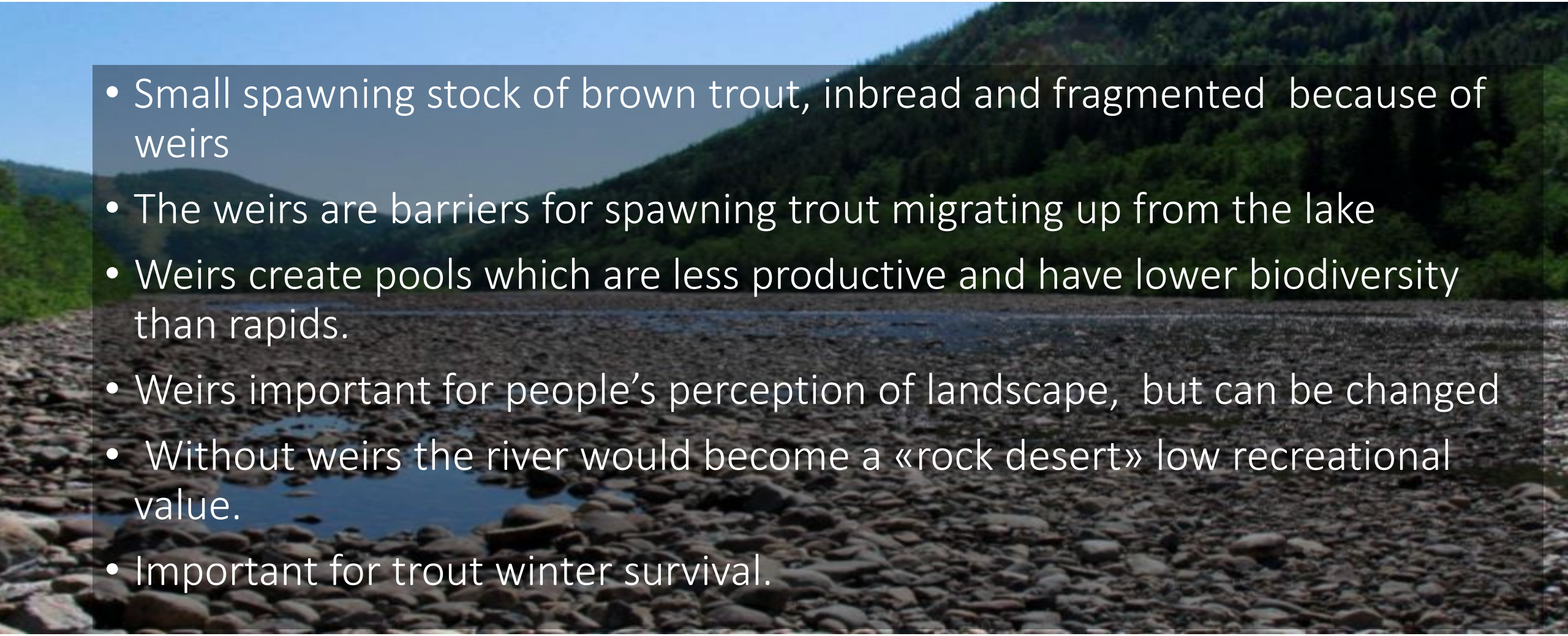
Diagnosis



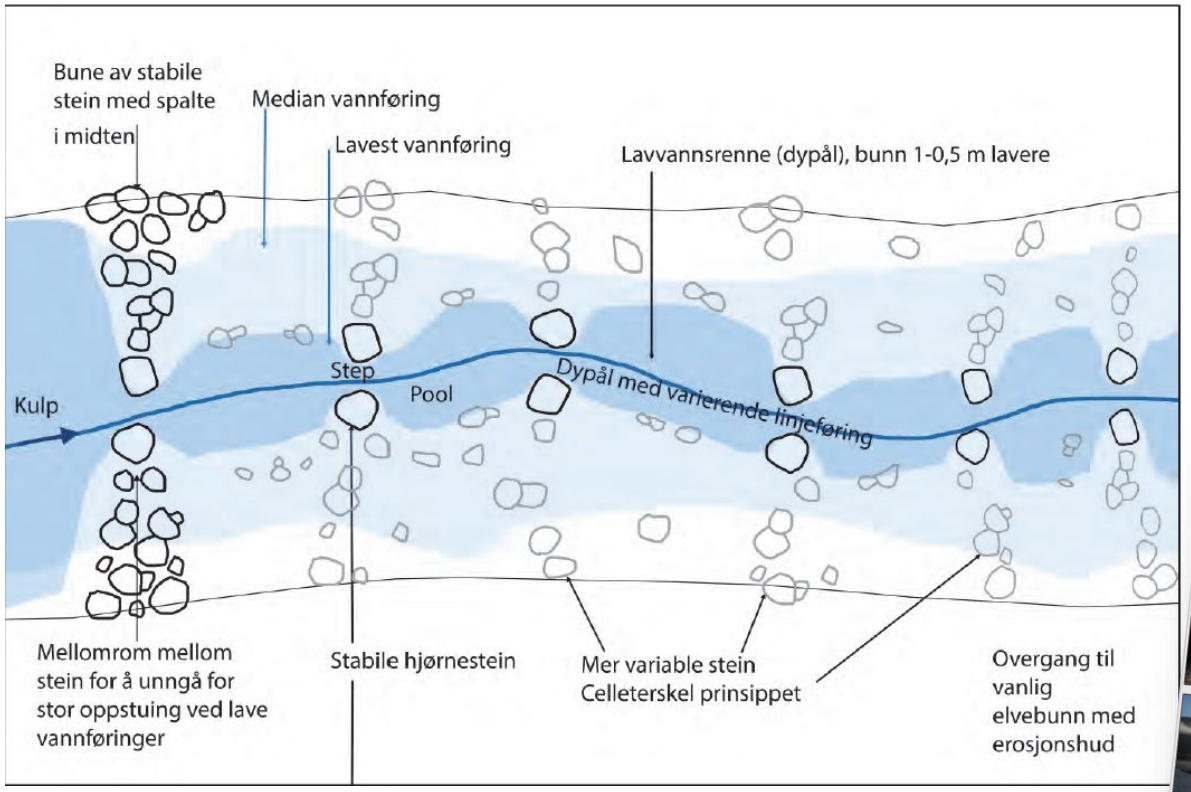
- Small spawning stock of brown trout, inbread and fragmented because of weirs
- The weirs are barriers for spawning trout migrating up from the lake
- Weirs create pools which are less productive and have lower biodiversity than rapids.
- Weirs important for people's perception of landscape, but can be changed
- Without weirs the river would become a «rock desert» low recreational value.
- Important for trout winter survival.

Design solution; potensial measures

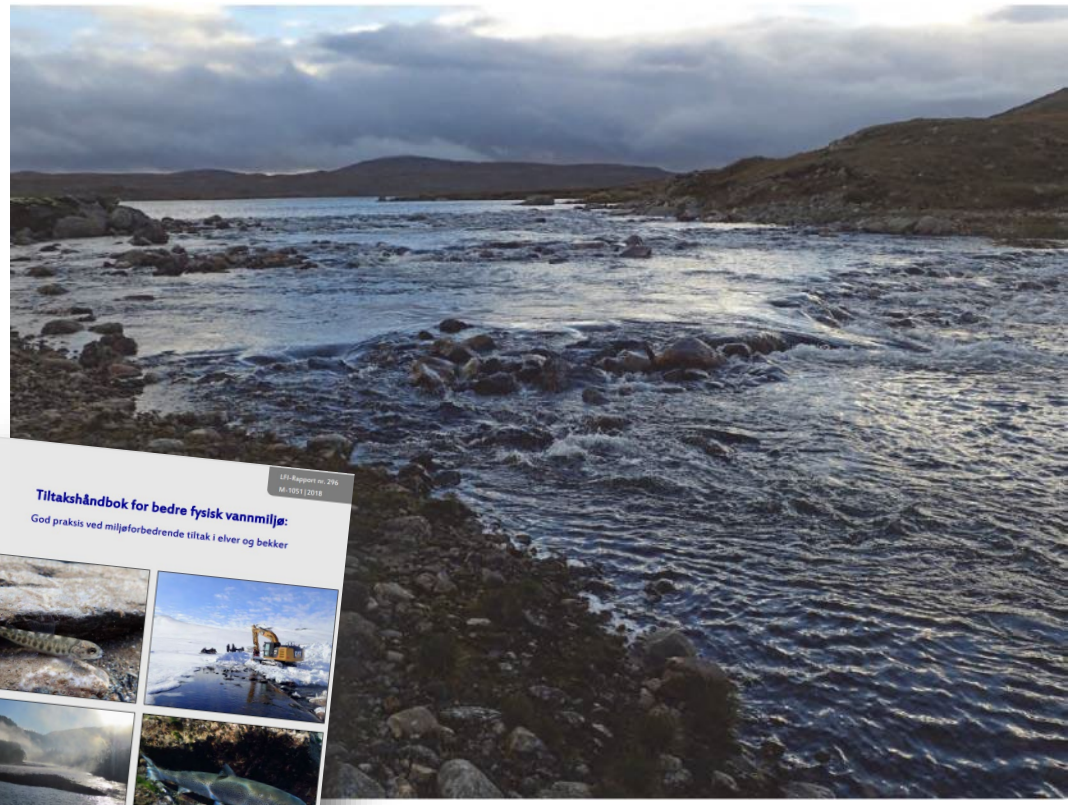
Function requirements for modification of weirs

1. Reestablish migration routes and connectivity for spawners
2. Reestablish unused spawning areas
3. Maintain deeper areas for over wintering

Solution? Modify weirs, remove some weirs , increase connectivity



Ramp weirs



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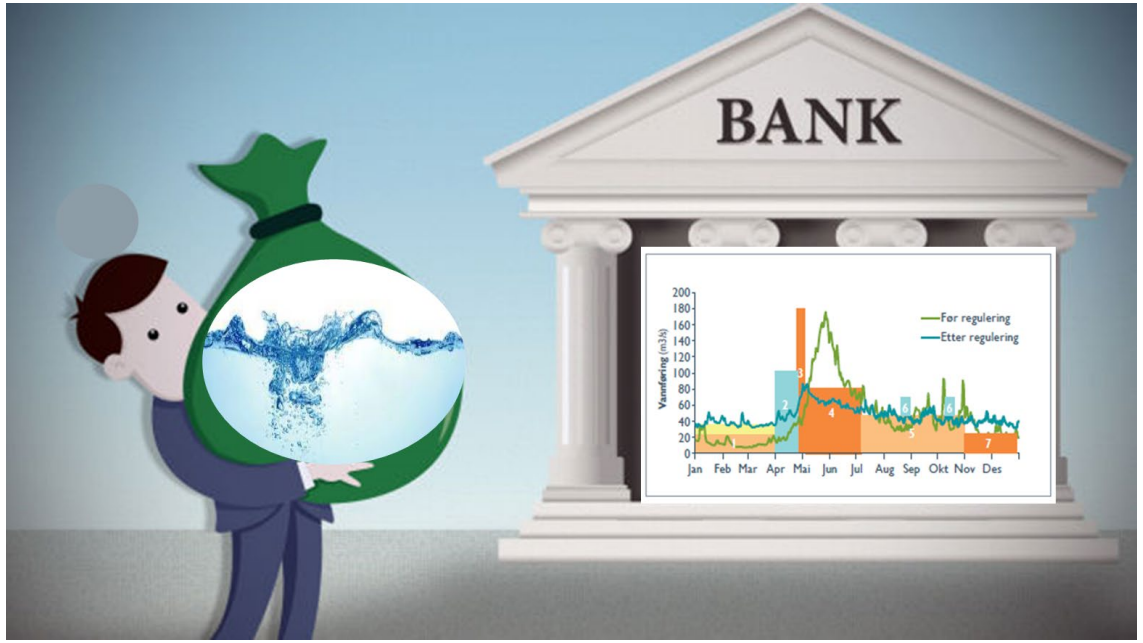
Vannbank – vann til rett tid



- Ny sesongfordeling av vannbanken

→Stimulere til oppvandring

→Sikre vinteroverlevelse av rogn, ungfisk og bunndyr

Summary case Nea

- Statkraft planning to use or suggestions for Nea
- HydroCen has updated the tools for an environmental design assessment
- Excited for the future projects and RenewHydro!

- Modifying and removing weirs in combination with release fo water will improve conditions for fish and invertebrates in River Nea

Other cool projects in HydroCen

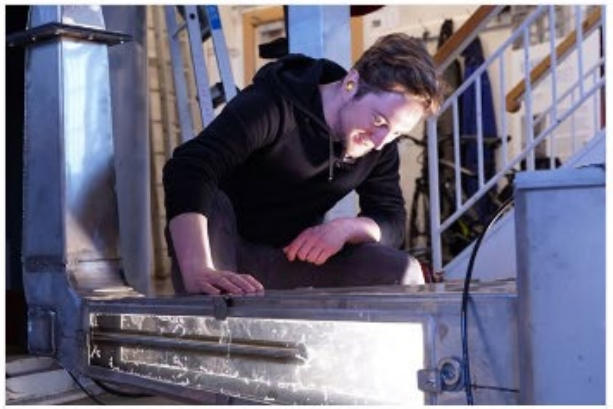
- Check out HydroCens knowledge bank!

CASE NEA

Improving environmental conditions by using environmental design

COUNTING SPAWNING FISH USING DNA

Method for estimating effective population size



DEGAS - ULTRASOUND CAN SAVE FISH

Sound waves can remove dissolved gas that harms wildlife in rivers with hydropower production

ENVIRONMENTAL CONDITION DEPENDS ON THE METHOD

New method uses environmental DNA

ENVIRONMENTAL MEASURES IMPACT ON HYDROPOWER SYSTEMS

Effects on the flexibility of the hydropower system

ENVIRONMENTAL MEASURES IN EUROPEAN HYDROPOWER NATIONS

Balancing energy and environment in Austria, Switzerland and Sweden

GUIDING FENCE FOR FISH

Solutions for fish migration

REMOTE SENSING IN RIVER MAPPING

LIDAR, aerial photography, drones and satellite images

SIMULATOR FOR OPERATIONAL COSTS

ProdRisk-SHOP simulator

SPECIES DIVERSITY IN RESERVOIRS

Effect of water regulation on the meiofauna

STATE-DEPENDENT DISCHARGE CONSTRAINTS

Dealing with state-dependent constraints in operational planning models

THE DECK-OF-CARDS METHOD ALTERNAFUTURE

Balancing environmental considerations and the increasing need for energy

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FME RenewHydro

Vannkraft i endring og fornyelse

Målsetting:

RenewHydro skal utvikle kunnskap og løsninger slik at fleksibel vannkraft kan støtte realisering av energiomstillingen og nå nasjonale energi-, klima- og naturmål.

2025-2032

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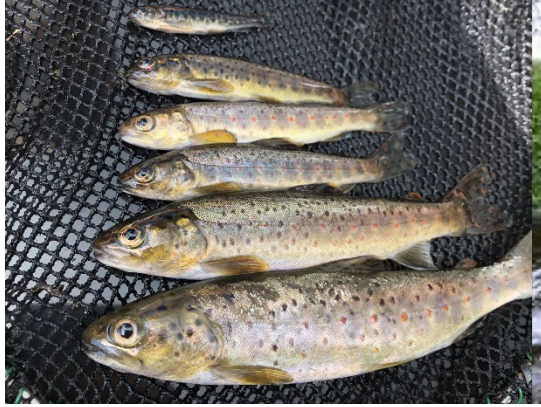
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH
The Research Council of Norway




Thank you!

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Leader of WP4 Environmental design in Hydrocen)

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