# Assessing trade-offs between ecosystem services using multi-criteria decision analysis (MCDA) – proof of concept

**Ecomanage user meeting**
**Nina huset 11.12.2014**

**Ana Adeva Bustos, Berit Köhler, David N. Barton**
***In collaboration with:***
**Richard Hedger, NINA; Hans-Petter Fjeldstad, SINTEF;**
**Knut Alfredsen, NTNU, Peggy Zinke, SINTEF, Håkon Sundt, SINTEF**

# Outline

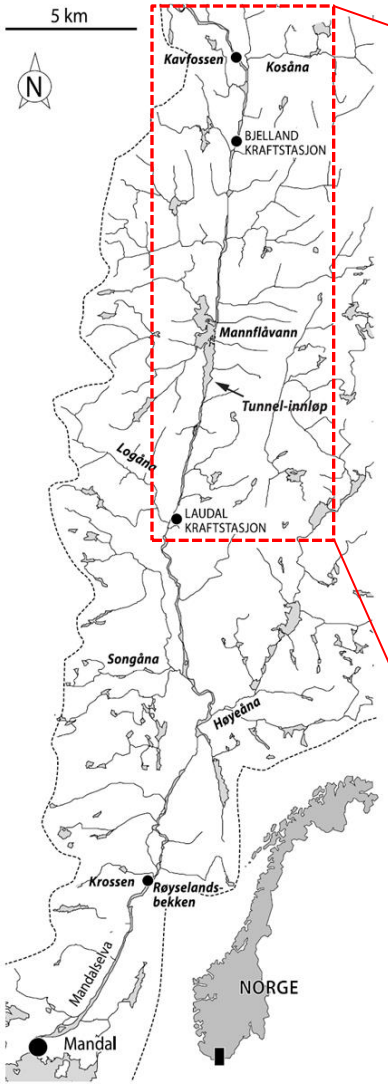
- Modeling the trade-off between the production of Atlantic salmon (*Salmo salar*) and power.

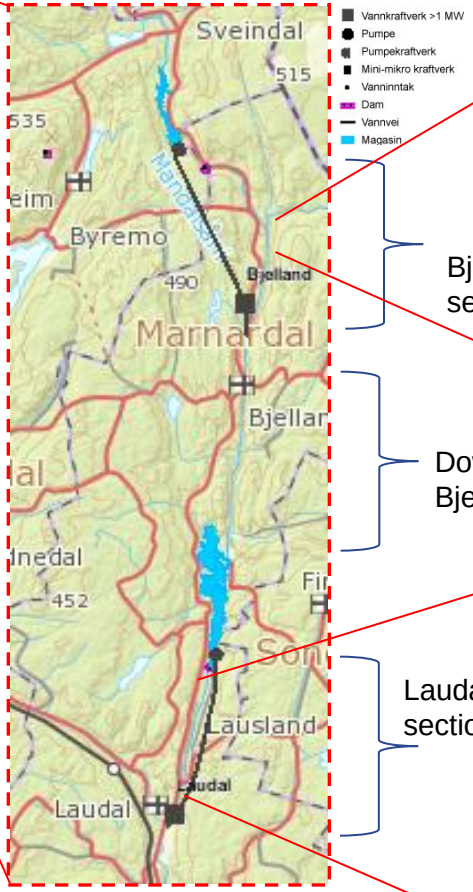
  **Ana Adeva Bustos**

- Visual impacts (aesthetics) of habitat remediation measures. **Berit Köhler**

- MCDA for habitat remediation and environmental flow measures. **David N. Barton**

# Decision-support objectives



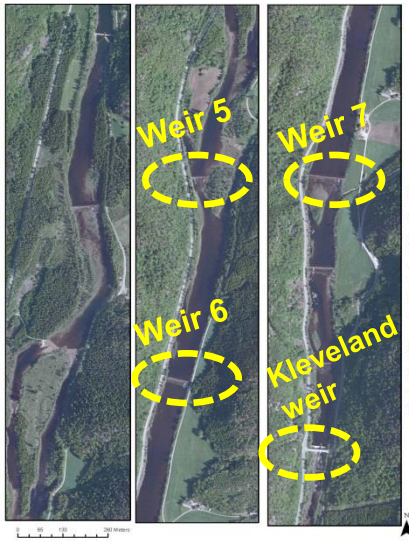




Bjelland bypass section

Downstream Bjellad outlet

Laudal bypass section


**OFF-SETS**
How much do Bjelland 'off-site' wier removal measures off-set flow regulation in Laudal bypass?




**MCDA**
ranking of habitat restoration vs. streamflow regulation alternatives

# Modeling the trade-off between the production of Atlantic salmon (*Salmo salar*) and power.

**Ana Adeva Bustos**
*MSc Ecosystem Restoration*

*In collaboration with:*

Håkon Sundt, SINTEF
David N. Barton, NINA
Richard Hedger, NINA
Hans-Petter Fjeldstad, SINTEF
Knut Alfredsen, NTNU
Berit Köhler, NINA
Peggy Zinke, SINTEF

# Outline

1. Introduction
2. Objective
3. Methods
4. Results
5. Bayesian Network Model
6. Discussion
7. Conclusions and Future Research

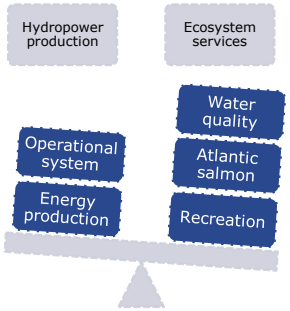
# Introduction

Regulated rivers have a recognized conflict between hydropower production and salmonid habitat.

However, there are many other ecosystem services provided by regulated rivers.

There is a need to clarify the applicability of ecosystem services as a management concept.

# Objective



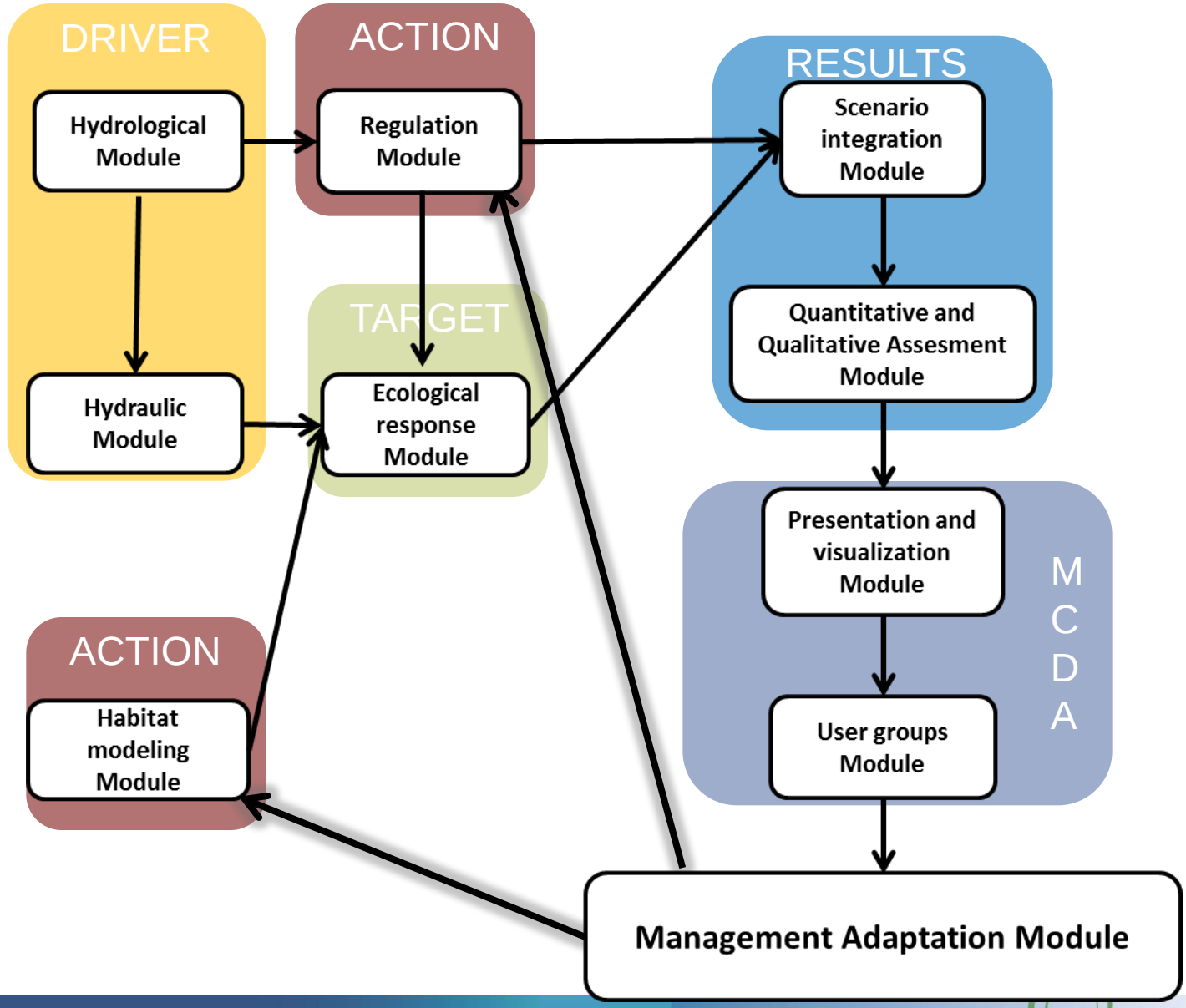

To generate a methodology that defines the "optimal" scenario or scenarios as a basis for decision-making.

"Integrative method" that includes models of:

- hydrology
- hydraulics
- ecosystem response
- mitigation cost

Into a **Decision support system** for finding **balanced environmental flows**.

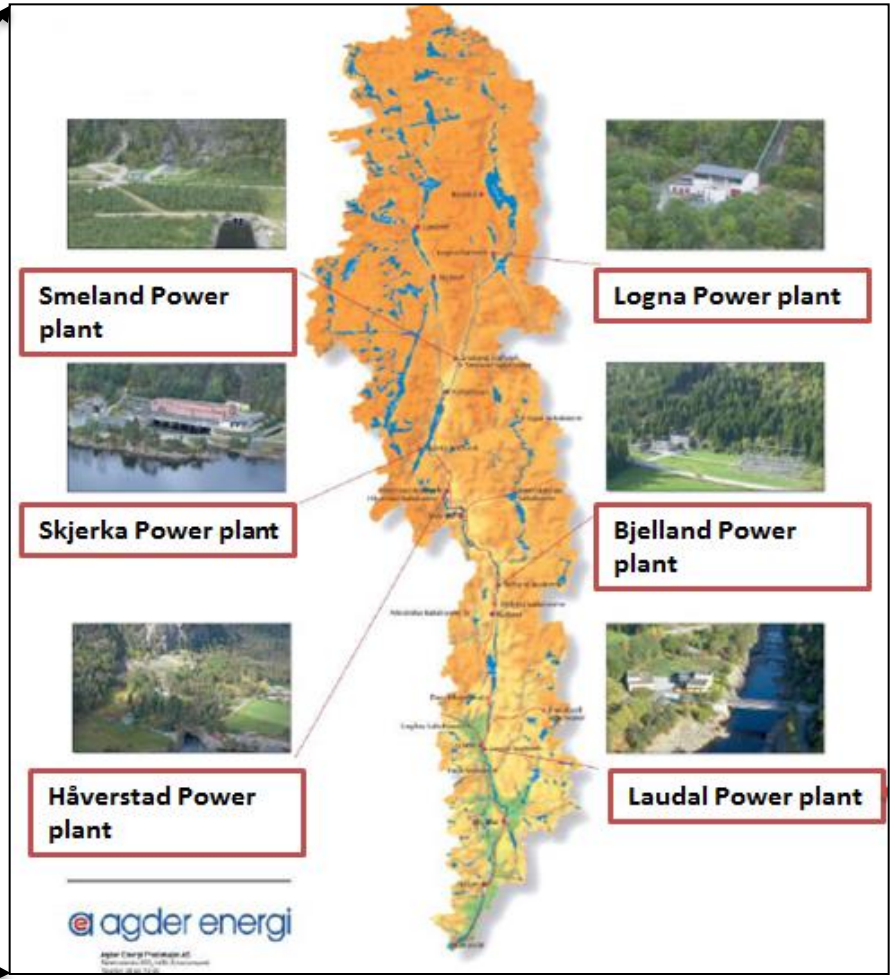
# Integrative Method



# Mandalselva Case

Mandalselva Basin located in southern Norway

Mandalselva River is regulated by 6 Power plants.

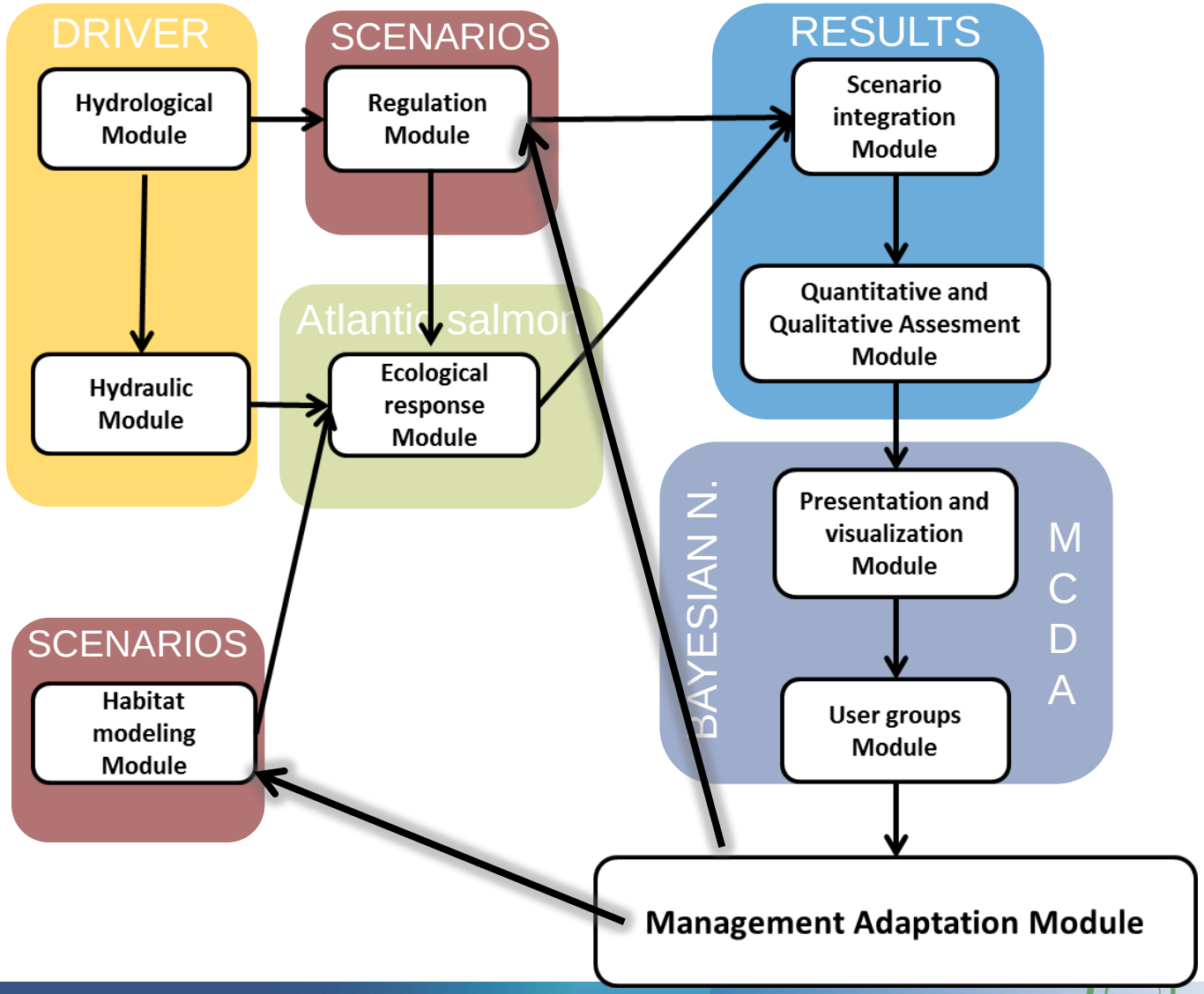
# Objective

The optimization of the minimum flow regime proposed by NVE using environmental design methods through and downstream of the Laudal Hydropower plant.

# Method

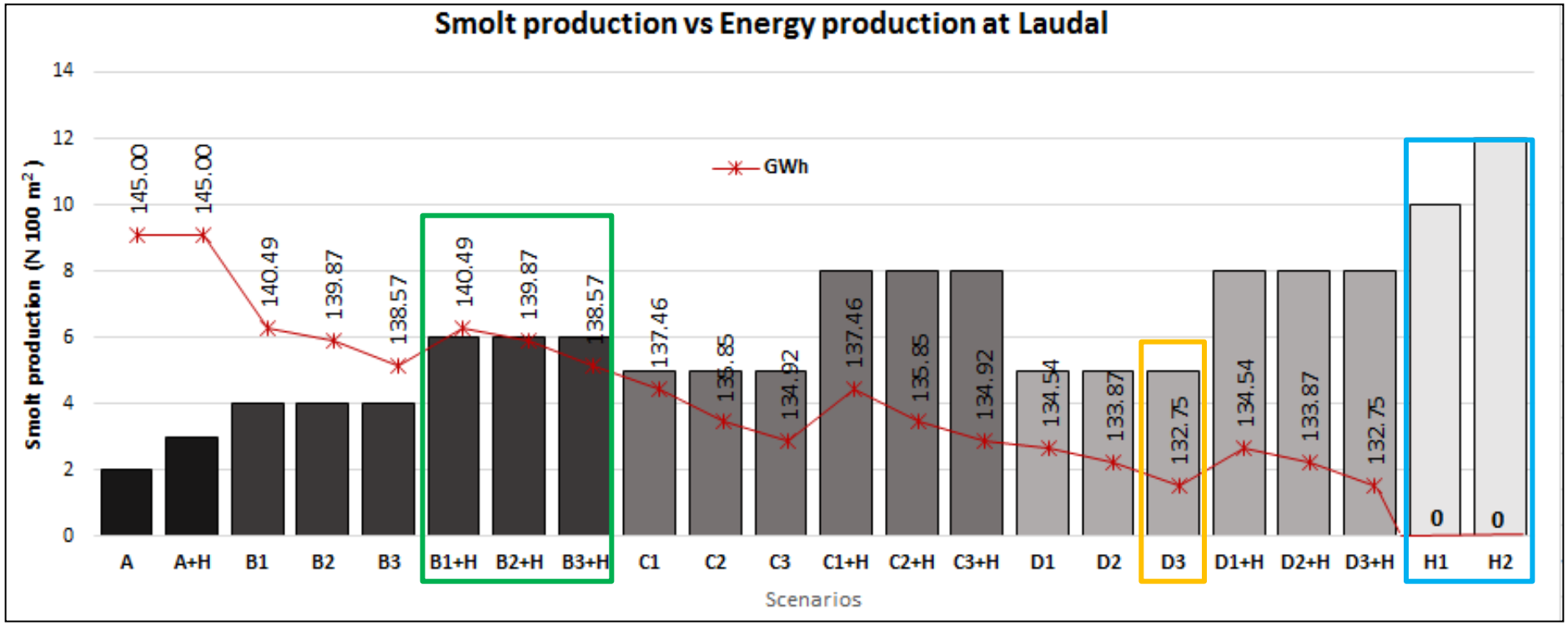
Develop the **"integrative method"** to help in the decision making for Laudal and compare it with Bjelland.

# Integrative method in Mandalseva case



# Results Laudal

Results from IB-salmon compared with Energy simulation results under each scenario:

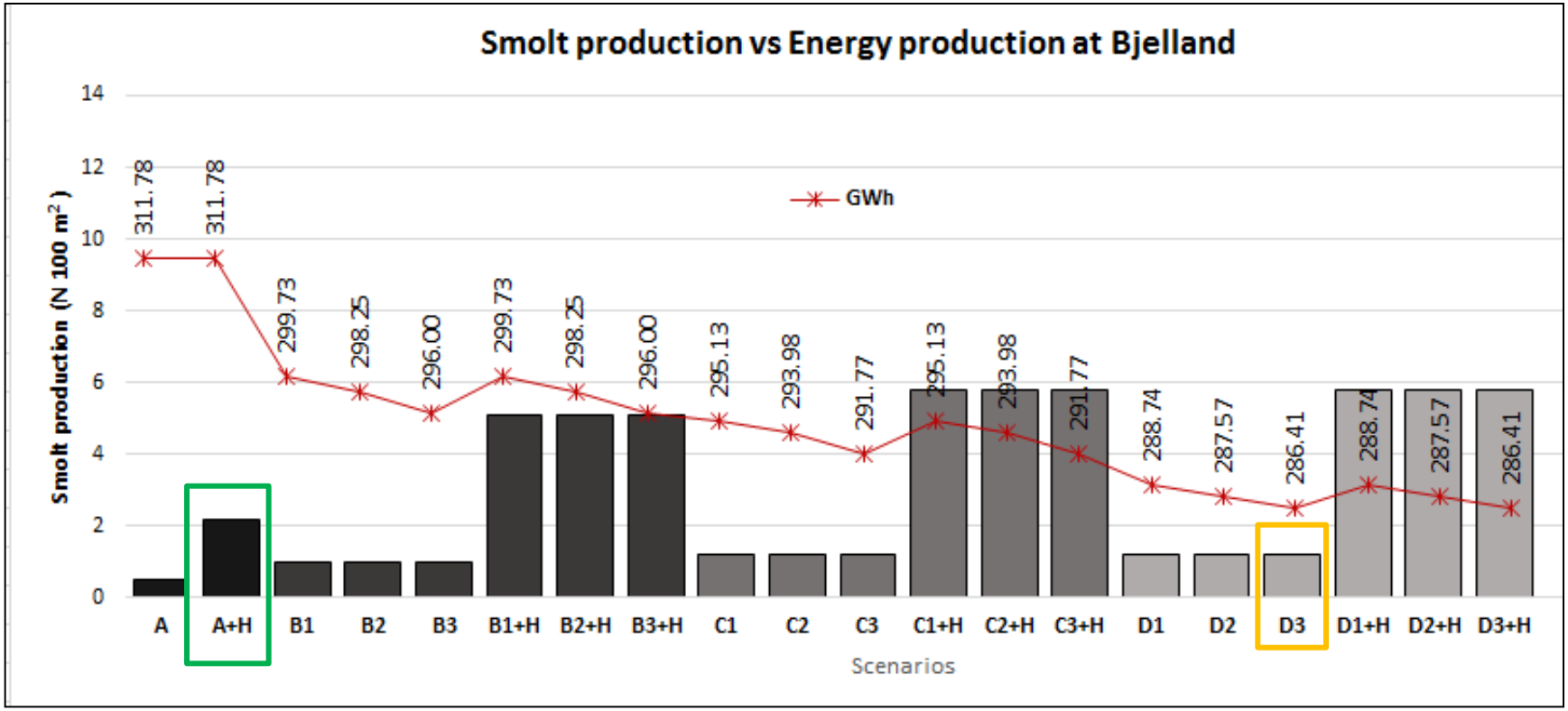



| Past | Past+ | Intermediate B | Intermediate B | Intermediate C | Intermediate C | NVE proposed | NVE proposed | Historical 1,2. |
|---|---|---|---|---|---|---|---|---|
| W:1.5<br>S: 3 | Hab. mod | W: 4<br>Spring: (1)- (2) 25%, (3) 50%<br>S:6-14 | + Habitat Modification | W: 6<br>Spring: (1)- (2) 25%, (3) 50%<br>S:8-14 | + Habitat Modification | W: 6<br>Spring: (1)- (2) 25%, (3) 50%<br>S:8-25 | + Habitat Modification | |

W: winter discharge ($m^3/s$), Spring: extra spill released depending on the inflow during smolt migration period, S: summer discharge ($m^3/s$).

# Results Bjelland

Results from IB-salmon compared with Energy simulation results under each scenario:

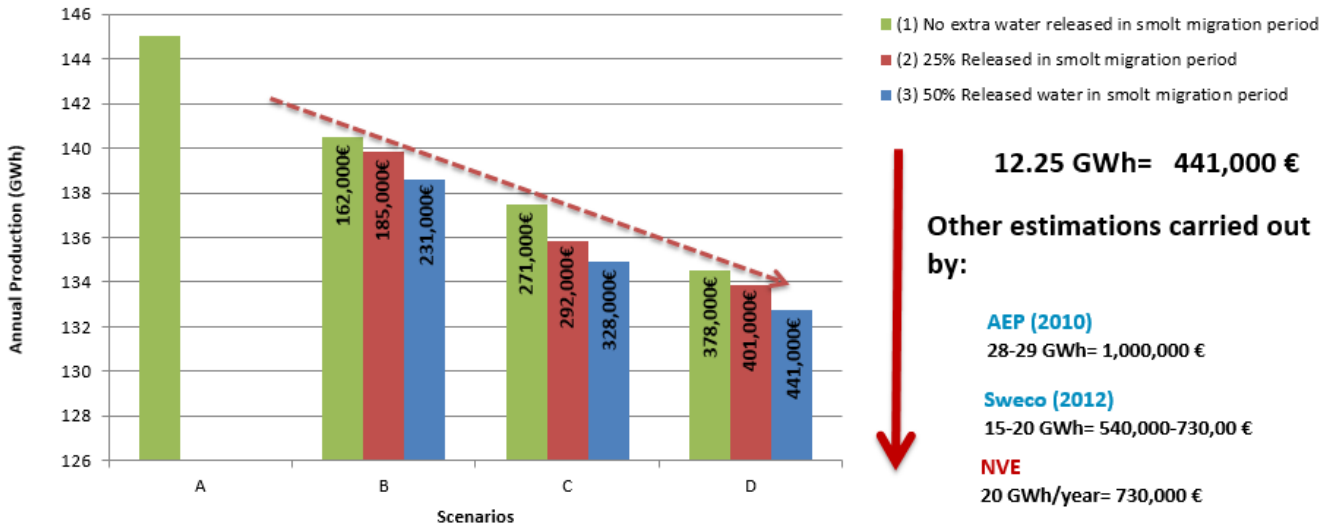



| Present W:1 S: 2 | Present + Hab. mod | Intermediate B W: 4 Spring: (1)- (2) 25%, (3) 50% S:6-14 | Intermediate B + Habitat Modification | Intermediate C W: 6 Spring: (1)- (2) 25%, (3) 50% S:8-14 | Intermediate C + Habitat Modification | NVE proposed W: 6 Spring: (1)- (2) 25%, (3) 50% S:8-25 | NVE proposed + Habitat Modification |
|---|---|---|---|---|---|---|---|

W: winter discharge ($m^3/s$), Spring: extra spill released depending on the inflow during smolt migration period, S: summer discharge ($m^3/s$).

# Cost of changes in the operational HPP system

## Laudal




**12.25 GWh= 441,000 €**

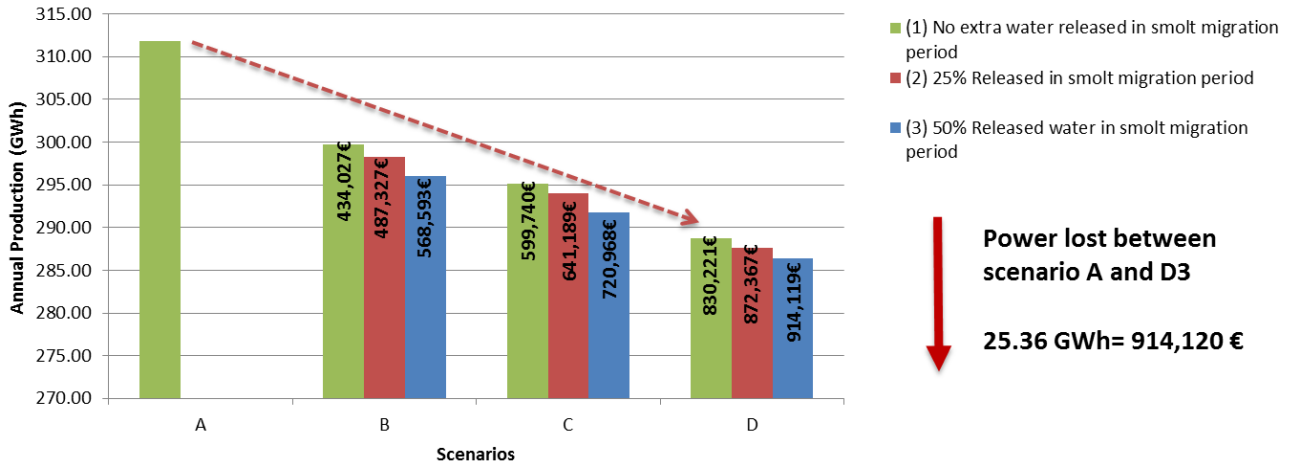
**Other estimations carried out by:**

**AEP (2010)**
28-29 GWh= 1,000,000 €

**Sweco (2012)**
15-20 GWh= 540,000-730,00 €

**NVE**
20 GWh/year= 730,000 €

## Bjelland




**Power lost between scenario A and D3**

**25.36 GWh= 914,120 €**

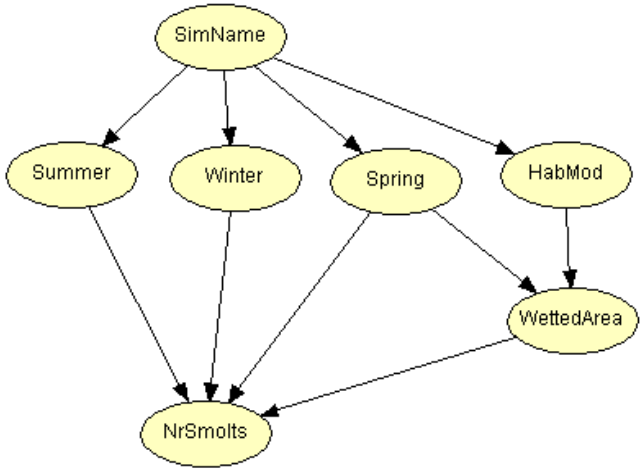
# Cost habitat modification

The **removal of weirs** a one-time expense, introduction of spawning gravel (with a three-year cycle) is roughly estimated:

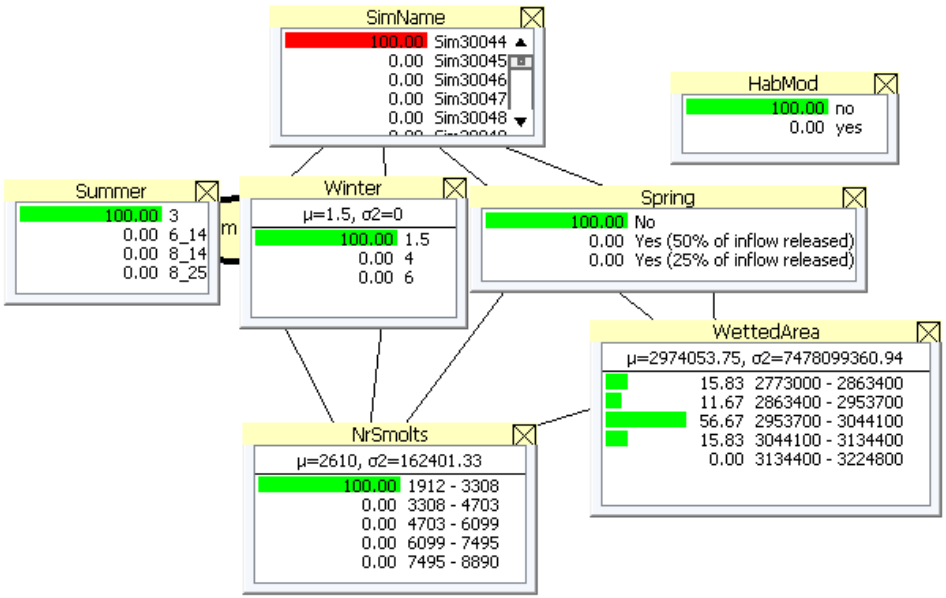
- At Laudal as **240,000 €**/investment
- At Bjelland as **200,000 €**/investment.

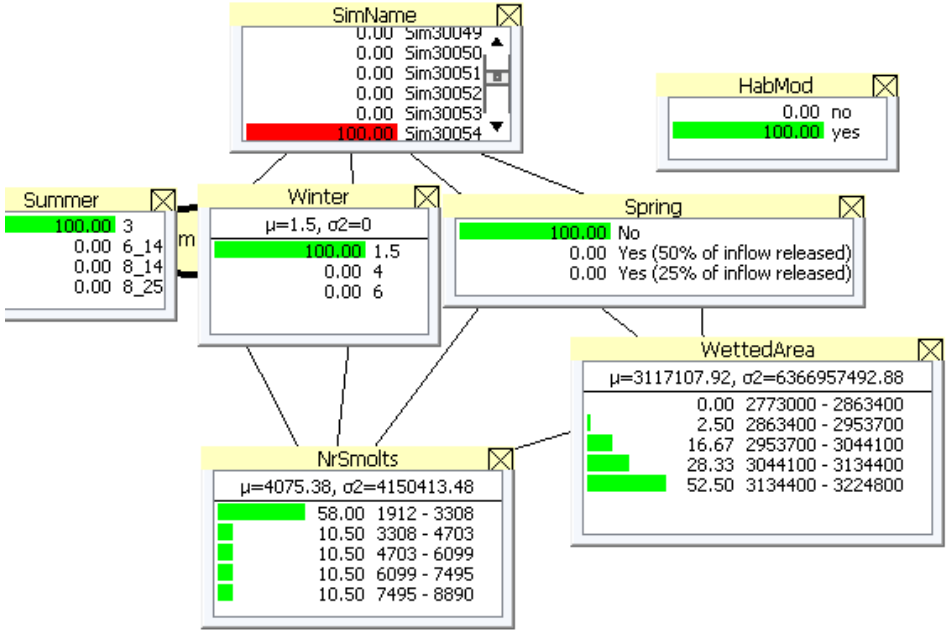
# BNN Model

Scenario A




Scenario A +H



# Discussion

- Fjeldstad et al (2013): an increased bypass discharge in spring increased the number of smolts on it, with an energy cost of 1.4 million kWh.

- Casas Mulet et al (2014): a targeted bypass release during specific periods allows optimal embryo survival with a reduced energy cost compared with a constant minimum flow.

- The Mandalselva case shows how it is possible find a balance between smolt and energy production with lower energy cost than the regulatory discharge imposed by the NVE.

# Conclusions

- An "integrative method" is a potential tool to generate outcomes to support decision-making in order to apply the Water Framework Directive in regulated rivers in Norway.
- This method gives the users cost estimates which is important in future assessments.
- It can be used in other projects/rivers as a tool to predict effects of changes in HPP operational system and habitat modification.
- The use of predictive modelling tools to link spatial scales will be fundamental for the assessment of future changes in regulated rivers and defining a sustainable operational management.

# Future Research

- Evaluate the results obtained using different resolution data.
- Improve the energy-cost estimations.
- Implement turbine mortality in oder to predict if the extra water spilled in spring is effective.
- Determine possibilities for applying an integrative method where the ecological target is not Atlantic salmon.

# Decision support for habitat restoration and environmental flow measures in regulated rivers -

# Assessing trade-offs between ecosystem services

**Ecomanage arbeidsmøte**

**Nina huset 23.10.2014**

**Ana Adeva Bustos, Berit Köhler, David N. Barton,** ***In collaboration with:***

**Håkon Sundt, SINTEF; Richard Hedger, NINA; Hans-Petter Fjeldstad, SINTEF; Knut Alfredsen, NTNU, Peggy Zinke, SINTEF**

CEDREN

Centre for Environmental Design of Renewable Energy

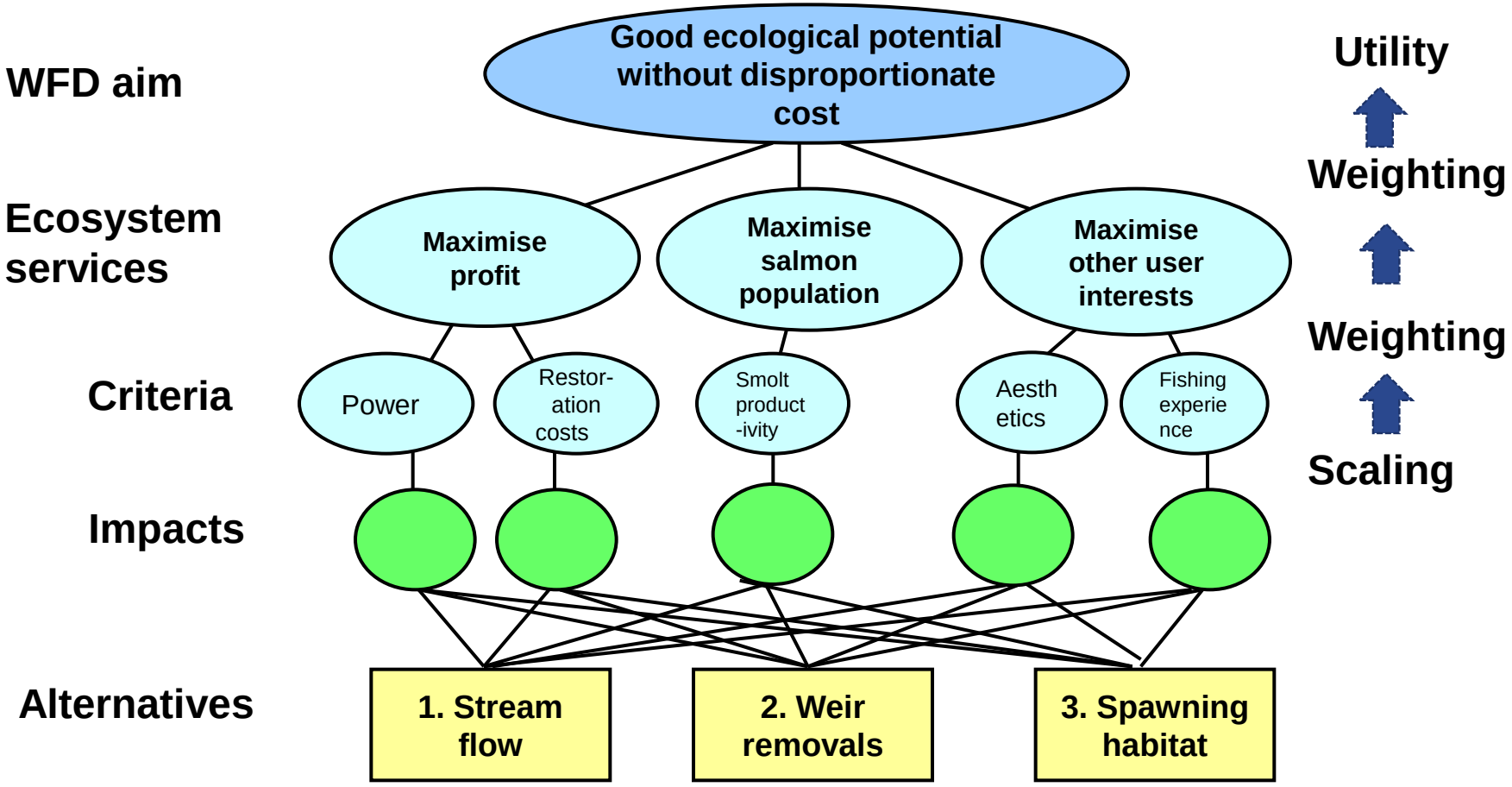
CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

# Visual impacts (aesthetics) of habitat remediation measures.

**Berit Köhler**

# Multi-criteria decision

Systematic structuring of decisions in a hierarchy of objectives criteria and alternatives



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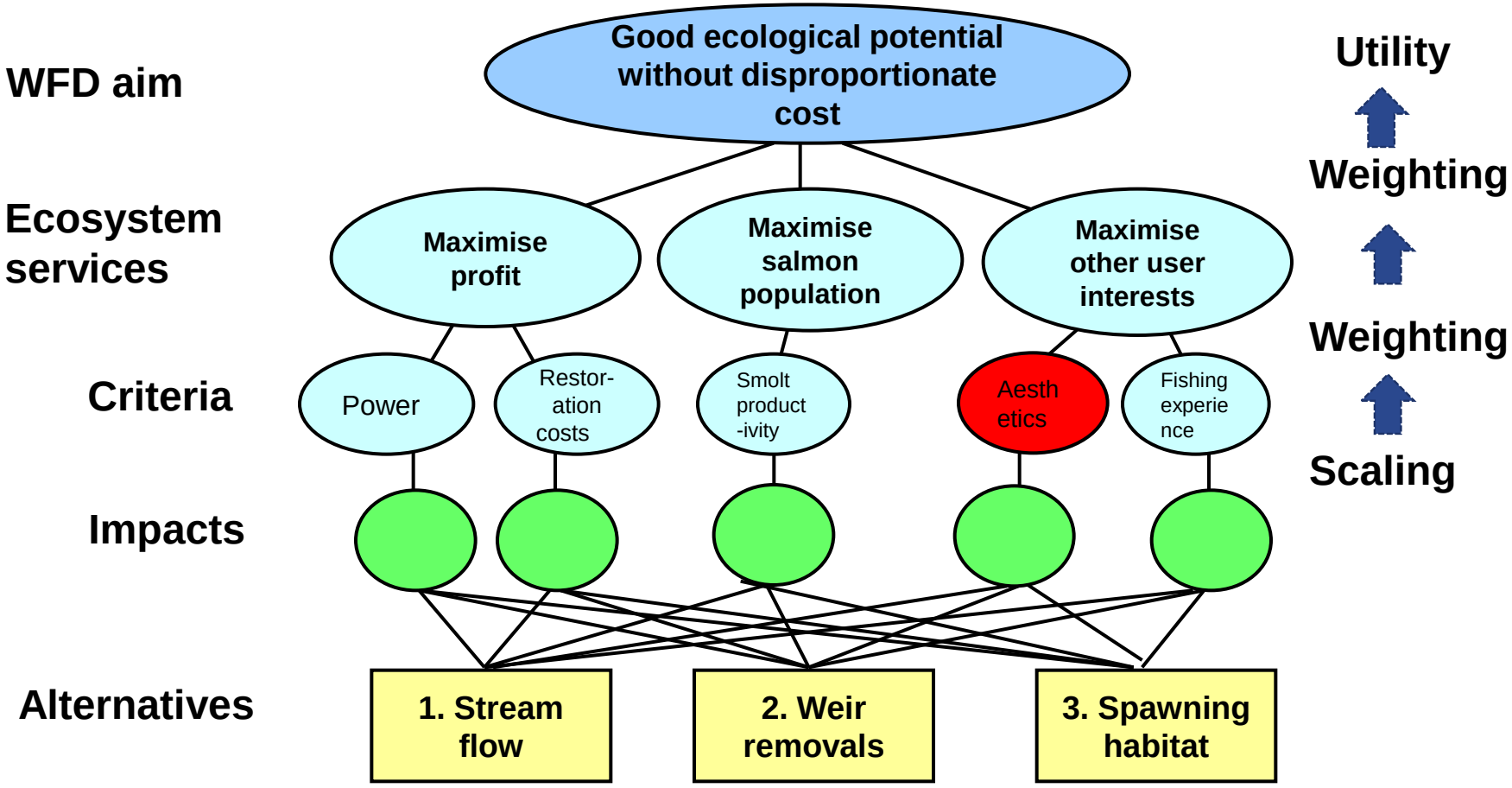
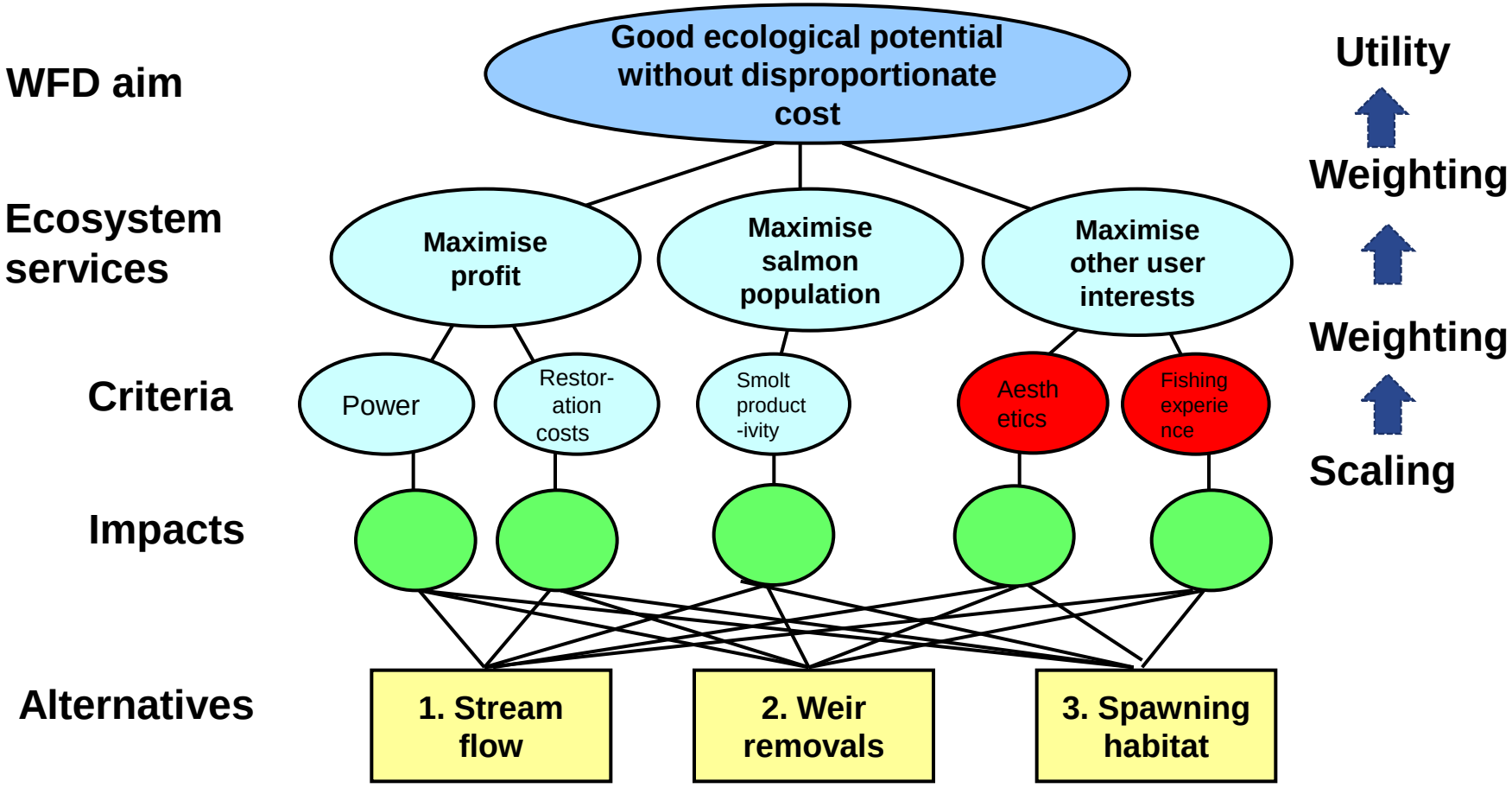


# Photo scenario method

- Aesthetics as visual evaluation of sites
- No detour of evaluation through textual description of sites
- series of computerized visual simulations of river rehabilitation scenarios depicting concrete management alternatives for the status quo situation

# Multi-criteria decision

Systematic structuring of decisions in a hierarchy of objectives criteria and alternatives



# Example from PhD on river rehabilitation

**representative photo test survey**

computer-aided editing of one basis-photo

ecological integrity measured by eco-morphological quality

here: classification according to Swiss module-step concept (MSC),
and expert evaluation

use in a Switzerland-wide representative survey

no restoration

MSC-Level: 1

lowest rest. effort

MSC-Level: 2

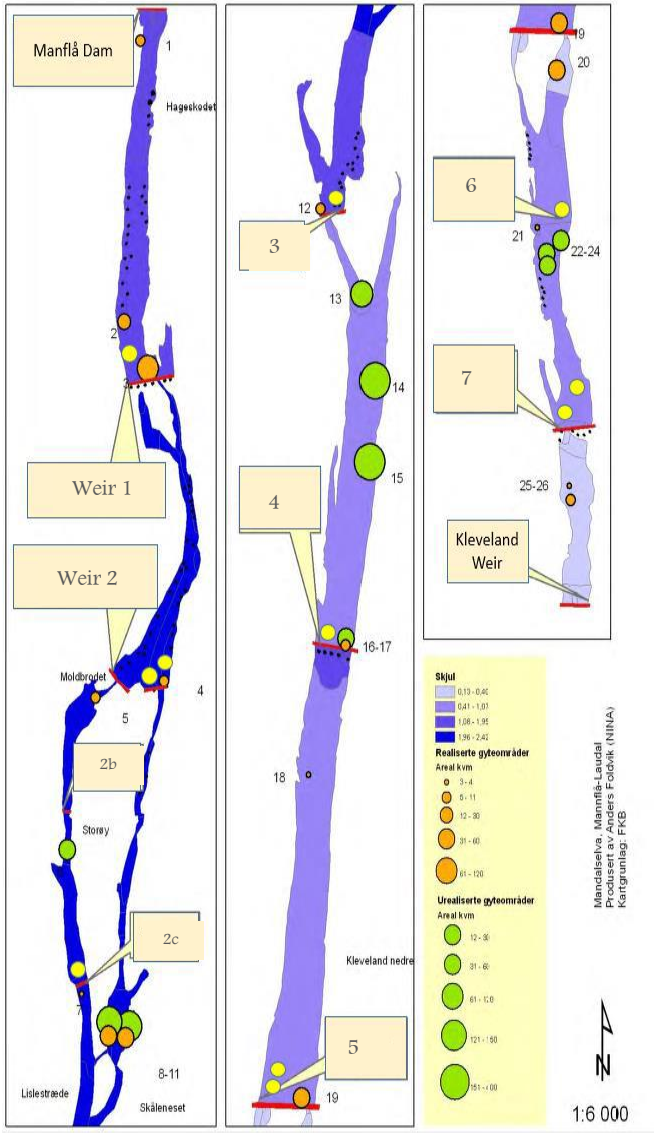
medium restoration effort

MSC-Level: 3

considerable rest. effort:

MSC-Level: 4

# Photo scenario development for Mandalselva



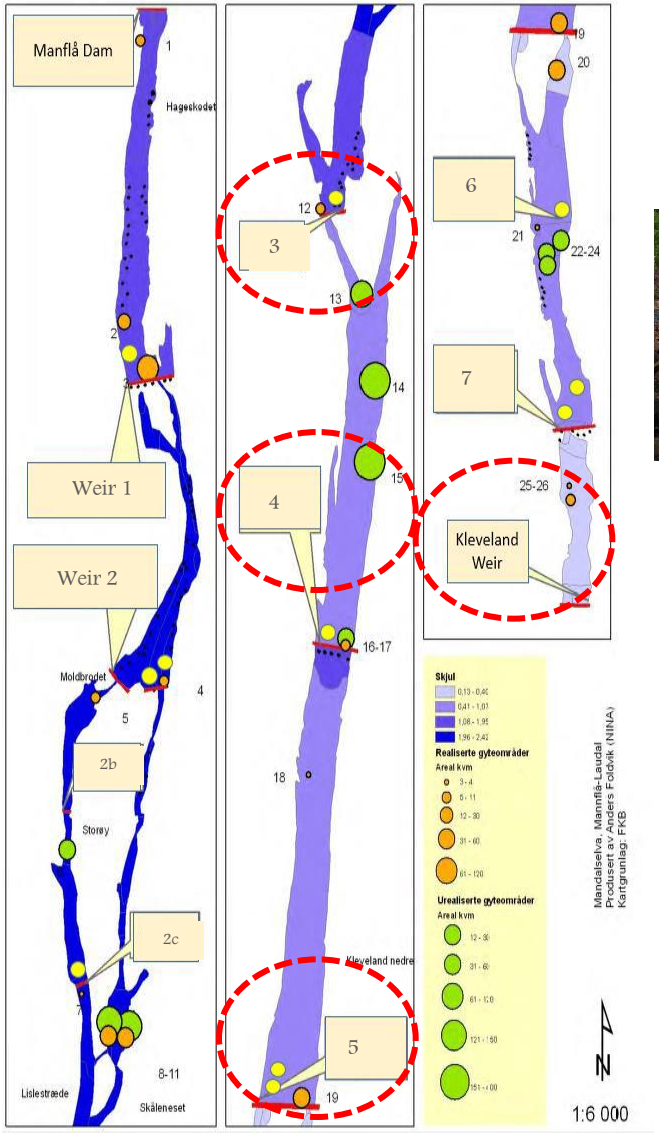

1. step:
baseline photos in july 2014 of all existing weirs

# Photo scenario development for Mandalselva

1. step:
baseline photos in july 2014 of all existing weirs

All photos: Berit Kohler

# Photo scenario development for Mandalselva




2. step:
reduction of sites for scenario development

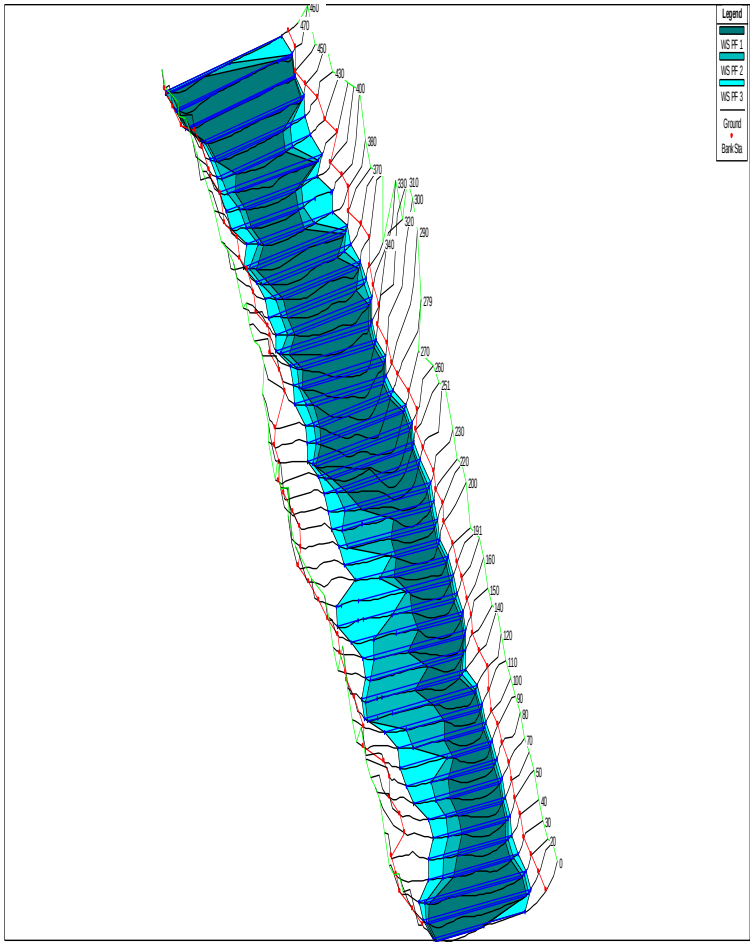
All photos: Berit Kohler

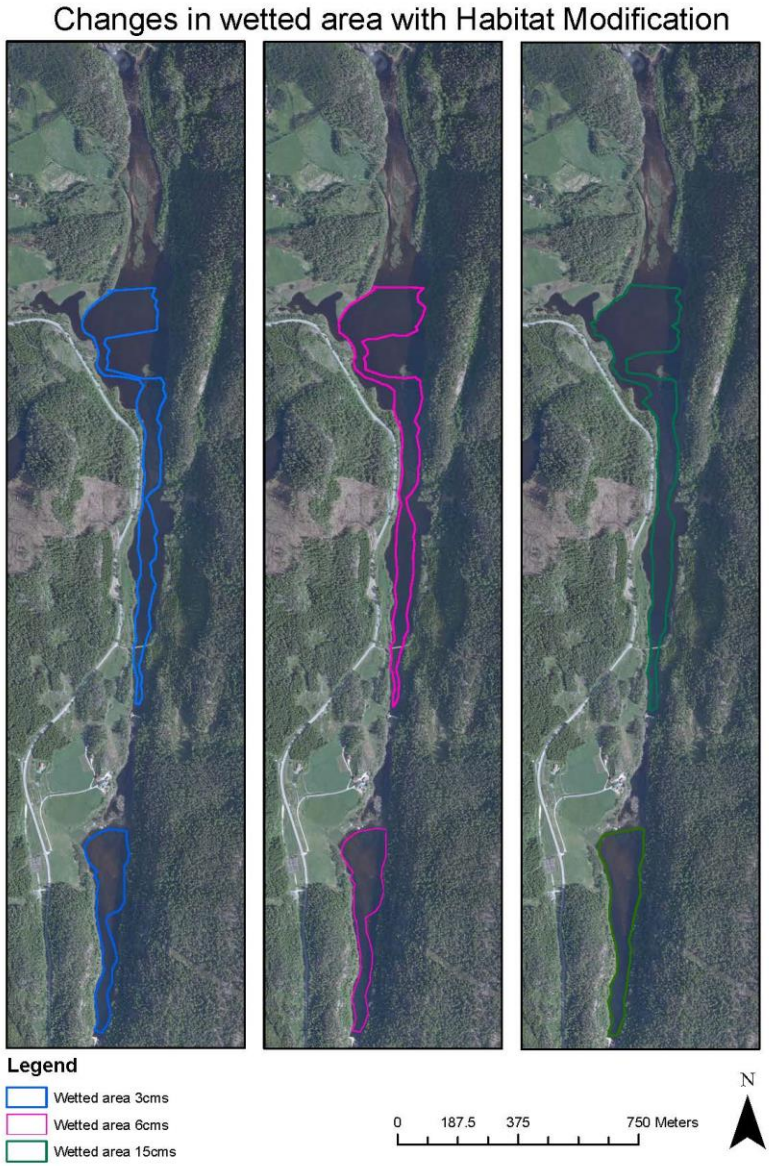
# Photo scenario development for Mandalselva

3. step:
decision on scenario simulation criteria

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| Weir removal, 6m³/s discharge | Weir removal, same discharge (6m³/s) | Weir removal, same discharge (6m³/s) | Weir removal, same discharge (6m³/s) | Weir removal, same discharge (6m³/s) |
| Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge |
| Weir removal 15m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge |

# Changes in wetted area



# Photo scenario development for Mandalselva

4. step:
photo simulation development → 5. step: application in focus groups interviews





| | | | | |
|---|---|---|---|---|
| Weir removal, 6m³/s discharge | Weir removal, 6m³/s discharge | Weir removal, 6m³/s discharge | Weir removal 6m³/s di… | …oval, …arge |
| Weir removal 3m³/s discharge | Weir rem… 3m³… | | …moval …m³/s discharge | Weir removal 3m³/s discharge |
| W… d… …ge | …eir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge | Weir removal 3m³/s discharge |

… work in progress …

# Photo scenario development for Mandalselva

Første scenario seriene:  Klevland weir


Photo: Berit Kohler


Simulation: 3D Smia Bjørnar Dervo


Simulation: 3D Smia Bjørnar Dervo


Simulation: 3D Smia Bjørnar Dervo

# Photo scenario development for Mandalselva

Første scenario seriene:  weir 5

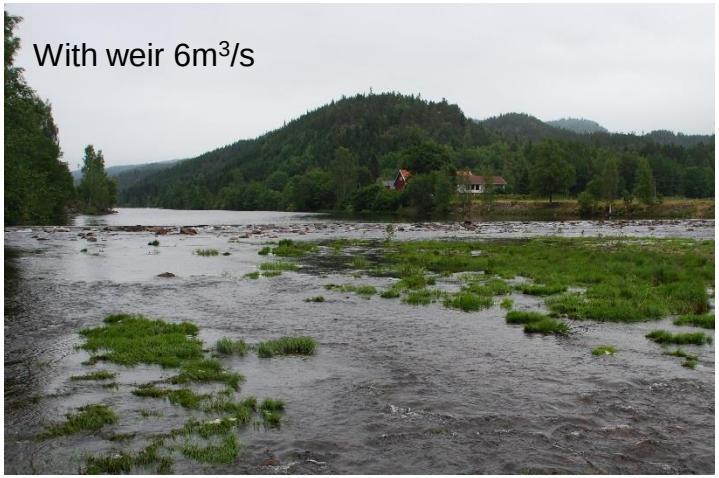
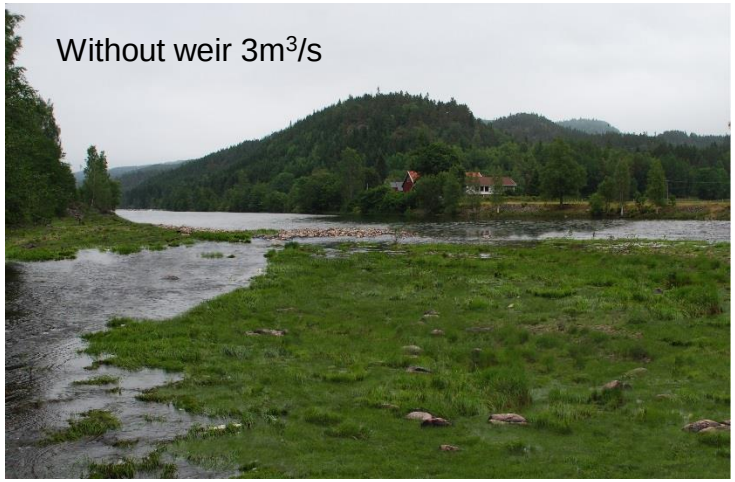
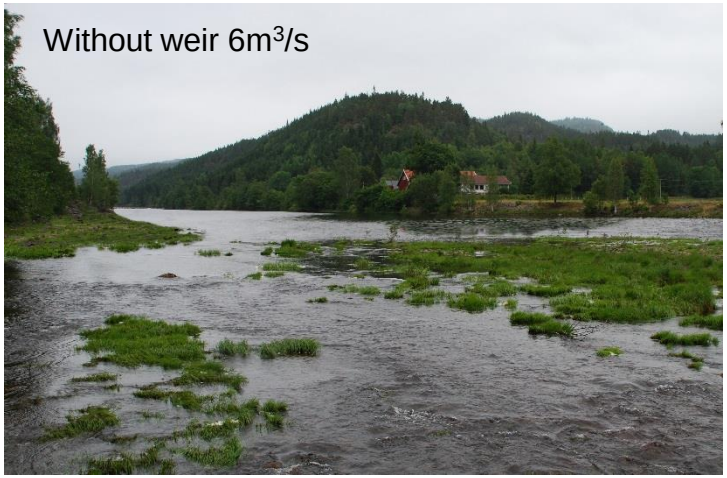


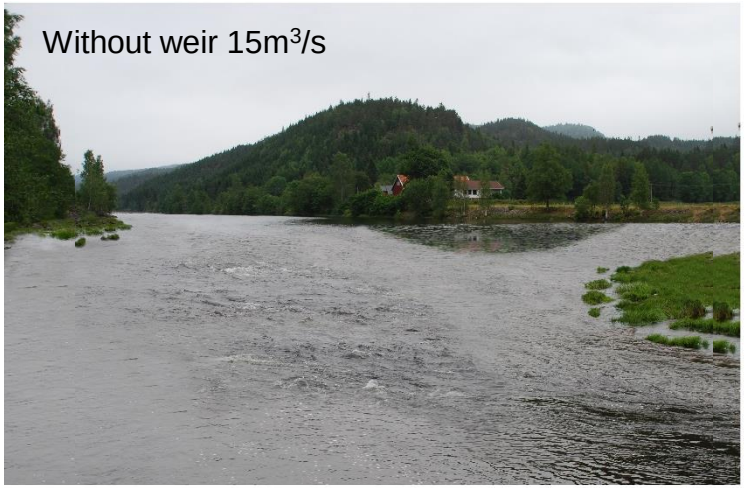

Photo: Berit Kohler




Simulation: 3D Smia Bjørnar Dervo




Simulation: 3D Smia Bjørnar Dervo




Simulation: 3D Smia Bjørnar Dervo

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Første scenario seriene:  weir 5

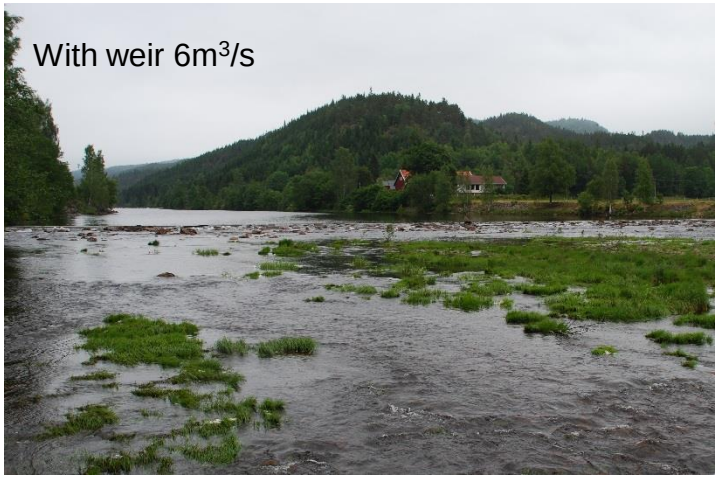
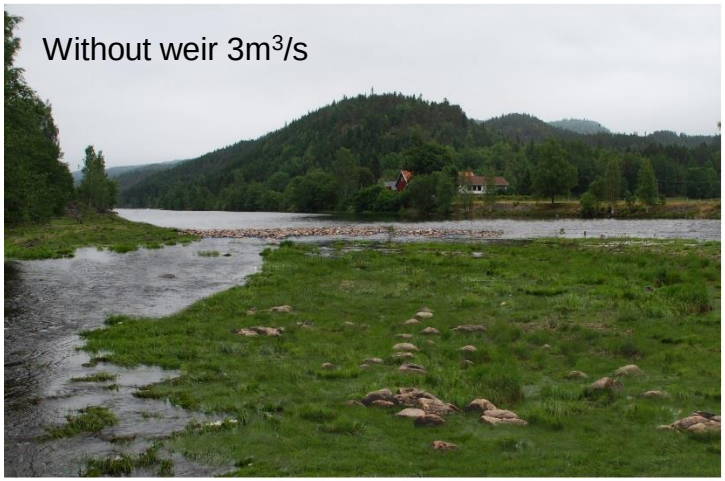



Photo: Berit Kohler

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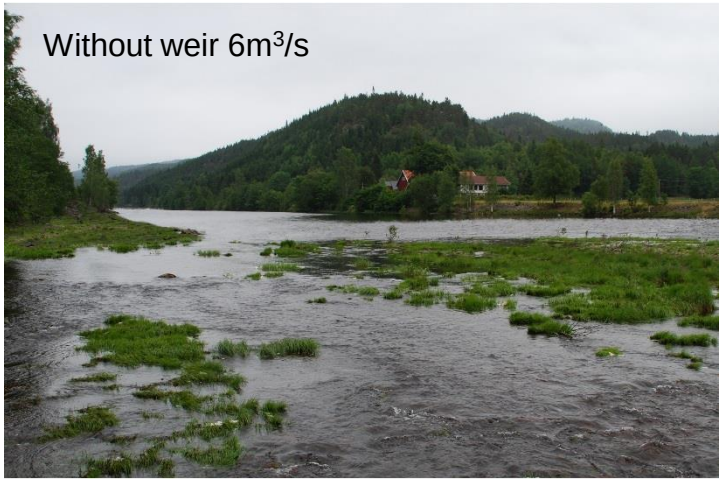
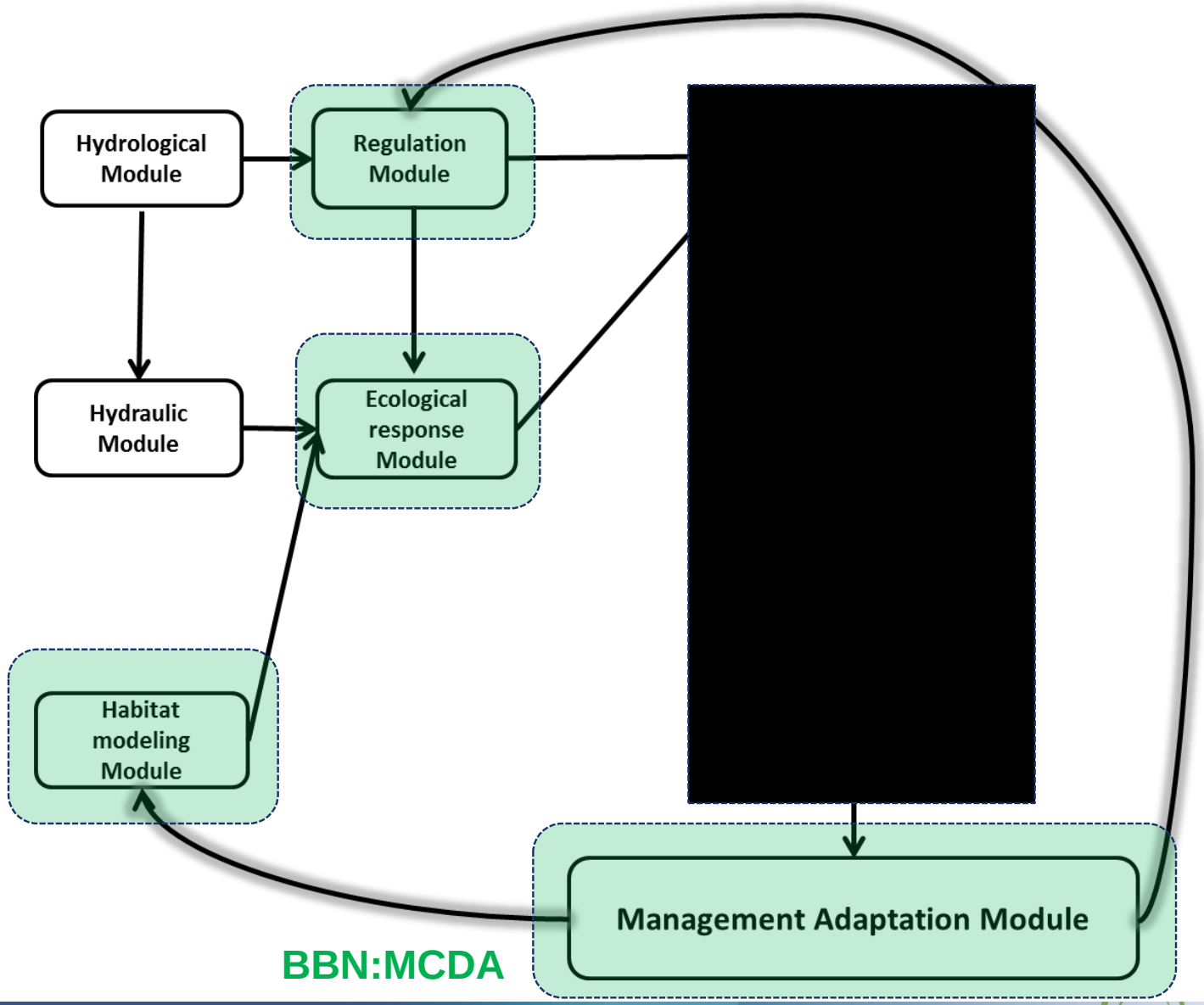



Simulation: 3D Smia Bjørnar Dervo


Simulation: 3D Smia Bjørnar Dervo

# Thank you!

# Integrative method in Mandalseva case as an MCDA



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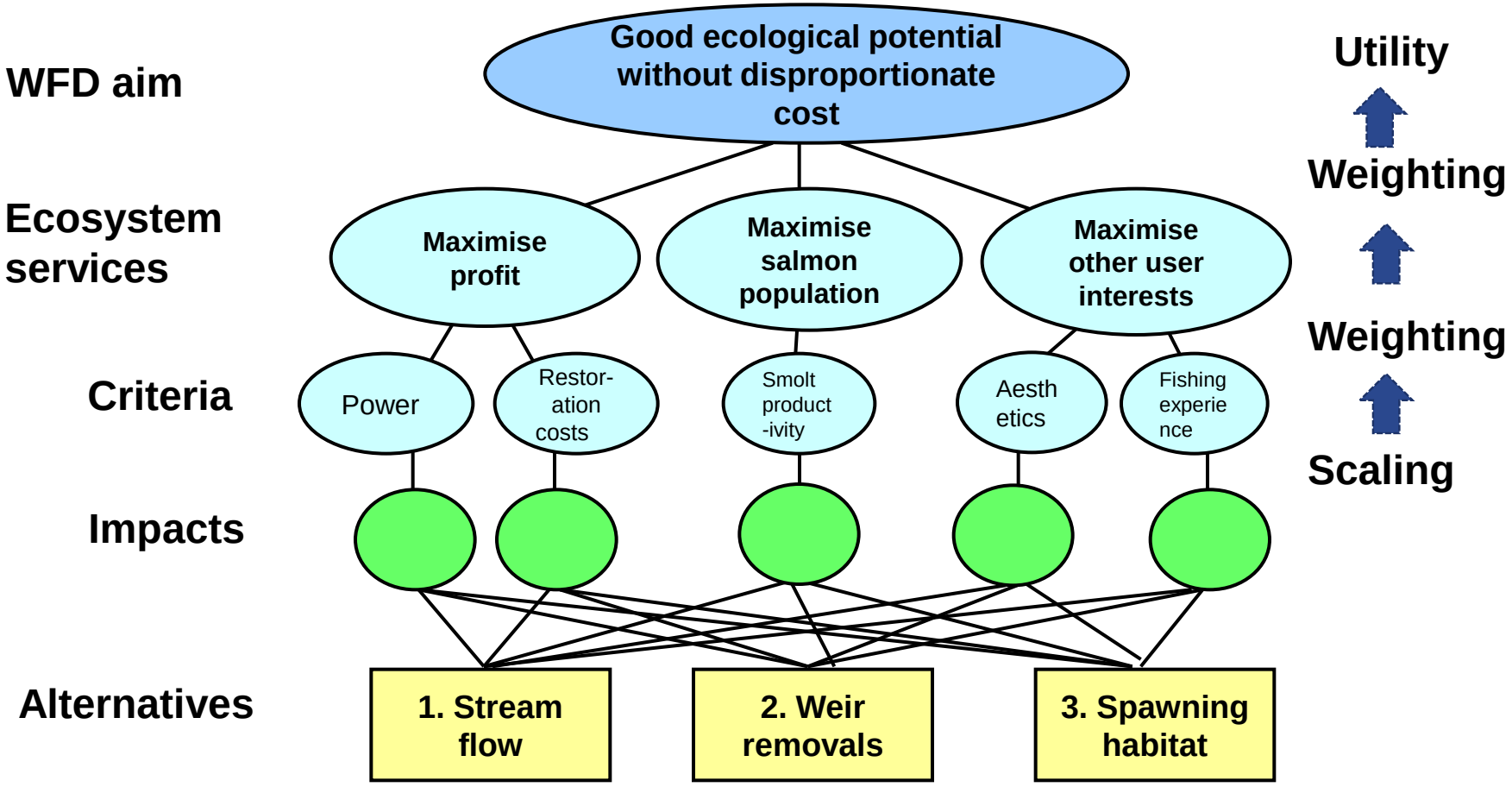
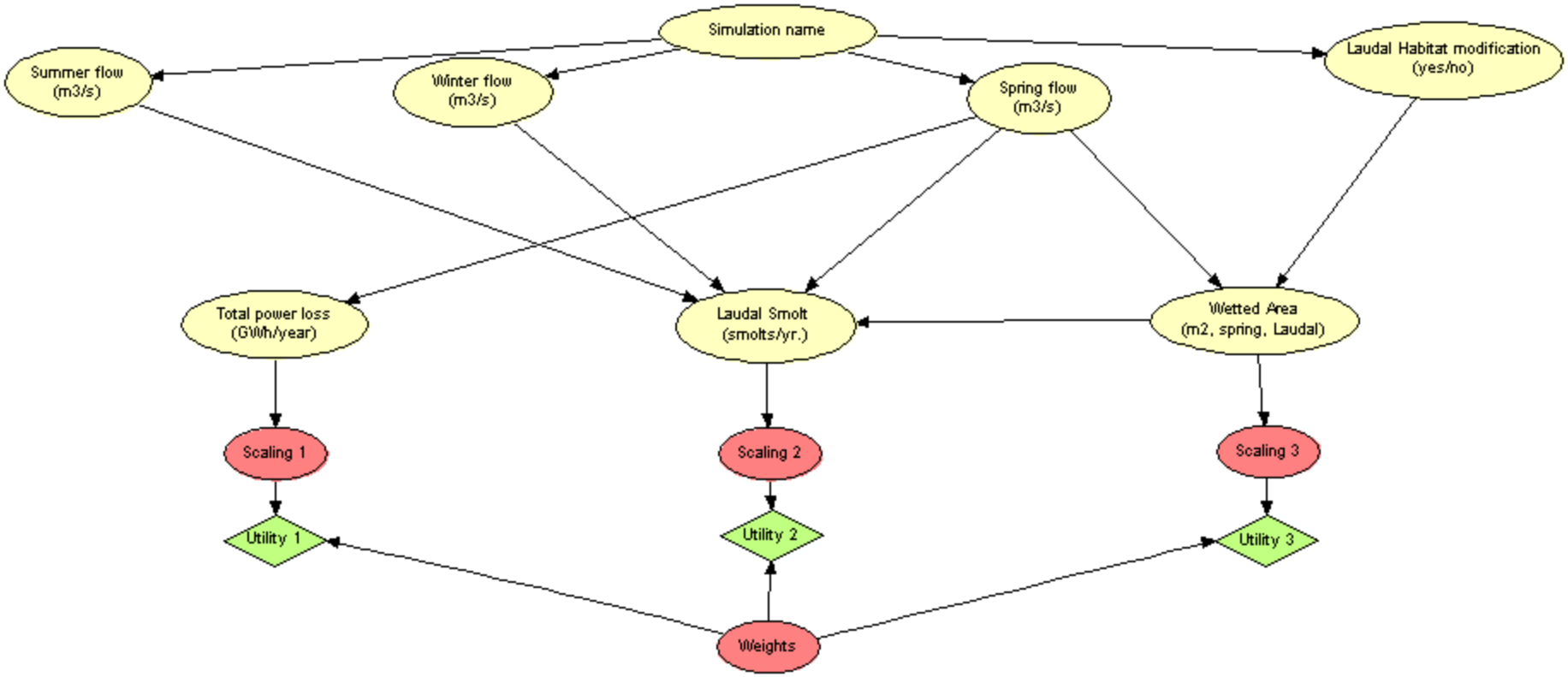
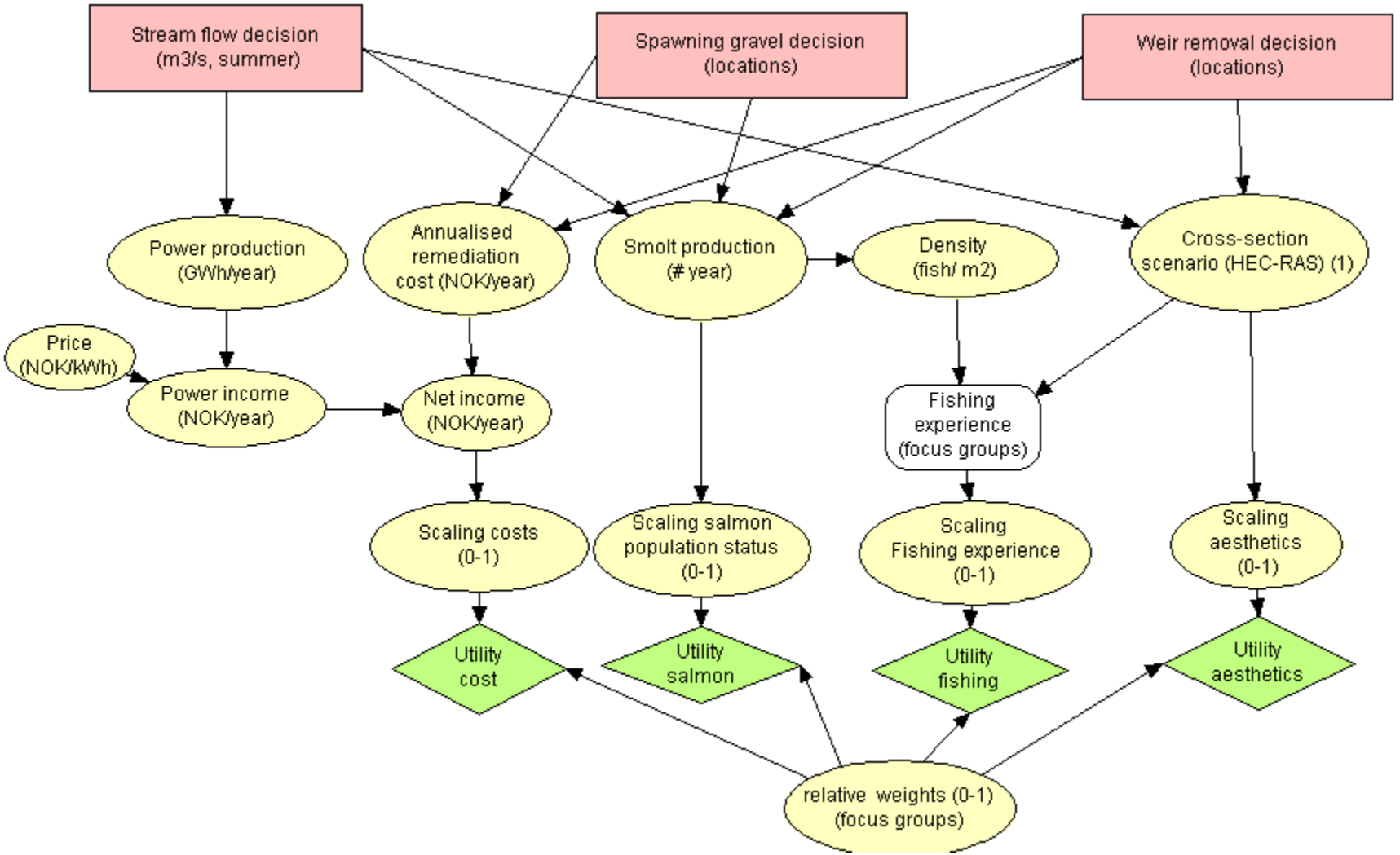
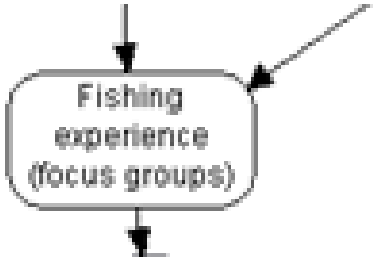


# DEMONSTRATION OF A SIMPLE MCDA MODEL USING IBSalmon simulations for Laudal stretch

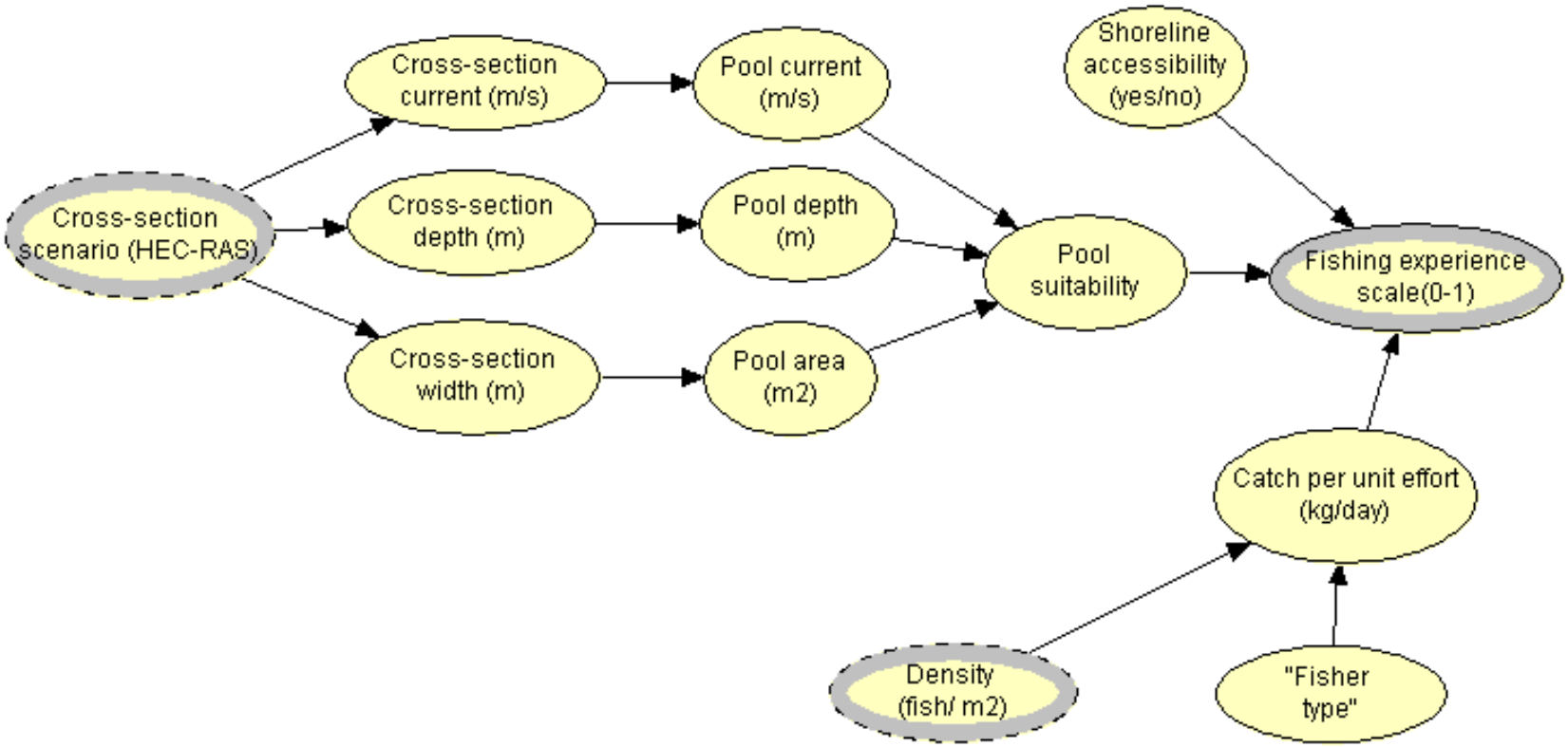


# Full MCDA model implementation (tentative)






# Fishing experience sub-model (tentative)



# Policy implications

Relevance for **Guidance Document on Ecological Flows (Eflows) in the implementation of the Water Framework Directive**

- habitat **offsetting** across concessions as part of programme of measures
- weighting utility of **multiple uses**

→ modifies definition of good ecological potential

→ changes analysis of disproportionate costs