WP4.4 Pilot Case Studies indicators database for MCA

Structure of Lech decisional tree

Date
15-06-2012

Report version
WP4 (action 4.4)

Author
Ianina KOPECKI

Member number and name
PP11 – IWS, Uni-Stuttgart

SHARE - Sustainable Hydropower in Alpine Rivers Ecosystems
http://www.sharealpinerivers.eu
Project reference number: 5-2-3-IT
Priority 3 – Environment and Risk Prevention
Project duration: 36 months – 1/08/2009 – 31/07/2012

Summary

SHORT DESCRIPTION

This document describes the structure of the SESAMO tree and the MCA application for the Pilot Case Study Lech.

Document Control

Project	SHARE - Sustainable Hydropower in Alpine Rivers Ecosystems (ref. 5-2-3-IT)
Action	WP4 – action 4.4
Type	Report
Due date	Project Month 35 (June 2012)
Dissemination	Internal
Origin	PP11 – IWS, Uni-Stuttgart
Author	Ianina Kopecki – ianina.kopecki@iws.uni-stuttgart.de

Version Control

VERSION	DATE	AUTHOR	AUTHOR'S ORGANIZATION	DESCRIPTION/CHANGES
v01.00	15/06/2012	KOPECKI	IWS	1st version

Table of contents

Summary

This report aims to describe the methodological approach, the criteria and indicators selected to test the multi criteria analysis (MCA) for the Lech pilot case study. After the short introduction into the Lech pilot case which describes the present hydropower use and considered alternatives, following aspects of the MCA application are given:

- General structure of the SESAMO decision tree;
- Detailed description of criteria, sub-criteria and indicators;
- Assigned indicator weights;
- Evaluation of alternatives performance.

The selection of criteria and indicators of this cases study is recommended for the MCA application in similar cases concerned with mitigation of hydropeaking effects on rivers.

Lech Pilot Case Study – Reach "Litzauer Schleife "

General situation and present hydropower use

Bavarian section of Lech River between Füssen and Danube River is extensively used by hydropower. Nature Reserve Litzauer Schleife represents the one of just a few freely flowing stretches of the river Lech. This river reach of about 6 km length with stretches of intact riparian vegetation and sand banks has a high nature preserve value and was reported to the EU Commission as protected area within the framework of the Habitat Directive.

In spite of its ecological value, the river reach is heavily affected by hydropeaking. The upstream power station Dessau (confession rights until 2058) operating within the chain of Lech hydropower stations controls the daily discharges which range between a basis discharge Q_{basis} of 10 m³/s in winter (20 m³/s in summer) and a maximum power plant turbine discharge Q_{max} of 155 m³/s, often inducing flow peaks two times a day.

The negative effects of hydro peaking on flora and fauna of the Litzauer Schleife are profound. The study of Schnell (2005) concludes that especially fish and macrozoobenthos fauna are affected by such extreme changes in daily discharges and shows typical deterioration marks.
Some of those are:

1. Reduction of natural habitat area due to low base discharges (Qmin in summer/winter are much lower than natural MQ). Periodically flooded areas during peak discharges are almost of no use for most river inhabitants. Pronounced reduction in macrozoobenthos biomass in these areas results in considerable losses in nursery habitats for young fish.
2. High flow velocities and corresponding hydraulic stress in the main channel alter negatively the value of this habitat for most species including macrozoobenthos and algae.
3. The high structural value of the reach does not correspond to low species richness and biomass. Altered age structure of grayling (*Thymallus thymallus*) population (key fish species) due to power plant operation during previous spawning periods is ascertained. Some fish species typical for this reach are missing or considerably underrepresented.

In respect to the Water Framework Directive obligations there is an urgent need to reconsider the discharge situation in the Litzauer Schleife. Thus the operational discharge management of the plant Dessau is the object of the Multi Criteria Analysis application to the Lech pilot case study.

Alternatives description

Alternative hydropeaking schemes for the plant Dessau aimed on reduction of negative effects on flora and fauna by means of

- increasing the basis discharge,
- reduction the maximum discharges and/or
- optimization of daily discharge variation

are developed and assessed in this case study.
Habitat modelling results performed for the investigation stretch with the length of 800 m together with the evaluation of flow hydrographs of previous years allow to suggest following alternatives for the MCA application:

Alternative 1: Typical flow regime in winter 2011/2012

Q_{basis} = 25 m³/s, Q_{max} = 80 m³/s

Alternative 2: Ecological regime – constant flow

Q = 44 m³/s

Alternative 3: Ecological regime – attenuated hydropeaking

Q_{basis} = 25 m³/s, Q_{max} = 50 m³/s

Alternative 4: Typical flow regime in winter 2003

Q_{basis} = 10 m³/s, Q_{max} = 155 m³/s

Alternative 5: Present agreement between energy producer and fishermen

Q_{basis} = 25 m³/s, Q_{max} = 135 m³/s

Alternative 6: MNQ in winter

Q = 20 m³/s

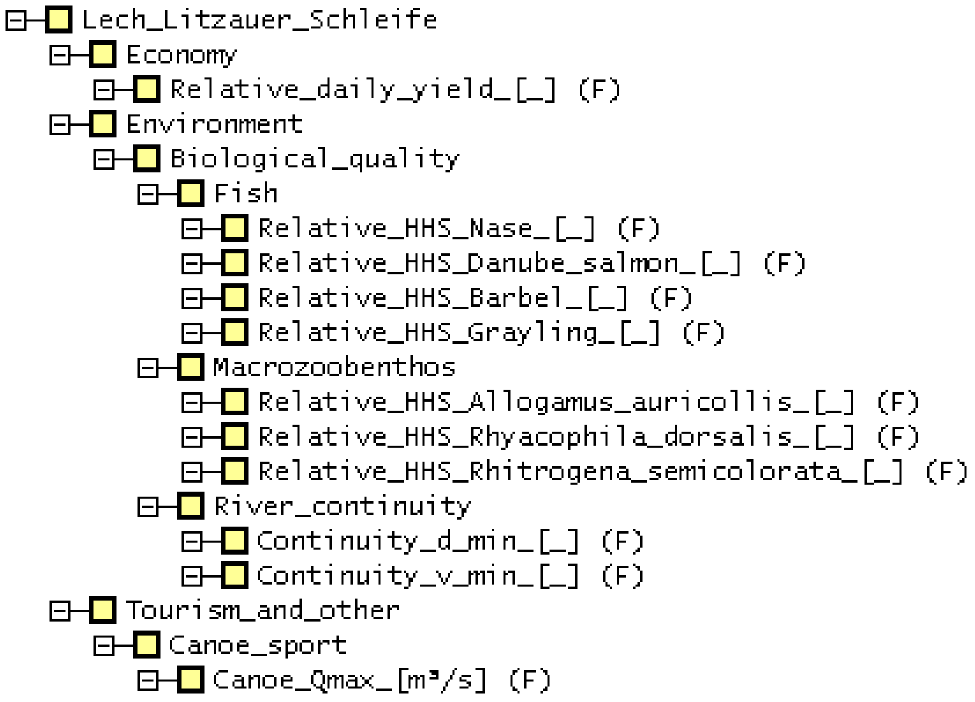
All alternatives besides the alternative 6 assume the same discharge volume per day to allow the reasonable economical comparison. Constant flow rate of 20 m³/s in the alternative 6 corresponds to an average minimum water discharge in winter for Litzauer Schleife.

The approximate discharge distribution during a day (average hourly values in m³/s) for every alternative is demonstrated in the table below. In this table the blue coloured cells denote basis load hours (with electricity price of 4 cent/kWh), the yellow coloured cells denote the hours with medium load (with electricity price of 6 cent/kWh), the red denote the hours with peak load (with electricity price of 8 cent/kWh).

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
hour	25-80	const 45	25-50	10-155	25-135	20
1	25	44	25	10	25	20
2	25	44	25	10	25	20
3	25	44	25	10	25	20
4	25	44	31	10	25	20
5	41	44	50	10	25	20
6	80	44	50	101	25	20
7	80	44	50	155	25	20
8	80	44	50	10	25	20
9	25	44	50	10	25	20
10	25	44	50	10	25	20
11	25	44	50	10	25	20
12	25	44	50	10	25	20

13	25	44	50	10	25	20
14	25	44	50	10	25	20
15	25	44	50	10	25	20
16	25	44	50	10	25	20
17	25	44	50	10	25	20
18	80	44	50	155	135	20
19	80	44	50	155	135	20
20	80	44	50	155	135	20
21	80	44	50	155	135	20
22	80	44	50	10	41	20
23	25	44	25	10	25	20
24	25	44	25	10	25	20

MCA tree



- Lech_Litzauer_Schleife
  - Economy
    - Relative_daily_yield_[_] (F)
  - Environment
    - Biological_quality
      - Fish
        - Relative_HHS_Nase_[_] (F)
        - Relative_HHS_Danube_salmon_[_] (F)
        - Relative_HHS_Barbel_[_] (F)
        - Relative_HHS_Grayling_[_] (F)
      - Macrozoobenthos
        - Relative_HHS_Allogamus_auricollis_[_] (F)
        - Relative_HHS_Rhyacophila_dorsalis_[_] (F)
        - Relative_HHS_Rhitrogena_semicolorata_[_] (F)
      - River_continuity
        - Continuity_d_min_[_] (F)
        - Continuity_v_min_[_] (F)
  - Tourism_and_other
    - Canoe_sport
      - Canoe_Qmax_[m³/s] (F)

Criteria and indicators

In the present study only the winter conditions are considered. Therefore, the most sensitive biological components during winter such as juvenile fish species (grayling, Danube salmon, barbel and nase) are selected as indicators of the **biological river quality** within the criteria **Environment**. Additionally, the reaction of typical macrozoobenthos species (the species of *Allogamus auricollis*, *Rhyacophila dorsalis* and *Rhithrogena semicolorata*) on flow regimes of different alternatives is investigated. For both juvenile fish and macrozoobenthos the relative Hydraulic Habitat Suitability (HHS) evaluated with the CASiMiR habitat model is used as indicator value in this case study. The relative HHS value is used because there is no generally normative for HHS for fish and macrozoobenthos.

River continuity is another indicator of the **biological river quality** within the criteria **Environment.** Generally it is defined by a minimum water depth and flow velocity required for adults of the indicator fish species. Although water depth and flow velocity are measurable indicators, the values of 1 and 0 are used in this case study to express continuity. 1 means an alternative satisfies the continuity requirement (on a water depth or flow velocity) for a fish species and 0 means it does not.

There is only one indicator within the criteria **Tourism**. Its value is based on the subjective assessment of a river quality in a touristic sense by a canoe-expert. The maximum flow discharge during canoeing event is selected as an indicator value. It is important to mention that the maximum discharge of a hydropeaking scheme does not necessarily corresponds to a maximum flow discharge during canoeing event as the latter is assumed to happen only during day-hours.

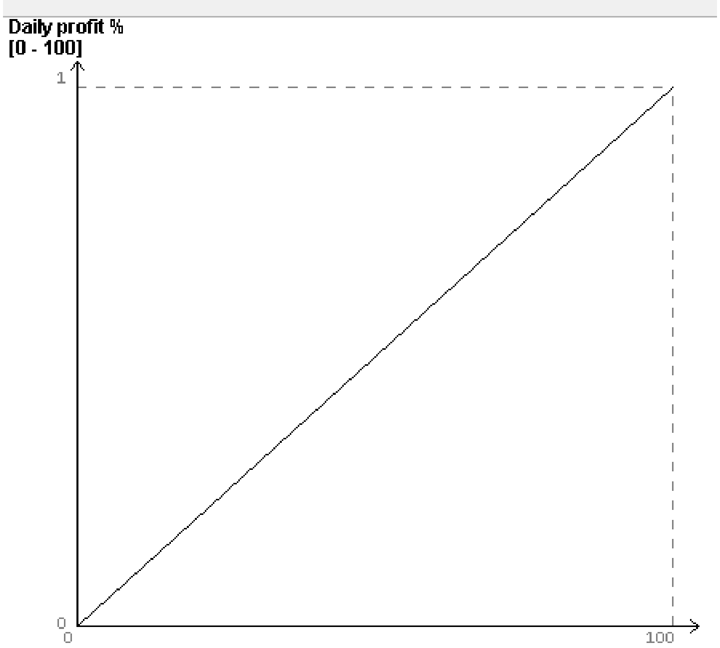
As a counter-indicator to the **Tourism** and **Environment**, the relative daily yield from energy production under the criteria **Economy** is considered.

Below the metadata of every indicator used in the Lech case study is given.

Lech tree | ECONOMY | (Relative) daily yield

<table>
<tr><th>FIELD</th><th>DESCRIPTION</th></tr>
<tr><td>INDICATOR NAME</td><td>Energy yield per day (Monetary equivalent/day)</td></tr>
<tr><td>ACRONYM</td><td></td></tr>
<tr><td>DPSIR</td><td>R (Responses)</td></tr>
<tr><td>DESCRIPTION</td><td>Sold energy volume per day by given hydropeaking regime.</td></tr>
<tr><td>AIM</td><td>To evaluate the effects of different hydropeaking regimes on energy yield.</td></tr>
<tr><td>KEY MESSAGE</td><td>The alternative hydropeaking regimes accounting for the river biota requirements have an effect on energy production and can be assessed with this parameter.</td></tr>
<tr><td>MEASURE UNIT</td><td>Monetary equivalent/day</td></tr>
<tr><td>REFERENCES</td><td>–</td></tr>
<tr><th>FIELD</th><th>METHODS AND MONITORING STANDARDS</th></tr>
<tr><td>INDICATOR ELABORATION</td><td>Via calculation of energy output for a suggested hydropeaking regime based on the technical characteristics of a HP station and approximation of peak and base prices for energy production.</td></tr>
<tr><td>INDICATOR LIMITS</td><td>Peak and base prices for energy production are not constant; not only prices for energy production play a role but also grid stabilization demands.</td></tr>
<tr><td>EVALUATION</td><td>The main parameters of the HP Dessau are:
<table>
<tr><td>Mean Head</td><td>8.5</td><td>m</td></tr>
<tr><td>Q</td><td>Depending on hydropeaking scheme</td><td>m3/s</td></tr>
<tr><td>Energy price</td><td>Depending on the load</td><td>Euro</td></tr>
<tr><td>η</td><td>0.8</td><td>-</td></tr>
</table>
The estimated relative energy yields for the different alternatives are given in the Chapter “

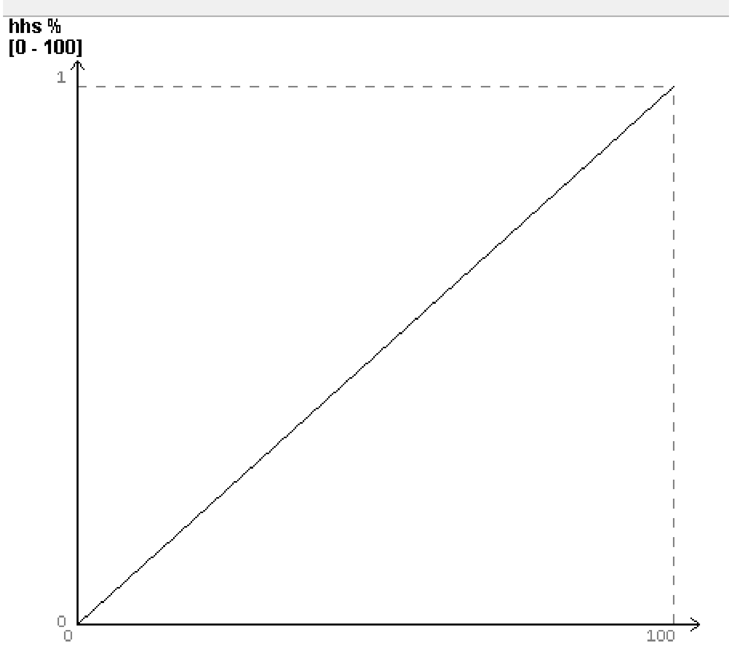
Evaluation Matrix”. Energy yields are relative to the value of an alternative with maximum daily yield.</td></tr>
</table>

AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR growing. 
SHARE RELATED IND.	yes
COUNTRY CODE	DE
WFD HER	eu12
FIELD	**DATASOURCES**
DATA SOURCE	Energy prices from energy market; technical characteristics of HPs; hydropeaking regime.
TIME COVER	-
UPDATE FREQUENCY	At request
NUT III CODE	DE21N
NORMATIVE REFERENCE	-
NORMATIVE RELEVANCE	-
SHARE PILOT CASE STUDY	Lech

Lech tree | ENVIRONMENT | (Relative) HHS

FIELD	DESCRIPTION
INDICATOR NAME	Hydraulic Habitat Suitability Index (fish, macrozoobenthos)
ACRONYM	*HHS*
DPSIR	S (States)

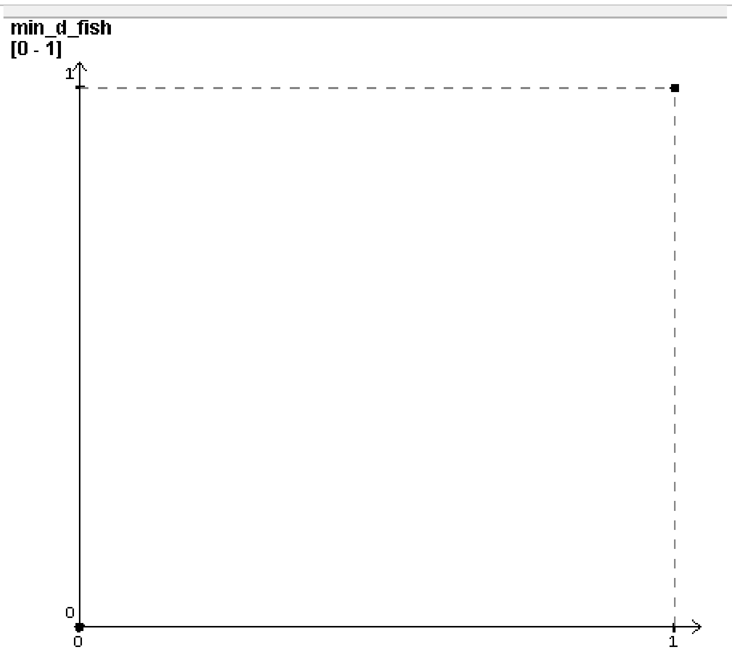
DESCRIPTION	Dimensionless integral characteristic of a river reach concerning habitat quality and quantity for a selected target species
AIM	Integral assessment of a habitat quality for a target species based on habitat modeling results
KEY MESSAGE	Indicator evaluation is based on results of habitat modeling. Advantages: forecasting possible, temporal aspects can be assessed, direct dependency to discharge (HP operation) and morphological changes; Disadvantages: integral parameter
MEASURE UNIT	Dimensionless
REFERENCES	www.casimir-software.com
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Via habitat modeling (for example using the habitat model CASiMiR).
INDICATOR LIMITS	Limited number of indicator (target) species with elaborated habitat preferences; difficulties for the application in steep mountain rivers with very coarse substrate (due to limitations of hydraulic models as a basis for habitat modeling)
EVALUATION	In the Lech case study the special adaptation of the habitat model CASiMR is undertaken aimed to account for the effects of hydropeaking. HHS is computed upon the lowest habitat suitability during a hydropeaking event. Only best suitable habitats (SI>0.6) are taken for the estimation of overall HHS. The estimated relative HHSs for every target species for the different alternatives are given in the Chapter “ Evaluation Matrix”. All HHSs for a given target species are relative to the value of an alternative with the maximum HHS.
AVAILABLE UF	YES
UF	The Utility Function adopted is LINEAR growing

	
SHARE RELATED IND.	yes
COUNTRY CODE	DE
WFD HER	eu12
FIELD	**DATASOURCES**
DATA SOURCE	
TIME COVER	-
UPDATE FREQUENCY	At request
NUT III CODE	DE21N
NORMATIVE REFERENCE	-
NORMATIVE RELEVANCE	-
SHARE PILOT CASE STUDY	Lech

Lech tree | ENVIRONMENT | River continuity

FIELD	**DESCRIPTION**
INDICATOR NAME	River continuity, passability for fish
ACRONYM	
DPSIR	S (States)

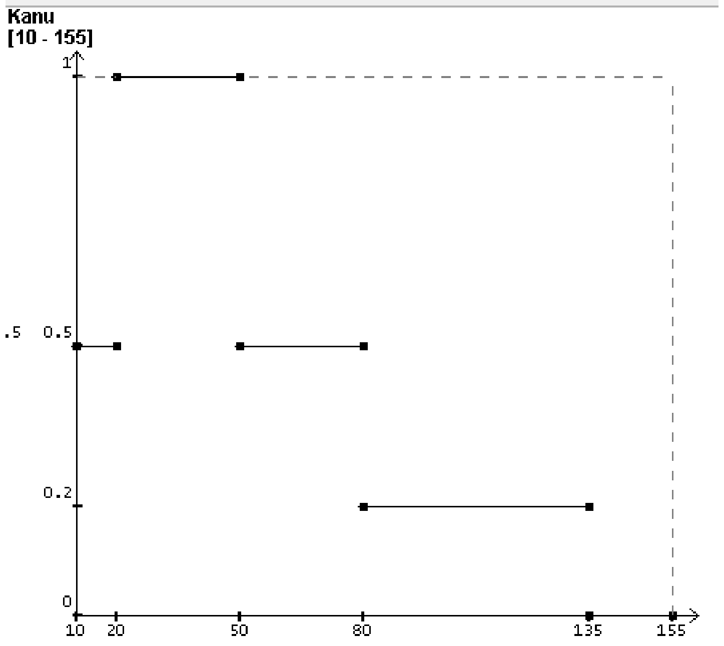
DESCRIPTION	Evaluation of passability for the typical indicator fish species within the framework of "biotop-discharge-approach"
AIM	Evaluation of a river reach condition in respect to the minimum requirements (defined through water depth and flow velocity) of typical local fish species
KEY MESSAGE	Indicator with a temporal and spatial forecasting ability; direct dependency to discharge (HP operation);
MEASURE UNIT	In Lech case study – dimensionless; Water depth in [m]; Flow velocity in [m/s]
REFERENCES	LAWA, 2001
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Via hydraulic modeling or field measurements in the critical river cross-section (shallowest cross-section and/or impounded water reach).
INDICATOR LIMITS	Considers only the conditions in a critical cross-section; Should be used only as an additional indicator as it allows only a threshold assessment (passable/not passable); effects of renaturation cannot be evaluated properly.
EVALUATION	In the Lech case study the river continuity is evaluated based on results of hydraulic modeling for a lowest flow rate at a given hydropeaking regime. The grayling is considered as a target species with highest requirements on the continuity. Value “1” means continuity requirement is fulfilled at a given regime for a given parameter (water depth or flow velocity), value “0” means the continuity requirement is not fulfilled. The estimated continuity values for the different alternatives are given in the Chapter “ Evaluation Matrix”.
AVAILABLE UF	YES
UF	The Utility Function adopted is of SINGLE POINTS type

	
SHARE RELATED IND.	yes
COUNTRY CODE	DE
WFD HER	eu12
FIELD	**DATASOURCES**
DATA SOURCE	Hydraulic model results or field measurements, fish requirements
TIME COVER	-
UPDATE FREQUENCY	At request
NUT III CODE	DE21N
NORMATIVE REFERENCE	Direct coherence
NORMATIVE RELEVANCE	-
SHARE PILOT CASE STUDY	Lech

Lech tree | TOURISMUS AND OTHER | Canoe sport quality

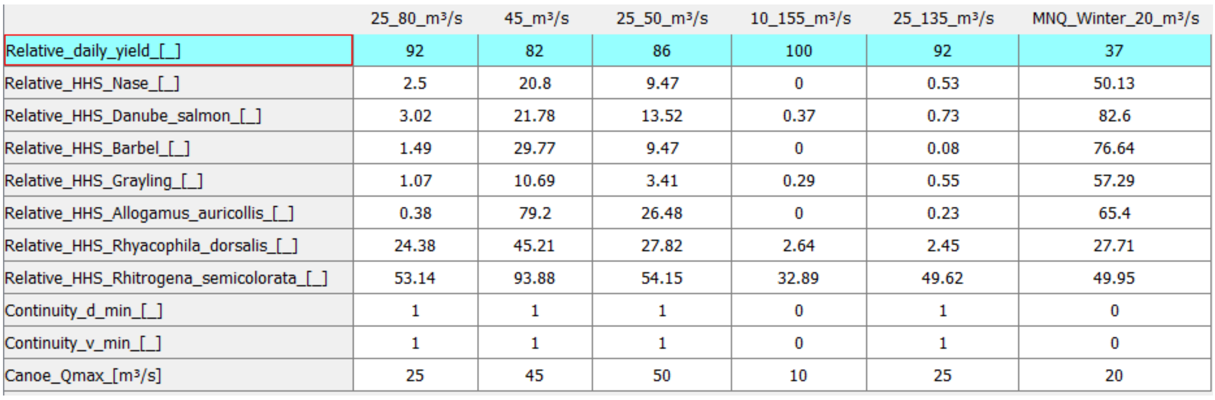
FIELD	DESCRIPTION
INDICATOR NAME	Canoe sport quality
ACRONYM	
DPSIR	S (States)

DESCRIPTION	Evaluation of river attractiveness for canoe sport
AIM	Evaluation of river attractiveness for canoe sport depending on flow conditions in the river
KEY MESSAGE	Touristic highly subjective indicator; depends on local conditions; direct dependency to discharge (HP operation);
MEASURE UNIT	In Lech case study – [m^3/s];
REFERENCES	
FIELD	**METHODS AND MONITORING STANDARDS**
INDICATOR ELABORATION	Via observation of river at different flow conditions.
INDICATOR LIMITS	Very subjective indicator. Can be different of skilled canoe-man or family with children.
EVALUATION	In the Lech case study this parameter was estimated upon consulting a canoe-expert. The estimated values of the indicator for the different alternatives are given in the Chapter " Evaluation Matrix".
AVAILABLE UF	YES
UF	The Utility Function adopted is of STEP type

	
SHARE RELATED IND.	yes
COUNTRY CODE	DE
WFD HER	eu12
FIELD	**DATASOURCES**
DATA SOURCE	Expert opinion
TIME COVER	-
UPDATE FREQUENCY	At request
NUT III CODE	DE21N
NORMATIVE REFERENCE	No coherence
NORMATIVE RELEVANCE	-
SHARE PILOT CASE STUDY	Lech

Evaluation Matrix

The values of all indicators for all alternatives for the Lech case study are shown in the table below.



	25_80_m^3/s	45_m^3/s	25_50_m^3/s	10_155_m^3/s	25_135_m^3/s	MNQ_Winter_20_m^3/s
Relative_daily_yield_[_]	92	82	86	100	92	37
Relative_HHS_Nase_[_]	2.5	20.8	9.47	0	0.53	50.13
Relative_HHS_Danube_salmon_[_]	3.02	21.78	13.52	0.37	0.73	82.6
Relative_HHS_Barbel_[_]	1.49	29.77	9.47	0	0.08	76.64
Relative_HHS_Grayling_[_]	1.07	10.69	3.41	0.29	0.55	57.29
Relative_HHS_Allogamus_auricollis_[_]	0.38	79.2	26.48	0	0.23	65.4
Relative_HHS_Rhyacophila_dorsalis_[_]	24.38	45.21	27.82	2.64	2.45	27.71
Relative_HHS_Rhitrogena_semicolorata_[_]	53.14	93.88	54.15	32.89	49.62	49.95
Continuity_d_min_[_]	1	1	1	0	1	0
Continuity_v_min_[_]	1	1	1	0	1	0
Canoe_Qmax_[m^3/s]	25	45	50	10	25	20

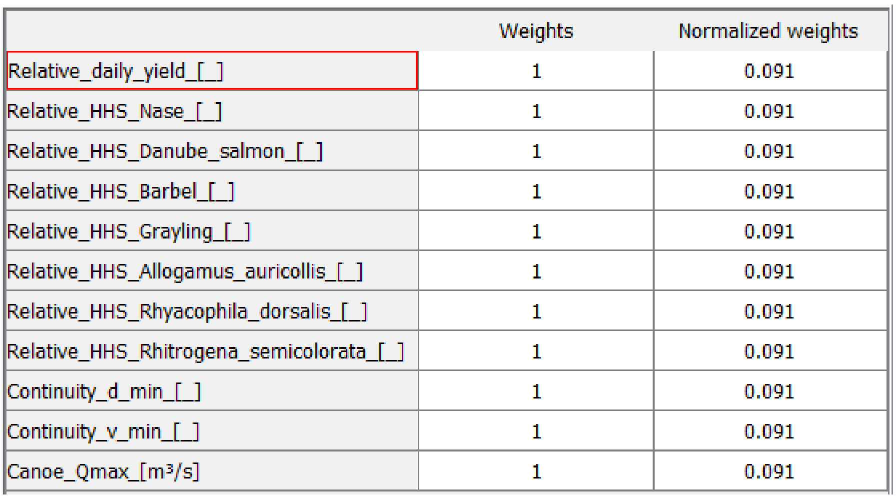
Evaluation of alternatives' performance

To test the importance of indicators and their sensitivity three weighting schemes are applied:

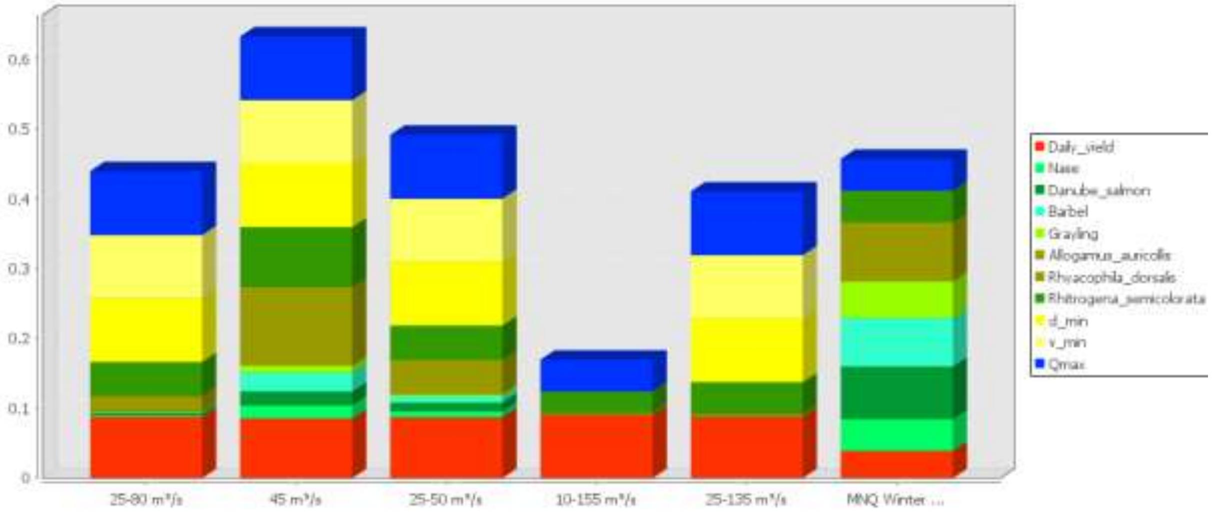
1. All indicators have the same weight
2. Priority on energy production
3. Priority on environment

The indicator weighs and alternative ranking results for all above mentioned weighting schemes are shown below.

All indicators have the same weight

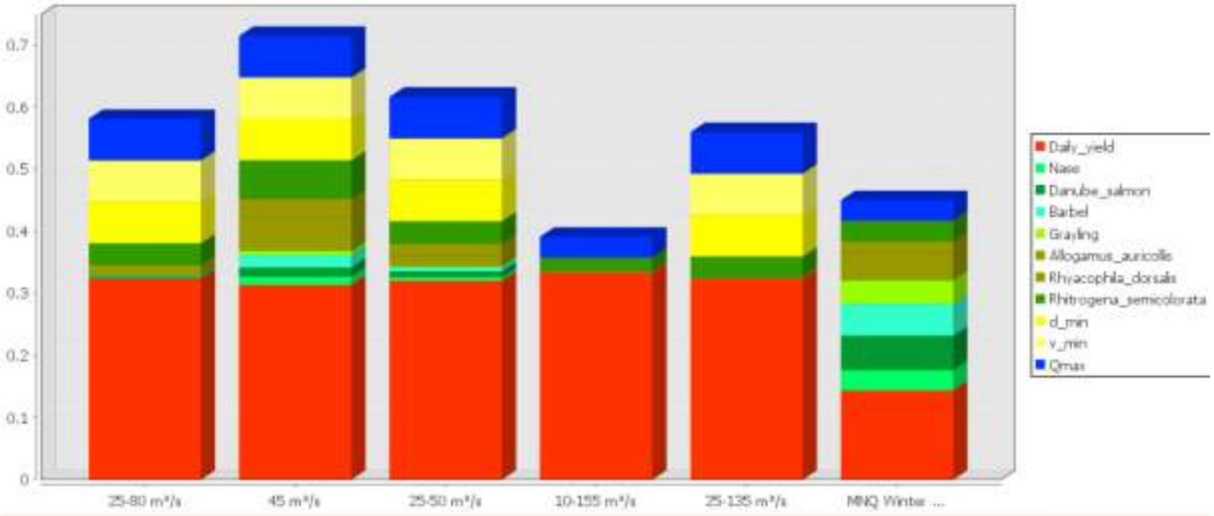


	Weights	Normalized weights
Relative_daily_yield_[_]	1	0.091
Relative_HHS_Nase_[_]	1	0.091
Relative_HHS_Danube_salmon_[_]	1	0.091
Relative_HHS_Barbel_[_]	1	0.091
Relative_HHS_Grayling_[_]	1	0.091
Relative_HHS_Allogamus_auricollis_[_]	1	0.091
Relative_HHS_Rhyacophila_dorsalis_[_]	1	0.091
Relative_HHS_Rhitrogena_semicolorata_[_]	1	0.091
Continuity_d_min_[_]	1	0.091
Continuity_v_min_[_]	1	0.091
Canoe_Qmax_[m^3/s]	1	0.091

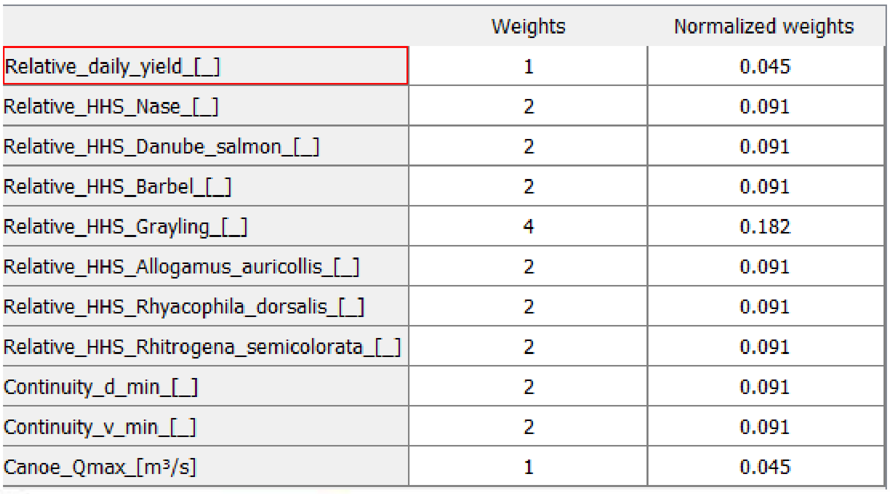


Priority on energy production

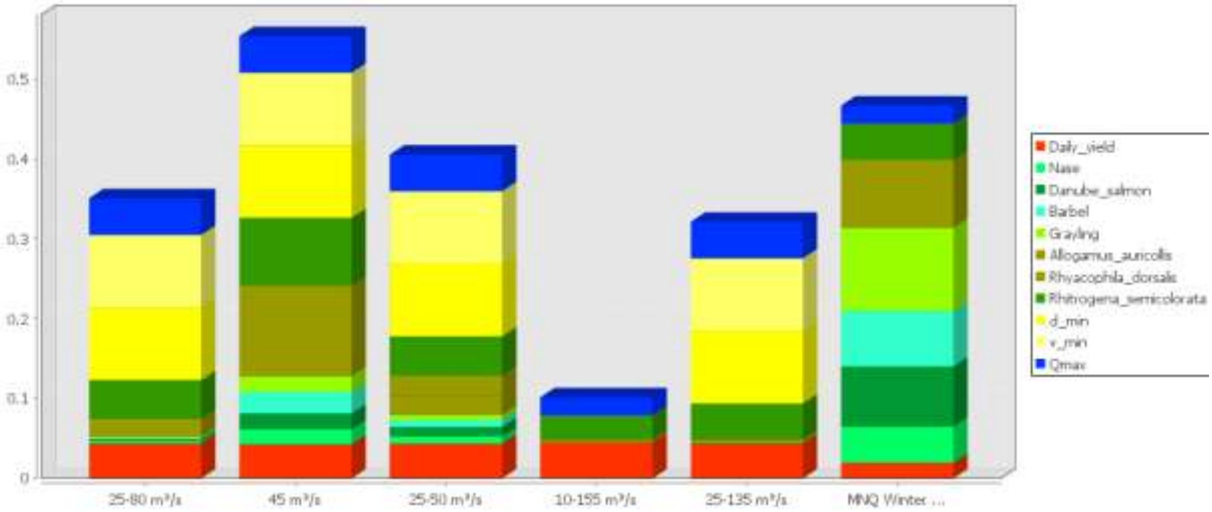
	Weights	Normalized weights
Relative_daily_yield_[_]	5	0.333
Relative_HHS_Nase_[_]	1	0.067
Relative_HHS_Danube_salmon_[_]	1	0.067
Relative_HHS_Barbel_[_]	1	0.067
Relative_HHS_Grayling_[_]	1	0.067
Relative_HHS_Allogamus_auricollis_[_]	1	0.067
Relative_HHS_Rhyacophila_dorsalis_[_]	1	0.067
Relative_HHS_Rhitrogena_semicolorata_[_]	1	0.067
Continuity_d_min_[_]	1	0.067
Continuity_v_min_[_]	1	0.067
Canoe_Qmax_[m³/s]	1	0.067



Priority on environment



	Weights	Normalized weights
Relative_daily_yield_[_]	1	0.045
Relative_HHS_Nase_[_]	2	0.091
Relative_HHS_Danube_salmon_[_]	2	0.091
Relative_HHS_Barbel_[_]	2	0.091
Relative_HHS_Grayling_[_]	4	0.182
Relative_HHS_Allogamus_auricollis_[_]	2	0.091
Relative_HHS_Rhyacophila_dorsalis_[_]	2	0.091
Relative_HHS_Rhitrogena_semicolorata_[_]	2	0.091
Continuity_d_min_[_]	2	0.091
Continuity_v_min_[_]	2	0.091
Canoe_Qmax_[m^3/s]	1	0.045



Independently of selected weighting scheme the best alternative considered in the Lech case study is the Alternative 2 (Ecological regime – constant flow) and the worst is the Alternative 4 (Typical flow regime in winder 2003)

References

Schnell, J. (2005) Gewässerökologische Auswirkungen des Schwellbetriebs am Lech im Bereich des Naturschutzgebietes „Litzauer Schleife“. Projekt im Rahmen einer Diplomarbeit an der Humboldt Universität zu Berlin und der TU-München AG Fischbiologie.

LAWA (2001): Länderarbeitsgemeinschaft Wasser: Empfehlungen zur Ermittlung von Mindestabflüssen in Ausleitungsstrecken von Wasserkraftanlagen und zur Festsetzung im wasserrechtlichen Vollzug, 1. Auflage, Schwerin: Kulturbuch-Verlag GmbH Berlin, 2001.