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Assessing Visual Preferences of the Local Public for Environmental Mitigation Measures of Hydropower Impacts—Does Point-of-View Location Make a Difference?

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Abstract: Hydropower is a highly appreciated climate-friendly source of energy production. However, it has non-negligible negative impacts on the environment and landscape aesthetics where the energy is produced, affecting the recreational interests of the public using the respective local river spaces. The preferences of the local public are increasingly assessed and involved in the planning of mitigation measures for impacted rivers. Aesthetic assessment methods using a common user perspective, i.e., an "on-the-ground" perspective, could potentially be improved by using an aerial perspective facilitated by modern drone technology. Studies on the compatibility of these two perspectives of assessment in terms of public preference elicitation are lacking so far. In river Nea, Norway, we conducted a quantitative analysis of the visual preferences of the local public for different environmental mitigation measures related to weirs, minimum flow, and recreational infrastructure using both perspectives. The results indicate that there exist significant differences in the preferences for scenarios based on the two different visual perspectives, and that a compatibility between them cannot be assumed and therefore requires further investigation. Finally, based on our study setup and previous experience, we outline and propose a standardized procedure for the visualization of mitigation measures as an input to environmental design projects where public perception is incorporated.

Keywords: photo-based questionnaire; aesthetic value; hydropower production; mitigation measures

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1. Introduction

There are large ambitions for a green energy transition worldwide in order to mitigate climate change and to rely increasingly on renewable sources of production. Hydropower production is one of the main pillars of this green energy transition. However, as with all sources of energy production, hydropower generation has non-negligible environmental impacts and is frequently seen as severely degrading river ecosystems and local biodiversity [1,2]. It also affects the aesthetic qualities and the recreational use of the respective local river spaces where people live [3,4]. Impacts on environmental, aesthetic, and recreational use are found to be highly relevant for the public perception and acceptance of hydropower projects [5,6]. The involvement and participation of the public in the planning of new and the revision of existing hydropower infrastructure is becoming increasingly relevant [7] and is mandated by the European Water Framework Directive as well as national guidelines [8,9]. As a consequence, there is an increasing number of assessments of local public preferences for environmental mitigation measures in rivers or lakes that are regulated for hydropower production [10,11]. Hereby, the use of visual simulation of different environmental mitigation scenarios at stake is a very valuable method.

The environmental impacts of hydropower production relate, in general, to changes in the natural flow and water temperature regime, hydro-morphology and sediment transport, the loss or alteration of habitats, obstructing downstream and upstream fish migration past dams, weirs, and other infrastructure. The impacts are so far best known for fish species, and many environmental mitigation measures aim to improve living conditions for fish specifically. Fish are a central quality element in the European Water Framework Directive and are considered a suitable indicator for hydro-morphological alterations in rivers [12].

Alterations of flow and water temperature can be mitigated by releasing environmental flows of a suitable volume. Different structural mitigation measures, such as constructing riffles and pools, adding stones and gravel, and adding large organic debris, when combined with flow release are used to re-establish or improve habitats. Guiding devices and fine trash racks can help fish move downstream. Fish ladders and nature-like fishways in dams in addition to removing or adjusting weirs can help them move upstream. Another common mitigation measure has been fish stocking [13]. While some of these environmental mitigation measures are not visible to the public, others affect the river landscape aesthetics, e.g., changes in flow, the removal/adjustment of weirs and low-head dams. These can be decisive for the approval or disapproval of measures by the local public. The most common view taken to develop and present visual scenarios of river scenes to the public in order to elicit its preferences has been an "on-the-ground" perspective, one that a person standing on the riverbank looking over the river would have [10,14–16]. There is an ongoing discussion on which perspective would be the most valid one in assessing visual preferences [17–19], including the question as to whether modern LIDAR/drone technology and the resulting aerial perspective would improve assessments by providing a larger overview of a scene [20,21]. Studies on the compatibility of these two perspectives of assessment—i.e., the compatibility of the on-the-ground and aerial perspectives—in terms of public preference elicitation are lacking so far.

Historically, weirs were introduced in rivers mainly for hydraulic and hydrological control as well as for aesthetic reasons, due to a lack of water cover in river sections with reduced flows [22,23]. Later studies have shown that weirs may be a threat to riverine species in terms of both their habitats and migration [24–27]. The adjustment and removal of dams and weirs are now considered a relevant environmental measure [28,29]. In a Norwegian study on weir removal, Fjeldstad et al. demonstrated that hydraulic modeling could be used for to simulate suitable fish habitats before and after weir removal [30]. Another example of the use of hydraulic simulation in a weir removal study is given by Mouton et al. [31], indicating improved habitat conditions for fish after removal. More recently, Tang et al. demonstrated improved fish migration and habitat suitability by removing a low-head dam [32]. While hydraulic models can provide flow-related hydrodynamics in river sections affected by environmental measures [33,34], few studies have used hydraulic model outputs to set up visual representations of the consequences of environmental measures such as weir adjustment or removal. One example of the visualization of environmental measures is given by Barton et al. in a multicriteria analysis study, where hydraulic simulations were used to set up photo scenarios for weir removal as an input for a reference group survey [10]. While the above-mentioned study provides a good example of a visual preference study, a standardized procedure for developing visual scenarios for preference elicitation has yet not been established.

We conducted a case study at the Norwegian Nea River with a quantitative analysis of visual preferences of the local public in the adjacent municipalities for different environmental mitigation measure scenarios related to weirs, minimum flow, and recreational infrastructure using both on-the-ground and aerial perspectives. We used hydraulic modeling to simulate outlines of the water-covered area for each alternative scenario of environmental measures. The outlines were used as an input for photo manipulation of the different scenarios. Photos were taken from two separate perspectives: aerial, using a drone-mounted camera, and on-the-ground, using a standard hand-held camera. We describe the procedure of generating visual simulations of environmental measure scenarios for preference assessment in the Materials and Methods section.

Our main objectives were to:

(1) Establish a standardized procedure for preference assessments using visualization of mitigation measure scenarios;

(2) Shed more light on the issue of aerial versus on-the-ground perspectives in terms of potential improvement of visual assessment studies. For the latter objective we tested the hypothesis that there are no significant differences between public visual preferences for scenarios with an on-the-ground perspective and scenarios with an aerial perspective.

2. Materials and Methods

2.1. Study Area

The study was conducted in the Nea River, situated in Central Norway (Figure 1). The Nea River runs through the Selbu and Tydal municipalities, where the power company Statkraft operates several hydropower plants and reservoirs along the course of the river. The regulation in the study reach includes an upstream reservoir and high-head dam, a bypass section, and a downstream outlet. Thirty-three low-head weirs were introduced to the bypass section in the 1980s to increase the water-covered area during low flows. A minimum flow of 1.5 m^3/s is released at the dam from May through September. No flows are released outside this period.

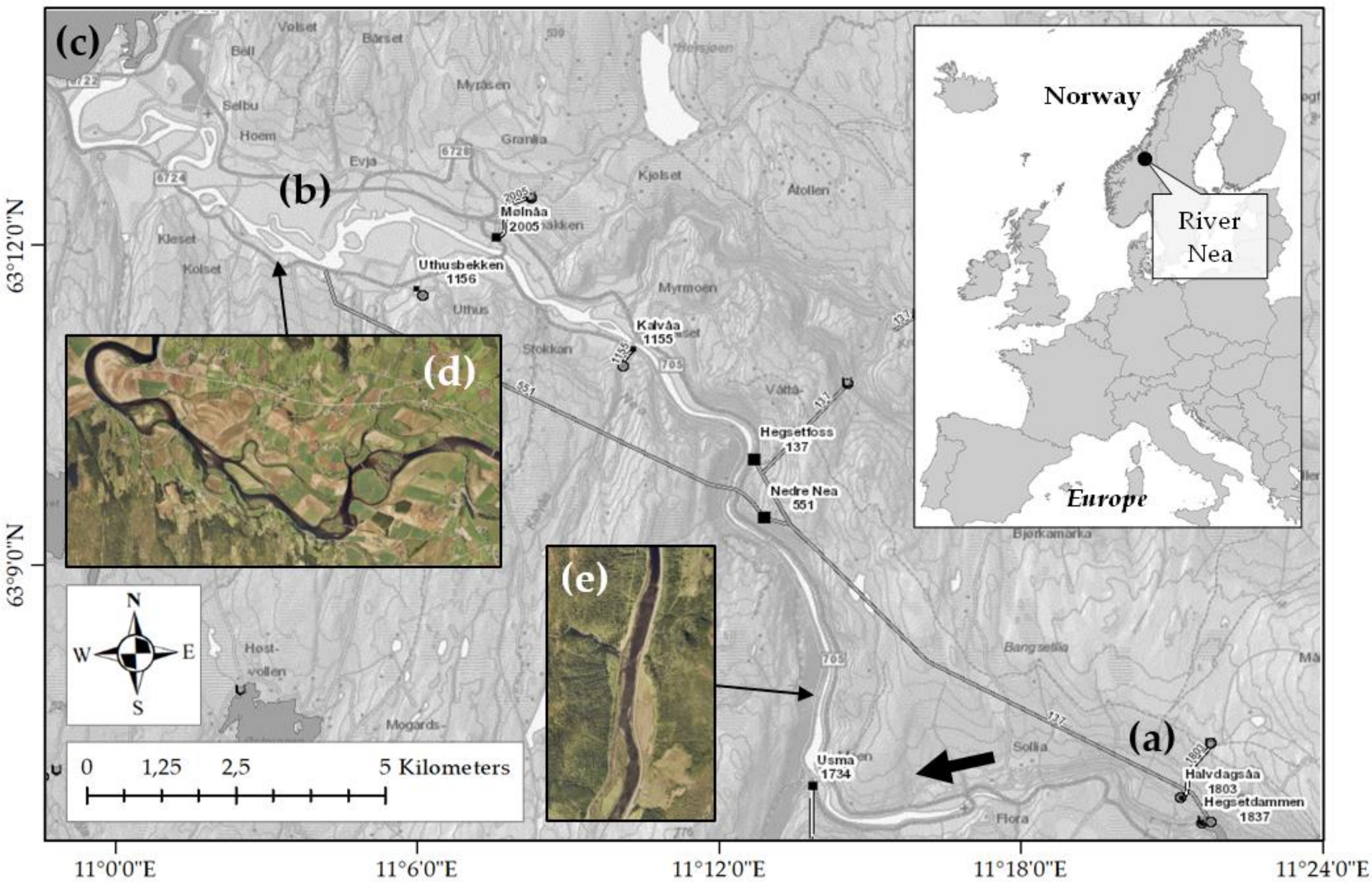

Figure 1. Nea River outline (main picture, in white) in Central Norway (upper-left picture), where (**a**) is the upstream part of the bypass section/dam location, (**b**) is the downstream part of the bypass section/hydropower plant outlet, and (**c**) is lake Selbusjøen. The surrounding landscape is dominated by floodplain agriculture in the lower parts (**d**) and a steep valley in the upper part (**e**). The thick, black arrow indicates flow direction. Straight lines are water transfer tunnels and outlined names are hydropower plants. © Kartverket, Geovekst.

The Nea River is part of the Nidelv catchment (3118.4 km^2), which originates in Sweden and runs into a fjord close to the city of Trondheim. The total length of the river is 176.9 km. The study reach is 30.0 km with a steep valley landscape in the upper part (Figure 1e) and a river delta landscape with floodplains dominated by agriculture in the lower part (Figure 1d). In the upper part of the study reach, the river is 20–200 m wide with depths ranging up to 3 m during normal flows. In the lower part, the river width is in the range of 50–230 m with depths up to 6 m close to the outlet into lake Selbusjøen. Most sections are within the 1–2 m depth range. The study reach is mainly dominated by gravel, with sections of larger rocks in the upper part and sand in the lower part. Due to the minimum flow release (i.e., 1.5 m^3/s during summer, no flow release during winter), the flow regime is dominated by inflow from tributaries. During a normal year of precipitation, the average flows in the upper and lower parts of the study reach are 5.3 and 18.9 m^3/s, respectively. The corresponding flows before regulation for hydropower was implemented were 67.8 and 75.4 m^3/s, respectively.

2.2. Method Outline

The visual simulation of the environmental measures and survey of public preferences was done in a structured way, building on earlier experiences in previous studies [10,30,35]. Figure 2 gives an overview of the methodology we used for the assessment of visual preferences in this case study, and which we propose as a standardized procedure for such assessments in the future. It included initial site selection and scenarios of environmental measures, hydraulic modeling, the visualization of environmental scenarios during different flows, and finally the public preference survey. The procedure is further described in the following chapters.

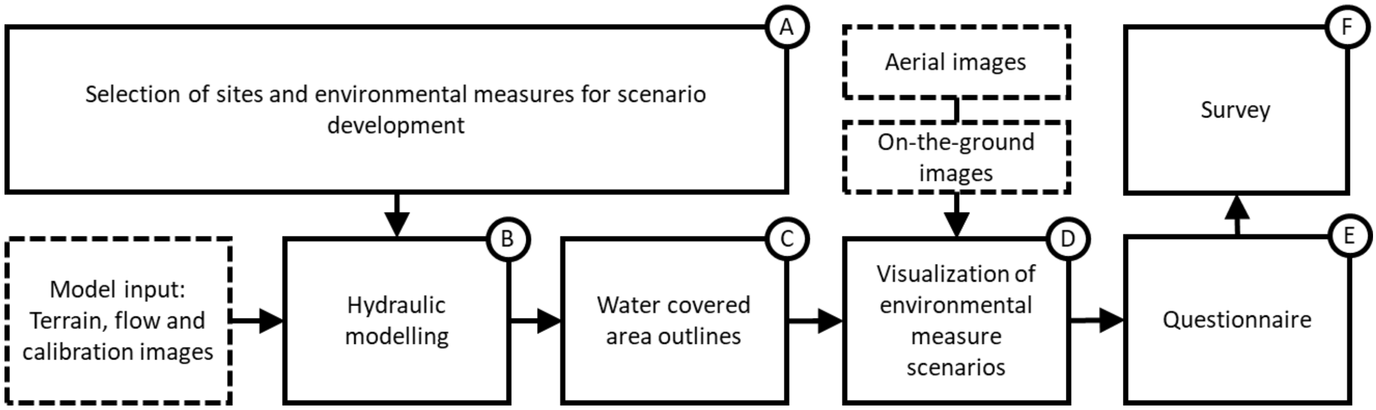

Figure 2. Method outline. (**A**) Selection of sites and environmental measures for scenario development, (**B**) hydraulic modeling of the scenario-based water-covered area, (**C**) outlines of the water-covered area in different environmental measures scenarios, (**D**) visualization of scenario images based on outlines and two sets of image acquisition types, and (**E**) the resulting questionnaires with weir scenario images as an input for (**F**) the survey.

2.3. Selection of Sites and Environmental Measures for Scenario Development

The selection of representative sites for visual simulation of measures in the study area was based on two criteria: (1) its relevance for recreational activities and (2) its bathymetric coverage obtained during the green LIDAR scanning process.

The first site-selection criterion was based on a qualitative pre-study, in which we had located where along the river the different types of use and recreational activities occurred. The different types of recreational use were each represented by one weir, resulting in the choice of weir no. 1 (named "Bogstadhølen"), no. 7 (named "Hyttbakken Bridge"), and no. 22 (near the Lower Nea power station). The separate locations of the three weirs are shown on the map for the study area in Figure 3.

Figure 3. Site selection for the preference study. Weirs no. 1, 7, and 22 (outlined in orange) were selected to be visualized in environmental measure scenarios. Original images of the weirs are shown from the on-the-ground perspective © Sweco 2015.

The second site-selection criterion was based on riverbed point measurement density during the pre-study green LIDAR data collection. To adequately simulate the water-covered area on different flows during the hydraulic modeling, riverbed coverage needed to exceed a certain density threshold (>1 points/m^2 on average in the area surrounding the weir and close to the riverbanks).

The choice of specific mitigation measures to be visualized in our study was based on the following sources:

(1) A pre-study assessment report by Sweco [36] that proposed a series of potential structural mitigation measures at the weirs in the Nea River.

(2) Expert opinion discussions by an interdisciplinary project group of research scientists active in the HydroCen national research center, including hydraulic engineers, fish ecologists, and a social scientist. This group of experts inspected the weirs in the Nea River during a joint visit in June 2019, discussed the measures proposed by Sweco in 2015, and drafted an adjusted set of measures coherent with new insights and experiences from research and practice, e.g., Pulg et al. [12].

(3) Flow conditions: We used the minimum summer flow of 1.5 m^3/s as a basis in the upstream part of the study area. In addition, we added a flow scenario of 3.0 m^3/s as a realistic requirement after an upcoming revision of concession terms [37]. The flows were used as an input for the hydraulic assessment.

(4) A qualitative pre-study of recreational use in the area as reported in [3], where the addition of recreational infrastructure on the riverbank near the weirs as a potential mitigation measure related to local visual preferences was identified.

Based on these sources we set up a draft of weir adjustments, relevant flow quantity, and recreational infrastructure. The two most relevant factors when deciding upon the shape of weir adjustments were fish migration (more specifically for brown trout, *Salmo Trutta* L.) and hydraulic stability across the weirs for different flows. For brown trout, the channel had to be shaped to facilitate possible upstream and downstream migration. This included inserting larger rocks just upstream of the entry point to the deepest channel across the weir to avoid too high velocities through the channel at higher flows. To provide hydraulic stability, the deeper channel was supplied with an adjacent shallow channel on one side. During higher flows, the water would thus fill the shallow channel in addition to the deep channel, allowing for a reduction in hydraulic stress on the entry point of the adjustment area, and a possible alternative migration route for brown trout.

Based on the project group discussion and drafts, each weir had three configurations to be simulated and visualized: original weir, adjusted weir, and full removal. For the original weir and the full removal configurations, two scenarios were added (based on [3]): (1) no recreational infrastructure and (2) added recreational infrastructure. The added infrastructure included a walking path, an information plate, boards and benches, and a campfire. The adjusted weir configuration consisted of two separate types of adjustments: (1) a lowering of the midsection and a deep channel across the weir and (2) a riffle-pool-type adjustment with cell-shaped, partly overlapping pools with a riffle structure in the overlapping sections. The first adjustment type was simulated in weirs no. 1 and 7, while the second adjustment type was simulated in weir no. 22. The adjusted weir configuration had no added recreational infrastructure during the visualization. During the subsequent hydraulic simulation all scenarios were run on (1) a typical mid-summer low flow specific to the location of the weir (i.e., 1.5 m^3/s at weirs 7 and 22; 3.0 m^3/s at weir 1), and (2) a doubled low flow rate (3.0. m^3/s at weirs 7 and 22; 6.0 m^3/s at weir 1). Table 1 summarizes the measures related to weir configuration and adjustments, simulated flows, and recreational infrastructure visualized in the single scenarios.

Table 1. Environmental measures visualized in the different scenarios in this study.

No.	Weir Configuration	Simulated Weir Adjustment	Simulated Flow in Weirs no. 1/7/22 (m3/s)	Recreational Infrastructure Added to Image
1	Original form	None	3.0/1.5/1.5	None
2	Original form	None	3.0/1.5/1.5	Walking path, information plate, boards and benches, and campfire
3	Adjusted	Weirs 1 and 7: lowering of midsection and deep channel Weir 22: cell-shaped, partly overlapping pools across weir	3.0/1.5/1.5	None
4	Removed	Removal	3.0/1.5/1.5	None
5	Removed	Removal	6.0/3.0/3.0	None
6	Removed	Removal	3.0/1.5/1.5	Walking path, information plate, boards and benches, and campfire

2.4. Hydraulic Modeling of Environmental Measure Scenarios

The Nea River was scanned with an airplane-mounted green LIDAR in 2018 and 2019. A green LIDAR scans the terrain using several light beams in the visible and near-visible spectrum, where the green light can penetrate a water surface. The scan returns a three-dimensional local point cloud, with each point's position defined in x-, y-, and z-coordinates. Fixed ground points with global coordinates are used to georeference the LIDAR point cloud. During scanning, the light in the beam is reflected off the surface of the terrain and returned to the LIDAR lens. In the LIDAR, the time of return and signal footprint are captured and determine the position and type of surface the light beam has hit. In post-processing, the surface points are then classified into different types of terrain.

The overall results from the scans of the Nea River were poor to adequate in areas with depths less than 1.0 m, while deeper areas were missing in the riverbed classification. Most areas of interest for the current study were in the shallow parts of the river. We used high-definition aerial images and local depth knowledge to estimate the height of the riverbed in the deeper parts of the river. The aerial images were downloaded from www.norgeibilder.no, accessed 1 June 2019. We used the riverbed classified points in the LIDAR dataset and supplied with manual adjustment using polygons and -lines with defined bed levels in the deeper sections of the river to set up a base raster terrain file using natural neighbor interpolation in ArcGIS [38].

We used Hec-RAS (HEC-RAS 5.0.7., https://www.hec.usace.army.mil/software/hec-ras, accessed on 1 June 2019) for modeling. Hec-RAS is a river analysis system that allows for one- and two-dimensional calculations of river hydraulics. We used the green LIDAR and polygon/-line interpolated raster terrain file as a basis for a 2D hydraulic model. The model was calibrated by adjusting the Manning's n value to match the water-covered area in the model to the observed water-covered area in high-definition aerial images during two different flows. The Manning's n value represents the riverbed roughness. No gauging stations were available in the sections of interest of the river. A minimum flow release from the upstream dam amounts to 1.5 m^3/s in the period from May through September. We estimated the calibration flows based on the minimum flow release from the dam and local knowledge of hydrology in the main river as well as the tributaries downstream of the dam. Local measurements of depth and velocity were conducted using a SonTek M9 RiverSurveyor [39]. Calculations of observed versus simulated depth resulted in a mean error of 0.20 m and a root mean square error (RMSE) of 0.21 m. For the velocity the corresponding values were -0.18 m/s and 0.22 m/s. RMSE was calculated as the square root of the mean of the squares of the deviations for 120 points in the study reach.

The three weirs were tested for changes in the water-covered area as a function of weir adjustment and removal. Each of the three weirs had three configurations in the hydraulic simulations: (1) original form, (2) adjusted form (excavated channel across the weir or interconnected cell-shaped pools across the weir, Figure 4), and (3) fully removed. Shape adjustments to the weirs were done using the original LIDAR point cloud with added break lines and bed elevation polygons as terrain restrictions. These restrictions were included in the interpolation process to obtain new terrain rasters with the added weir adjustments.

2.5. Creating Water-Covered Area Outline Maps

Hydraulic simulations were run at flows of 1.5, 3, and 6 m^3/s for all three weirs. The resulting water-covered areas in each of the weir river sections were exported as polygons from the hydraulic model into ArcGIS. For each weir, the three weir-state polygons (i.e., original, adjusted, and removed) were displayed as outlines in the same image. The process was repeated for the most relevant flows. Figure 5 shows weir no. 1 for all three configurations during a flow of 6 m^3/s.

2.6. Visualization of Environmental Measure Scenarios

2.6.1. Taking Baseline Photographs

To establish the baseline photos for our scenario simulation we took photos of the original weirs on a day with low flow conditions in June 2019, using a Canon SX70HS camera. The two locations for photo capture were:

A. From an on-the-ground perspective, standing on the banks of the river, ca. 50 m below the weir, and looking up the river (see also Figure 6);
B. From an aerial perspective, using a drone flying 10 m above the ground, and ca. 50 m below the weir (see also Figure 7).

Figure 4. Polygons for weir adjustment in weirs no. 1 (**a**), 22 (**b**), and 7 (**c**). For (**a**,**c**), the cross-hatched, thickly outlined polygons represent a 2 m deep and wide channel across the weir, while the thin-lined polygons represent a minor lowering of the weir level, gradually increasing towards the deep channel. White-outlined black dots indicate the placement of rocks for hydraulic disruption at the entry point to the deep channel. For weir 22 in picture (**b**) the cross-hatched, thickly outlined polygons represent gradually lowered cell pools. The thick white arrow indicates flow direction.

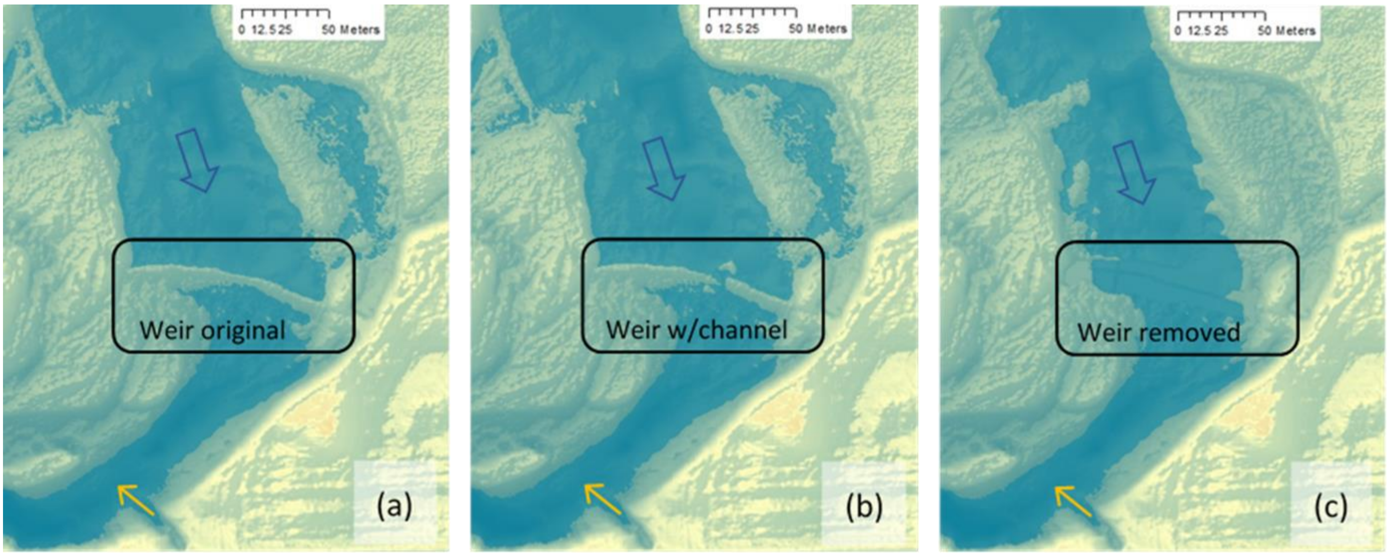

Figure 5. Water-covered area for weir no. 1 with the following configurations: (**a**) original form, (**b**) with a channel across, and (**c**) fully removed. The simulated flow is 6 m^3/s. The blue arrow shows the flow direction. The yellow arrow indicates the location of the hydropower plant outlet and thus the end of the bypass section.

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

Figure 6. Visual scenario example from the questionnaire with the complementary answer scale. The scenario represents the on-the-ground-perspective with the weir removed at weir no. 22 (visual scenario: Rolseth Foto).

Figure 7. The same scenario as shown in Figure 6 from an aerial perspective (visual scenario: Rolseth Foto).

The weather and light conditions were constant for all three weirs. Flow was measured onsite at the same time as taking the photos resulting in the low flow quantities used in this study (1.5 m^3/s for weirs 7 and 22 in the upstream part of the study area, and 3 m^3/s for weir 1 in the downstream part of the study area).

2.6.2. Visualizing Water-Covered Area, Changes in Weirs, and Recreational Infrastructure

The baseline photos were manipulated with Adobe Photoshop [40] to show the selected environmental measures listed in Table 1 and using the water-covered area outline maps. The manipulation was done in an iterative process by a photo manipulation expert (K. Rolseth at Rolseth Foto), an expert on hydro-morphology and fish ladders (H. P. Fjeldstad), and an expert on recreational use (B. Junker-Köhler). Photographic material of recreational infrastructure and existing weirs in other rivers (e.g., cell-shaped weirs in river Mandalselva and river Numedalslågen) were also used to aid photo manipulation to visualize the different scenarios.

2.7. Setting Up the Questionnaire and Conducting the Survey

We designed a questionnaire that started with a short introduction stating the intention of our study. To assess the visual preferences of the respondents for the different scenarios we asked "To what degree do you like what you see on the following pictures? Mark the value on the scales that fits you best. −3 = I don't like it at all, and +3 = I like it very much. Please give an answer to each single one of the pictures." We then showed the different visual scenarios per weir location, one after another, each with its own respective answer scale to receive the respondents' ratings for all of them. Figure 6 shows an example of one of the visual scenarios for weir no. 22 with the weir removed, from an on-the-ground perspective, and the answer scale.

All scenarios were developed both from an on-the-ground perspective as well as from an aerial perspective from 10 m above ground.

Figure 7 shows the corresponding aerial scenario to the scenario depicted in Figure 6.

For the specific purpose of this study, which was to compare preferences for on-the-ground vs. aerial perspectives, we assembled two questionnaires. One contained the entire series of scenarios with the on-the-ground perspective and the other one was identical except for the aerial perspective. We sent questionnaires with scenarios based on these two different perspectives alternately to the potential respondents on our address list.

In order to receive quantitative information on the recreational use of the Nea River by the local inhabitants, we further asked our respondents to answer the following question: "Have you participated in any of the following activities in or along Nea in the last 12 months?", followed by a list of recreational activities that we found to be relevant in a qualitative pre-study in the case study area, and an additional item with an open category to give room for indicating any additional activities. Using the two versions of our questionnaire, we conducted a representative postal survey of the local public in the Selbu and Tydal municipalities, located along the Nea River in our case area.

We sent the printed questionnaire together with a pre-paid return envelope to all households within the Selbu and Tydal municipalities that were located directly adjacent to the Nea River in November 2019. A reminder to those that had not answered yet was sent in January 2020.

2.8. Characteristics of the Survey Respondents

From the postal survey in the two municipalities of the case study area (Selbu and Tydal), we received 526 valid responses. That corresponded to a relatively high response rate of 35.7%. Male respondents prevailed over female respondents, and older age groups prevailed significantly over younger ones. About two-thirds of the respondents grew up in the case study municipalities, and about two-thirds reported that their domicile overlooks the Nea River. Most of the respondents reported that the Nea River was of large importance to them (Table 2). This corresponds with the share of the respondents having conducted one or several recreational activities in or along the Nea River during the previous 12 months. The activities walking and staying along the river, observing plants and animals, and biking along the river were the most favored.

Table 2. Socio-cultural characteristics of survey respondents.

Socio-Cultural Variables	Classification	Sample Proportion (%)
Gender	Female	26.4
	Male	73.6
Age	16–39	9.9
	40–59	38.0
	60+	52.1
Grown up in the case study municipalities	Yes	60.3
	No	30.4
	Partially	9.3
Domicile overlooking Nea River	Yes	35.6
	No	64.4
Importance of the Nea River	Low importance	4.7
	Middle importance	25.4
	High importance	69.9
Recreational activity (during the last 12 months)	Fishing	31.7
	Bathing	31.0
	Canoeing	13.9
	Walking along the river	65.0
	Staying at the river (relaxing, picnic, campfire, etc.)	49.8
	Biking along the river	38.0
	Observing animals and plants	44.1
	Ice skating	3.4
	Other	5.2

3. Results

3.1. Water-Covered Area Outlines from Hydraulic Model

Simulation results from the hydraulic models show that weir adjustment scenarios in all three river sections will alter the water-covered areas minimally, while full removal of the weirs will result in a larger reduction in the water-covered area. The main changes in the water-covered area due to weir adjustment will appear near the proposed channels or cell-shaped pools through the weirs. Figure 8 shows the water-covered area outlines for the three weirs for all configurations at a simulated flow of 1.5 m^3/s.

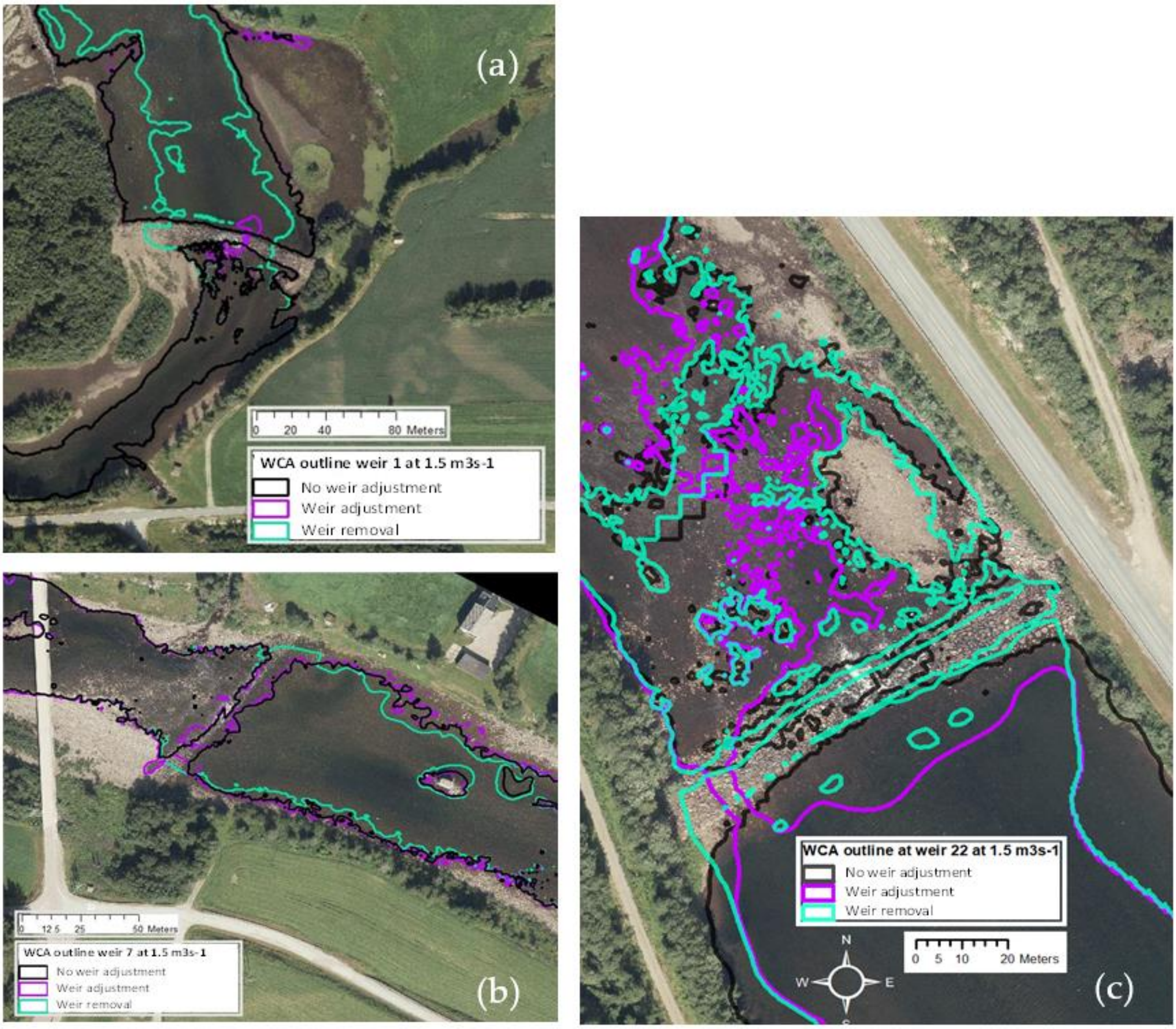

Figure 8. Results on water-covered area outline at (**a**) weir 1, (**b**) weir 7, and (**c**) weir 22 at a simulated flow of 1.5 m^3/s. The outline colors of black, purple, and light green represent original weir, adjusted weir, and removed weir, respectively.

While adjusted weirs resulted in minor visual changes of the water-covered area during low flows when compared to the original weirs, full weir removal reduced the water-covered area significantly during low flow. By doubling the simulated flow with weirs removed, the effect of removal on the water-covered area was reduced. An example of the effect of weir adjustment and removal on the water-covered area for weir no. 1 at flows 3 and 6 m^3/s is given in Figure 9.

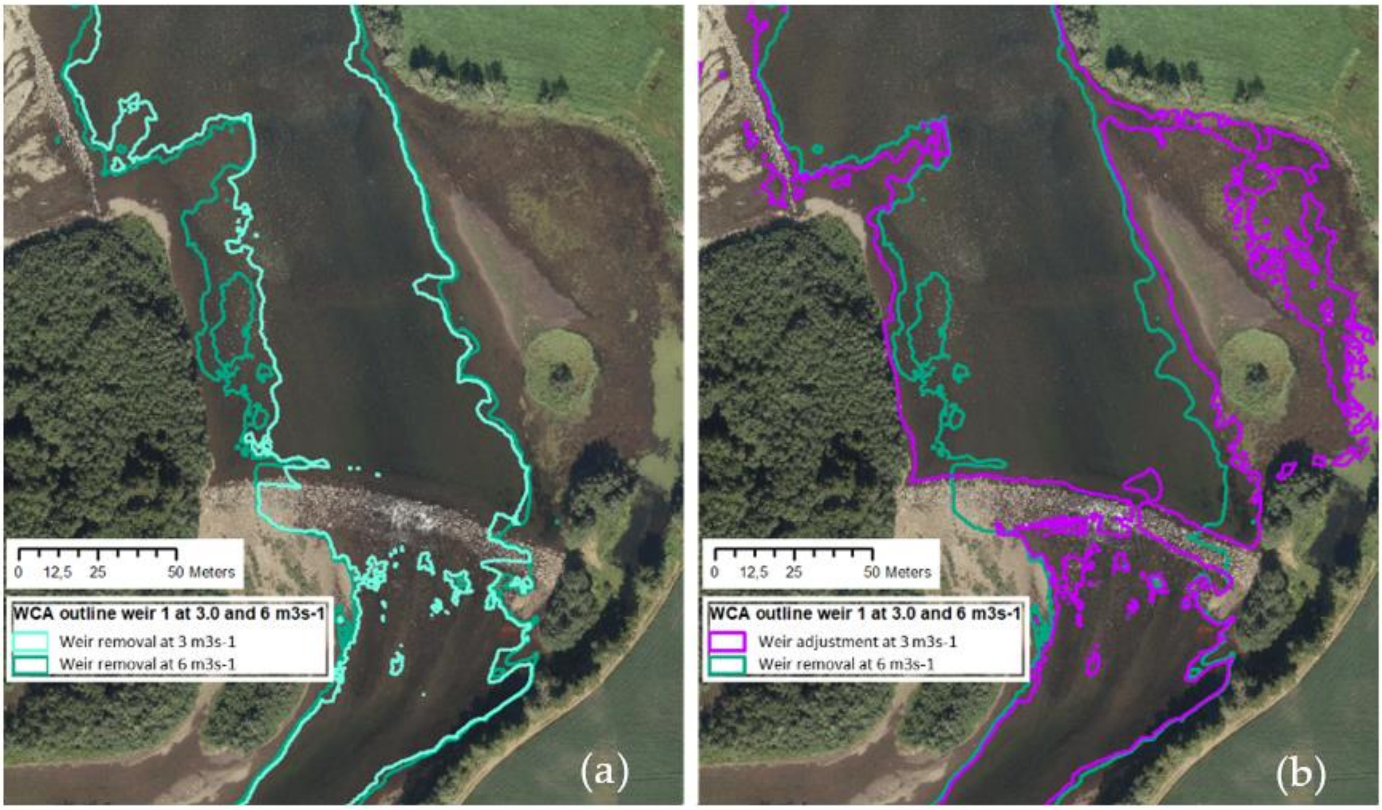

Figure 9. Example of the effect of weir adjustment and removal on the water-covered area for weir no. 1 at flows 3 and 6 m^3/s. (**a**) WCA outline for full weir removal simulated at flows of 3 m^3/s (light green) and 6 m^3/s (dark green). (**b**) WCA outline for weir adjustment at 3 m^3/s (purple) and weir removal at 6 m^3/s (dark green). As shown in (**b**), doubling the flow to 6 m^3/s with weir removal compensates for a large proportion of the WCA for weir adjustment at a flow of 3 m^3/s.

3.2. Visual Scenarios

Following the structured procedure described in the method section, we arrived at the 18 visual scenarios shown in Table 3 and used them in our questionnaire to elicit the preferences of the survey respondents.

3.3. Visual Preferences for On-the-Ground versus Aerial Scenarios

Figures 10–12 show the mean values for respondents' visual preferences for the different mitigation measures related to weirs, minimal flow, and recreation infrastructure for the three sites. We found significant differences in mean values between visual scenarios with on-the-ground versus aerial perspectives for all measures (1–6) at weirs 1 and 7. This was not entirely the case for weir 22, where we could not detect significant differences between the two different perspectives for three of the six measures (1, 3, and 4). An important finding was that visual scenarios from an on-the-ground perspective were generally rated higher than those from an aerial perspective. The only exception is the rating for measure 3 at weir 1 (where the mean value for the aerial perspective is higher than the one for its on-the-ground counterpart, Figure 10).

Table 3. Visual scenarios of environmental measures.

Location Perspective \ Mitigation Measures	Existing Weir, Low Flow	Existing Weir, Low Flow Recreational Infrastructure	Weir Adjusted Low Flow	Weir Removed Low Flow	Weir Removed Doubled Low Flow	Weir Removed Low Flow Recreational Infrastructure
Weir 1 On-the-ground						
Aerial						
Weir 7 On-the-ground						
Aerial						
Weir 22 On-the-ground						
Aerial						

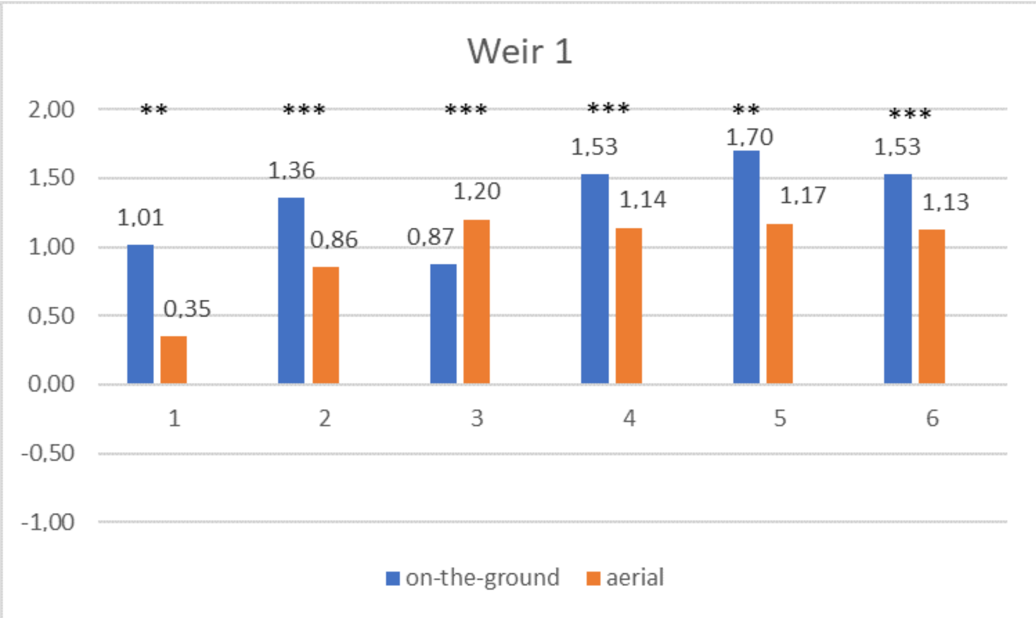

Figure 10. Mean values for preference ratings for pairs of scenarios developed from on-the-ground and aerial perspectives for weir 1 at Bogstadhølen. Differences between mean values are indicated at the respective significance levels: ***, $p \leq 0.001$; **, $p \leq 0.01$; and *, $p \leq 0.05$.

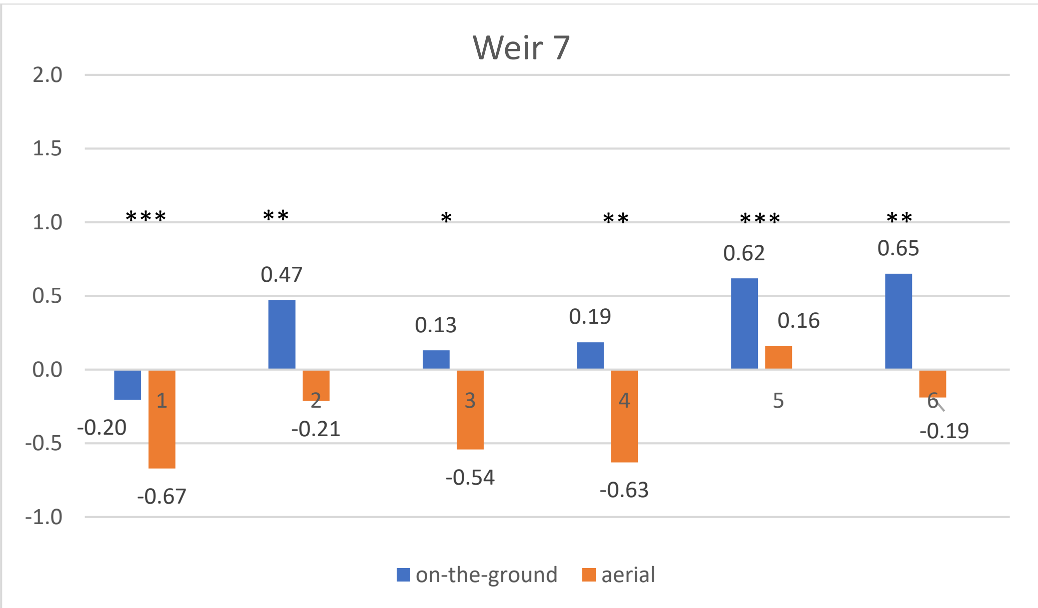

Figure 11. Mean values for preference ratings for pairs of scenarios developed from on-the-ground and aerial perspectives for weir 7 near the Hyttbakken bridge. Differences between mean values are indicated at the respective significance levels: ***, $p \leq 0.001$; **, $p \leq 0.01$; and *, $p \leq 0.05$.

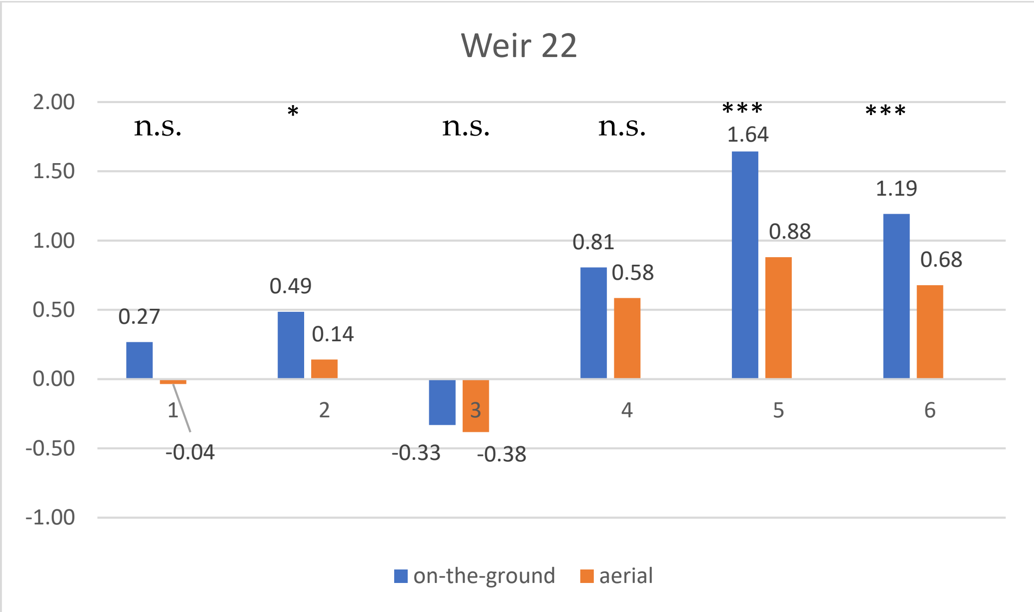

Figure 12. Mean values for preference ratings for pairs of scenarios developed from on-the-ground and aerial perspectives for weir 22 near the Lower Nea power station. Differences between mean values are indicated at the respective significance levels: ***, $p \leq 0{,}001$; **, $p \leq 0{,}01$; and *, $p \leq 0{,}05$. n.s. = not significant.

Table 4 shows the order of mean preference ratings among the measures at the single sites. The numbered scenarios in the final column correspond to those given in Table 1. We can observe large differences in the orders between on-the-ground and aerial perspectives for weirs 1 and 7. This is not the case for weir 22, where the order is the same for both perspectives.

Table 4. Order of mean values of the preference ratings for the single sites. The numbered scenarios in the final column correspond to those given in Table 1.

Weir No.	Perspective	Descending Order of Preference Ratings for Single Scenarios (Scenario No.)
1	On-the-ground Aerial	5–4/6–2–1–3 3–5–4–6–2–1
7	On-the-ground Aerial	6–5–2–4–3–1 5–6–2–3–4–1
22	On-the-ground Aerial	5–6–4–2–1–3 5–6–4–2–1–3

4. Discussion

The purpose of our study was twofold. Based on this and our previous work we intended (1) to establish a standardized procedure for the visualization of mitigation measure scenarios. Additionally, (2) we aimed to test the hypothesis that visual preferences for such scenarios are related to perspective (on-the-ground versus aerial perspectives).

4.1. A standardized Procedure for Visualization of Mitigation Measures

To our knowledge there are no studies that have outlined a detailed procedure for designing visual scenarios of environmental mitigation measures in rivers regulated for hydropower production to be used in public preference assessments. Visual assessment studies of the scenic beauty of rivers and riverscapes do not commonly lay much focus on describing in detail how the depicted scenarios were developed. That is an aspect that the standardized procedure we propose aims to amend. Regarding a structured selection of variables and environmental measures depicted in the survey, however, we were inspired by several aesthetic preferences studies using visualized scenarios that are explicit about this issue [10,35,41].

While model simulation visualization of hydrological and hydrodynamic responses of alternative flow regimes have been central in environmental design projects, the transfer from model simulation visuals to photorealistic scenarios has not been extensively tested. By using hydraulic model output as an input for the photo manipulation of alternative scenarios, we were able to consolidate a realistic flow-to-water-covered area to be used as a baseline for the scenarios. Our model results also indicated during which flows the adjustment and potential removal of weirs would be less protruding in terms of the reduced water-covered area visible to the public. The visualization of environmental measure scenarios that we propose here has the advantage that all resulting visual images show the same rate of light and shadow since they are based on the same base photo. This is a known disadvantage of surveys, with photos showing, for example, different flows of a river section, yet with a differing light/shadow rate [42].

We consider it useful to propose a questionnaire design as described in Chapter 2.7 as a standard for future assessments to ease the preparation and to make assessment results comparable between different rivers. As, for example, the overview by LeLay et al. [21] of previous river- and waterscape perception studies shows, there is a multitude of answer scales that could potentially be employed. After ample consideration we suggest a seven-point answer scale to allow for enough data resolution, but at the same time sufficient lucidity for the respondents.

What is the minimum input of data necessary for our proposed method to work? A certain amount of bathymetric and topographical data must be available for setting up a river model and simulating the flow/water-covered area relationship. As our study included the adjustment or removal of weirs, these hydraulic structures needed to be adequately covered by topographical points. We used a combination of LIDAR data covering the weirs and riverbank areas and manually inserted breakpoints and -lines in the deeper parts mid-river. We did not test the sensitivity of the added breakpoints and -lines in the simulation results. As the LIDAR data were collected at very low flows, we assumed the areas covered by LIDAR to adequately represent the bathymetry and topography of the weirs and riverbank areas.

In terms of the selection of sites for scenario development, an overview of the recreational use of the respective river stretch is highly beneficial, and a qualitative or quantitative pre-study, as in our case, should be taken into consideration. If this is not a feasible option, an effort should be made to gain information, for example, from local community managers or other persons with longstanding knowledge of the locality.

In our study, the three specific weirs that we visualized were selected based on a pre-study in the case area at the Nea River [3]. As there are more than 30 weirs along the bypass reach downstream of the dam, results are thus limited to the selected weirs only. Still, the three weirs with their respective combinations of environmental measures resulted in a total of 18 visual scenarios to be judged and assessed in the public survey. A higher number of scenarios would most likely have provided an exhaustive exercise for the participants of the survey, potentially reducing the number of respondents. This is a commonly occurring methodological trade-off in visual aesthetic preference surveys that requires sensitive judgement for each case context.

For the visual manipulation of the scenarios, it is otherwise highly relevant to also gain other photo material than the baseline photos from the respective river stretch, showing, for example, larger rocks and gravel. As these have a specific appearance in all locations, a realistic visualization of areas where reduced flow uncovers the underlaying river structure is dependent on such visual baseline material.

4.2. On-the-Ground versus Aerial View

The results of our study did not confirm our hypothesis that the public visual preference that there are no significant differences between public visual preferences for scenarios with an on-the-ground perspective and scenarios with an aerial perspective. We found instead statistically significant differences between the mean values of visual preference ratings for most of the visual scenario pairs (i.e. on-the-ground versus aerial view scenarios) for two of the three weirs (Figures 10–12). Our results also show, clearly, that scenarios from an on-the-ground perspective are then also rated distinctly higher than aerial view scenarios. That there is a difference in the visual preference ratings for the two perspectives was confirmed by comparing the ranking order of the respective visual scenarios per weir for the two different perspectives (Table 4). These findings indicate that visual scenarios from an aerial perspective cannot be taken as surrogates for scenarios from an on-the-ground perspective—i.e., the point-of-view location that is commonly used until now.

However, the results for the third weir in our study—weir 22—appear different. Discussing the possible reasons for this might be interesting for our comparison of the interchangeability of the two perspectives. Weir 22 is located at the upper section of the Nea River case study area where the state road to Sweden runs directly along the river, granting car drivers and cyclists an elevated view over the river, substantially above the on-the-ground perspective, yet still below an aerial view (in this study from a 10 m height). Figures 6 and 7 give an impression of this. Apart from some recreational anglers, the main share of the population has this elevated view of the river. This might be a reason for the less pronounced differences in mean visual preference ratings (see Figure 12) as well as the congruence in the order ranking for weir 22 (see Table 4). This might imply then that it would be most accurate to choose the most common user perspective for visual preference elicitation. Following this line of thought, one could then also argue that an on-the-ground perspective would be the more accurate and valid one for river sections where user activities with an on-the-ground point of view are the most common, such as for the other two weirs (1 and 7) in our study [3].

The comparison between visual preferences based on the two different perspectives was a special objective for this study. In our view, it would not be recommendable to develop visual scenarios based on both perspectives in parallel—as was done here—in future assessments. However, we think that this study gives an indication that an ample examination should be given of the most common view that recreational users in the respective river sections would have in order to choose the "right one" before starting to design visual scenarios for a preference assessment. To confirm these interpretations, more studies will be needed.

We did not find that the photo manipulation of aerial perspective scenarios was more difficult than of on-the-ground view scenarios, or vice versa. Given the availability of a drone with a mounted photo camera there is thus a large specter of technical possibilities to gain appropriate base photos in relation to the local context.

4.3. Weir Adjustment and Modeling

The Nea River is a relatively wide and mostly shallow river, especially after the establishment of hydropower regulation, where most areas are affected by the withdrawal of water for production. Areas just downstream of many of the weirs are hydraulically complex during lower flows due to course substrate occasionally obtruding the water surface. This hydraulic complexity is indicated in the water-covered areas shown for weir 22 in Figure 8c. At higher flows (i.e., >10 m^3/s) the complexity diminished as the weirs become less of a hindrance for flows.

We used two different weir adjustment strategies: deep/shallow channel combination and partly overlapping cell pools. The former strategy is adapted to low-head weirs with relatively limited width across, while the latter is better suited for wider, high-head weirs.

In our study, we defined weirs no. 1 and 7 as low-head while weir no. 22 was defined as high-head (i.e., upstream/downstream water level difference during low flows > 2 m).

Although the weir configuration scenarios were based on expert knowledge within the project group, we used a simplified setup for the weir adjustments. As the main goal of the hydraulic simulations was to create water-covered area outlines for photo manipulation, as opposed to creating weir adjustments specifically for fish migration, we did not consider factors such as optimal bed roughness or flow-related water velocity and depth for the weir adjustment scenarios. A detailed overview of relevant factors for weir adjustment and removal can be found in Pulg et al. [12] and Fjeldstad et al. [29].

While we used the publicly available model software Hec-Ras for creating the flow/water-covered area relationship, other model tools may also be applied. The possible biggest bottleneck for successful modeling of mitigation measures at different flows is the density of the bathymetric/topographical data. While we had access to a dense LIDAR point cloud, other sources of riverbed elevation such as differential GPS and boat-mounted ADCPs could potentially provide an adequate dataset to be used as an input for the hydraulic modeling.

In our view, the procedure that we describe here could be used as a standardized method for developing visual simulation scenarios of environmental measures for the mitigation of negative effects due to hydropower production in rivers. It could potentially ease the design of surveys and preference assessments in future studies and practical preference assessments, as, for example, in the large number of upcoming revisions of older hydropower concessions. A more standardized design would also improve the comparability of results and thus the state of the art of visual preferences of the public for mitigation measures and riverscapes. While we assessed the adjustment and removal of weirs specifically in our study, other mitigation measures could be modeled and provided as an input for photo manipulation. Examples may include dam removal, fish migration barrier adjustment, and de-channelization.

As our experience shows, it is important to develop such visual scenario assessments in a multi-disciplinary team. While the standardized procedure we propose here aims to make the design more efficient and easier, it still requires relatively specific expertise for a successful implementation, in terms of hydraulic modeling, hydro-morphology, fish ecology, photo manipulation, and social science.

5. Conclusions

Assessing local public preferences for decisions regarding the management of near-by river spaces is increasingly demanded and desired. Visual stimuli play an important role. To our knowledge, there has been no previous study that establishes and describes a detailed procedure for designing visual scenarios of environmental mitigation measures in rivers regulated for hydropower production to be used in public preference assessments. Neither have there been studies testing the comparability of the traditional on-the-ground and the modern aerial perspectives in visual assessments. Therefore, we consider our study novel in these two ways.

The methodological framework or procedure that we have outlined here consists of the following steps: (A) selection of sites and environmental measures for scenario development, (B) hydraulic modeling of the scenario-based water-covered area, (C) outlines of the water-covered area in different environmental measures scenarios, (D) and the visualization of scenario images based on outlines and photo image acquisition, (E) resulting in questionnaires with weir scenario images as an input for (F) the survey. The detailed information given in regard to these single steps together with the results of the comparison of using on-the-ground versus aerial perspectives can be a steppingstone to a standardized procedure for future visual preference assessments.

We expect this procedure to gain an increasing relevance in the public administration of watercourses with hydropower production in the years to come. It might also be beneficial for hydropower companies in their attempt to gain local acceptance and to avoid conflicts when planning new hydropower infrastructure or in the revision process of existing concession terms. However, we acknowledge that further elaboration and standardization of this procedure requires additional testing and implementation, together with proper documentation in future studies to make it robustly applicable in different contexts.

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References

1. Abazaj, J.; Moen, Ø.; Ruud, A. Striking the Balance between Renewable Energy Generation and Water Status Protection: Hydropower in the context of the European Renewable Energy Directive and Water Framework Directive. *Environ. Policy Gov.* **2016**, *26*, 409–421. [CrossRef]
2. Forseth, T.; Harby, A. Handbook for Environmental Design in Regulated Salmon Rivers. 2014. NINA Special Report 53. 90 pp. Available online: www.nina.no/archive/nina/PppBasePdf/temahefte/052.pdf (accessed on 6 October 2021).
3. Skår, M.; Köhler, B. Rekreasjonsinteresser i Utvidet Miljødesign: Demovassdrag Nea. 2019. HydroCen report No. 9. Available online: www.ntnu.no/documents/1269211504/1279317385/Rapport_Nea_Nr9.pdf/62254e43-fc23-460e-aac6-cec929a2283e (accessed on 6 October 2021).
4. Whittaker, D.; Shelby, B. Flows and Aesthetics: A Guide to Concepts and Methods. 2017. National Park Service, Hydropower Assistance Program, Hydropower Reform Coalition, Confluence Research and Consulting, Oregon State University. Available online: https://hydroreform.org/wp-content/uploads/2020/05/Flows-and-aesthetics-A-guide-to-concepts-and-methods-2017_Final_web.pdf (accessed on 6 October 2021).
5. Mayeda, A.; Boyd, A. Factors influencing public perceptions of hydropower projects: A systematic literature review. *Renew. Sustain. Energy Rev.* **2020**, *121*, 109713. [CrossRef]
6. Venus, T.E.; Hinzmann, M.; Bakken, T.H.; Gerdes, H.; Godinho, F.N.; Hansen, B.; Pinheiro, A.; Sauer, J. The public's perception of run-of-the-river hydropower across Europe. *Energy Policy* **2020**, *140*, 111422. [CrossRef]
7. Hostmann, M.; Buchecker, M.; Ejderyan, O.; Geiser, U.; Junker, B.; Schweizer, S.; Truffer, B.; Zaugg Stern, M. *Collective Planning of Hydraulic Engineering Projects. Manual for Participation and Decision Support in Hydraulic Engineering Projects*; Eawag: Dübendorf, Switzerland; WSL: Santa Monica, CA, USA; LCH-EPFL: Lausanne, Switzerland; VAW-ETHZ: Zurich, Switzerland, 2005; p. 8. [CrossRef]
8. Feichtinger, J.; Pregernig, M. Beyond Mandated Participation: Dealing with hydropower in the context of the water framework directive. *Environ. Policy Gov.* **2016**, *26*, 351–365. [CrossRef]
9. Newig, J.; Koontz, T. Multi-level governance, policy implementation and participation: The EU's mandated participatory planning approach to implementing environmental policy. *J. Eur. Public Policy* **2013**, *21*, 248–267. [CrossRef]
10. Barton, D.N.; Sundt, H.; Adeva-Bustos, A.; Fjeldstad, H.-P.; Hedger, R.; Forseth, T.; Köhler, B.; Aas, Ø.; Alfredsen, K.; Madsen, A.L. Multi-criteria decision analysis in Bayesian networks - Diagnosing ecosystem service trade-offs in a hydropower regulated river. *Environ. Model. Softw.* **2020**, *124*, 104604. [CrossRef]

11. Sundt-Hansen, L.; Alfredsen, K.; Bongaard, T.; Fossøy, F.; Arnesen Hagen, I.J.; Harby, A.; Köhler, B.; Majaneva, M.A.; Sivertsgård, R.; Skoglund, H.; et al. Utvidet Miljødesign i Demovassdrag Nea. 2021. HydroCen report No.19. Available online: https://www.ntnu.edu/hydrocen/hydrocen-report (accessed on 6 October 2021).
12. Pulg, U.; Barlaup, B.; Skoglund, H.; Velle, G.; Gabrielsen, S.; Stranzl, S.; Espedal, E.; Lehmann, G.; Wiers, T.; Skår, B.; et al. Tiltakshåndbok for Bedre Fysisk Vannmiljø. God Praksis ved Miljøforbedrende Tiltak i Elver og Bekker. 2017. Uni Research Miljø. Report 296. Available online: https://www.miljodirektoratet.no/globalassets/publikasjoner/m1051/m1051.pdf (accessed on 6 October 2021).
13. Harby, A.; Adeva Bustos, A.; Szabo, M. Good International Practice for Mitigating Hydropower Impacts on Aquatic Ecosystems Himalayan Aquatic Biodiversity and Hydropower: Review and Recommendations. SINTEF Energy Research Report. 2020. Available online: https://sintef.brage.unit.no/sintef-xmlui/bitstream/handle/11250/2753952/2020-01331.pdf?sequence=2&isAllowed=y (accessed on 6 October 2021).
14. Hetherington, J.; Daniel, T.C.; Brown, T.C. Is motion more important than it sounds? The medium of presentation in environment perception research. *J. Environ. Psychol.* **1993**, *13*, 283–291. [CrossRef]
15. Le Lay, Y.-F. L'évaluation environnementale du bois en rivière par les gestionnaires des cours d'eau français. *Geocarrefour* **2006**, *81*, 265–275. [CrossRef]
16. Pflüger, Y.; Rackham, A.; Larned, S. The aesthetic value of river flows: An assessment of flow preferences for large and small rivers. *Landsc. Urban Plan.* **2010**, *95*, 68–78. [CrossRef]
17. Meitner, M.J. Scenic beauty of river views in the Grand Canyon: Relating perceptual judgments to locations. *Landsc. Urban Plan.* **2004**, *68*, 3–13. [CrossRef]
18. Lange, E. 99 volumes later: We can visualise. Now what? *Landsc. Urban Plan.* **2011**, *100*, 403–406. [CrossRef]
19. Gobster, P.H.; Ribe, R.G.; Palmer, J.F. Themes and trends in visual assessment research: Introduction to the Landscape and Urban Planning special collection on the visual assessment of landscapes. *Landsc. Urban Plan.* **2019**, *191*, 103635. [CrossRef]
20. Daniel, T.C. Aesthetic preference and ecological sustainability. In *Forests and Landscapes: Linking Ecology, Sustainability and Aesthetics*; CABI: Wallingford, UK, 2009; pp. 15–29.
21. Le Lay, Y.-F.; Cottet, M.; Piégay, H.; Rivière-Honegger, A. Ground Imagery and Environmental Perception: Using Pho-to-Questionnaires to Evaluate River Management Strategies. In *Fluvial Remote Sensing for Science and Management*; Carbonneau, P.E., Piegay, H., Eds.; Wiley-Blackwell: Hoboken, NJ, USA, 2012; pp. 405–429.
22. Grill, G.; Lehner, B.; Thieme, M.; Geenen, B.; Tickner, D.; Antonelli, F.; Babu, S.; Borrelli, P.; Cheng, L.; Crochetiere, H.; et al. Mapping the world's free-flowing rivers. *Nature* **2019**, *569*, 215–221. [CrossRef] [PubMed]
23. Jones, J.; Borger, L.; Tummers, J.; Jones, P.; Lucas, M.; Kerr, J.; Kemp, P.; Bizzi, S.; Consuegra, S.; Marcello, L.; et al. A comprehensive assessment of stream fragmentation in Great Britain. *Sci. Total. Environ.* **2019**, *673*, 756–762. [CrossRef] [PubMed]
24. Winter, H.V.; Van Densen, W.L.T. Assessing the opportunities for upstream migration of non-salmonid fishes in the weir-regulated River Vecht. *Fish. Manag. Ecol.* **2001**, *8*, 513–532. [CrossRef]
25. Poff, N.L.; Hart, D.D. How Dams Vary and Why it Matters for the Emerging Science of Dam Removal. *Bioscience* **2002**, *52*, 659–668. [CrossRef]
26. Atkinson, S.; Bruen, M.; Sullivan, J.J.O.; Turner, J.N.; Ball, B.; Carlsson, J.; Bullock, C.; Casserly, C.; Kelly-Quinn, M. An inspection-based assessment of obstacles to salmon, trout, eel and lamprey migration and river channel connectivity in Ireland. *Sci. Total. Environ.* **2020**, *719*, 137215. [CrossRef]
27. Koster, W.M.; Dawson, D.R.; Kitchingman, A.; Moloney, P.D.; Hale, R. Habitat use, movement and activity of two large-bodied native riverine fishes in a regulated lowland weir pool. *J. Fish Biol.* **2020**, *96*, 782–794. [CrossRef]
28. Branco, P.; Segurado, P.; Santos, J.M.; Ferreira, T. Prioritizing barrier removal to improve functional connectivity of rivers. *J. Appl. Ecol.* **2014**, *51*, 1197–1206. [CrossRef]
29. Fjeldstad, H.-P.; Pulg, U.; Forseth, T. Safe two-way migration for salmonids and eel past hydropower structures in Europe: A review and recommendations for best-practice solutions. *Mar. Freshw. Res.* **2018**, *69*, 1834–1847. [CrossRef]
30. Fjeldstad, H.-P.; Barlaup, B.T.; Stickler, M.; Gabrielsen, S.-E.; Alfredsen, K. Removal of weirs and the influence on physical habitat for salmonids in a Norwegian river. *River Res. Appl.* **2012**, *28*, 753–763. [CrossRef]
31. Mouton, A.M.; Schneider, M.; Depestele, J.; Goethals, P.L.; De Pauw, N. Fish habitat modelling as a tool for river management. *Ecol. Eng.* **2007**, *29*, 305–315. [CrossRef]
32. Tang, L.; Mo, K.; Zhang, J.; Wang, J.; Chen, Q.; He, S.; Zhu, C.; Lin, Y. Removing tributary low-head dams can compensate for fish habitat losses in dammed rivers. *J. Hydrol.* **2021**, *598*, 126204. [CrossRef]
33. Im, D.; Kang, H.; Kim, K.-H.; Choi, S.-U. Changes of river morphology and physical fish habitat following weir removal. *Ecol. Eng.* **2011**, *37*, 883–892. [CrossRef]
34. Adeva-Bustos, A.; Alfredsen, K.; Fjeldstad, H.-P.; Ottosson, K. Ecohydraulic Modelling to Support Fish Habitat Restoration Measures. *Sustainability* **2019**, *11*, 1500. [CrossRef]
35. Junker, B.; Buchecker, M. Aesthetic preferences versus ecological objectives in river restorations. *Landsc. Urban Plan.* **2008**, *85*, 141–154. [CrossRef]
36. Haug Bjølstad, O.K.; Angell-Petersen, S.; Skatvold, B.R.; Bergan, P.I.; Storfor, M. *Plan for Biotoptiltak i Nea på Strekningen Bogstadhølen til Gresslidammen, 2015–2017*; Oversikt og visualiseringer av tiltak. Sweco Report; Sweco Norge AS: Stockholm, Switzerland, 2015.

37. NVE. Vannkraftkonsesjoner Som Kan Revideres Innen 2022. Nasjonal Gjennomgang og Forslag til Prioritering. NVE Report 49/2013. 2013. Available online: https://www.miljodirektoratet.no/globalassets/publikasjoner/m49/m49.pdf (accessed on 6 October 2021).
38. Esri Inc. 2020. ArcGIS Desktop (Version 10.8). Esri Inc.. Available online: https://www.esri.com/en-us/home (accessed on 6 October 2021).
39. Sontek. RIVERSURVEYOR®S5 AND M9. 2021. Available online: www.sontek.com/riversurveyor-s5-m9 (accessed on 6 October 2021).
40. Adobe 2021, Photoshop. Available online: https://www.photoshop.com (accessed on 6 October 2021).
41. Hunziker, M.; Michel, A.H.; Buchecker, M. Landschaftsveränderung durch Erneuerbare Energien aus der Sicht der Bevölkerung. Forum für Wissen 2014, Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Birmensdorf. 2014, 43–49. Available online: https://www.researchgate.net/publication/274057357 (accessed on 6 October 2021).
42. Brown, T.C.; Daniel, T.C. Landscape Aesthetics of Riparian Environments: Relationship of Flow Quantity to Scenic Quality Along a Wild and Scenic River. *Water Resour. Res.* **1991**, *27*, 1787–1795. [CrossRef]