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How Important for Society Is Recreation Provided by Multi-Purpose Water Reservoirs? Welfare Analysis of the Vltava River Reservoir System

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Abstract: Contrary to the other functions of multi-purpose reservoirs, recreational use is not associated with a tangible social value, which hinders the search for new balances among optimal uses of water that will likely be needed under climate change. The objective of this study is to analyze visitation behavior and its patterns at a large-scale reservoir system on the Vltava River to quantify the total social benefits associated with recreation in monetary terms and to suggest how the magnitude of estimated recreation welfare relates to hydro-energy benefits, which are in usual practice taken much more into account than recreation in the strategic management of water dams. The elicited average consumer surplus per person and trip is EUR 55.7, which yields a total yearly recreation value of EUR 34 billion (ranging between 22 and 57). When compared to, e.g., the social value of hydro-energy generation, the actual yearly recreation welfare represents 1/3 of this nowadays more prioritized use. The results of the study bring new information for water management bodies that has been missing up to now, and they bring new arguments for reaching socially optimal water use in the strategic and operational management of the cascade of dams. From this perspective, the actual strategic relative prioritization of these two reservoir functions at the pilot site may be viewed as rational.

Keywords: recreation; water reservoir system; non-market valuation; economic assessment; travel cost method (TCM)

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1. Introduction

The optimal use of water resources by humankind and the allocation of this scarce resource among highly competing water uses and different water use sectors has always been a vital strategic issue. During recent decades, this issue has become even more relevant considering the increasing uncertainty related to climate change and other pressures. Multi-purpose water reservoirs have been frequently analyzed from the perspective of their contribution to flood protection, the supply of water to municipalities, agriculture, and industry, and also to hydropower generation. These water uses have received much attention in academic research [1–4]. Biophysical models and economic data on the social benefits related to these functions are typically relatively available to researchers and water managers. Only very limited attention has been paid to other water dam purposes and effects such as recreation [2,5], health impacts related to water quantity and quality, [6] or the contribution to environmental quality, e.g., through sediment evacuation [7]. These water reservoir functions represent ecosystem services that are not traded or directly related to the market but are free to enjoy and therefore more difficult to assess and their estimates are less available [5]. Due to the lack of evidence on these benefits, water management decisions usually stem from an incomplete view of distribution of societal welfare provided by the water reservoir across various purposes and users.

Despite being mentioned as relevant for most multi-purpose water reservoirs, quantification of recreational function is usually not covered in studies and applications conducted all over the world. In Europe, these studies include reservoir water management optimization research [8] and individual multi-user models that optimize the reservoir releases with respect to time and volume objectives of various users and help identify a robust reservoir operation policy [1–3,7–10] and also cost–benefit analyses and real option analyses [11] on particular water-related investment projects [4,12]. If entering the optimization models, the various aspects of recreation use are simplified into a constraint of a minimum water flow that is necessary for the navigability of boats [2,13].

The evidence on non-market recreation values of freshwater ecosystems is far from non-existing, but the quantities of value estimates in the literature are very low compared to terrestrial ecosystems [14,15]. Among the value estimates related to water, only a negligible fraction are values of the recreation ecosystem service of water reservoirs, dams, or lakes. Several studies that estimate how much a water body is worth to its visitors have been carried out in the USA [5,16,17]. In Europe, most of the existing valuation research has provided less complex results. A variety of valuation studies have focused on particular water-based activities such as swimming trips [18,19], bathing or swimming [20], white-water kayaking [21], boating trips [22], and recreational and sport fishing [23,24]. Mostly due to the unavailability of data on visitation loads, these values have been frequently expressed per one recreationist, and they were not further aggregated into the total value of the lake. The results rarely represent the preferences and recreation values of the whole visitor population, including other recreation uses.

Very valuable are the studies [20,25] that have focused on the recreation value of a wider set of water ecosystems in European countries and also study [26] which statistically compared various benefits related to lakes estimated by valuation studies all over the world. These studies suggest that despite the growing knowledge on values of particular sites, there is still no consensus on how the recreation values differ across water ecosystem types, water-related recreation activities, or geographical regions. Due to the high variability of the focus of the existing research as indicated above, it is quite problematic to statistically distinguish the magnitude of values of particular water uses—i.e., to tell whether recreation benefits are larger/similar/smaller than other benefits, for example flood protection. The same holds for identifying the differences of recreation values across recreation activities [26]. The value estimates from North America are significantly higher than those from the rest of the world (including Europe), and the magnitude of the water body is positively related to its value [26]. In most cases, the differences between recreation values estimated by particular studies are caused by the different methodology across studies, not so much by dissimilarities in water ecosystem characteristics [27], which is true also for terrestrial ecosystems [28–30]. As it is rather common in methodologically similar meta-analytic works of non-market values of ecosystems, none of the studies yet [20,25,26] have offered a more detailed insight into the factors affecting the recreation values of reservoirs or lakes. That could be carried out, e.g., by using interaction terms in modelling equations, but it is likely that the datasets are not rich enough to accommodate these additional variables. The existing evidence on the recreation values of water bodies is therefore still far from being sufficiently complete. It could not be used for reliable value transfers from already analyzed sites to other sites [29] with reasonably low transfer errors [27]. This is also the case, however, for other ecosystems that are much more frequently analyzed [28,29,31].

The research gap described above is in sharp contrast to the expected challenges related to climate change in the future that may force the water management authority to continually search for new balances among socially optimal uses of water. Practically all the climate adaptation and mitigation measures, which the water management authority may be forced to apply in the future, are likely to affect recreationists and tourism business in the area.

Aims of the Study

With the aim of enhancing the discussion on the role of recreation benefits in the optimization of water uses and the economic welfare analyses of multi-purpose water reservoirs, this study analyzes the beneficiaries of water-based recreation and quantifies the recreational value of a large-scale reservoir system on the Vltava River across all types of water-based activities in physical and monetary terms. The resulting total recreation welfare of the area is then compared to the benefits from hydro-energy generation, which represents one of the water reservoir purposes that has been frequently quantified in research studies and is already quite routinely used to guide the water policy and management of the multi-purpose water bodies.

The study demonstrates a complex approach that follows after applying a non-market valuation technique so that the results can be mainstreamed into water management. Figure 1 visualizes the subsequent steps of the study.

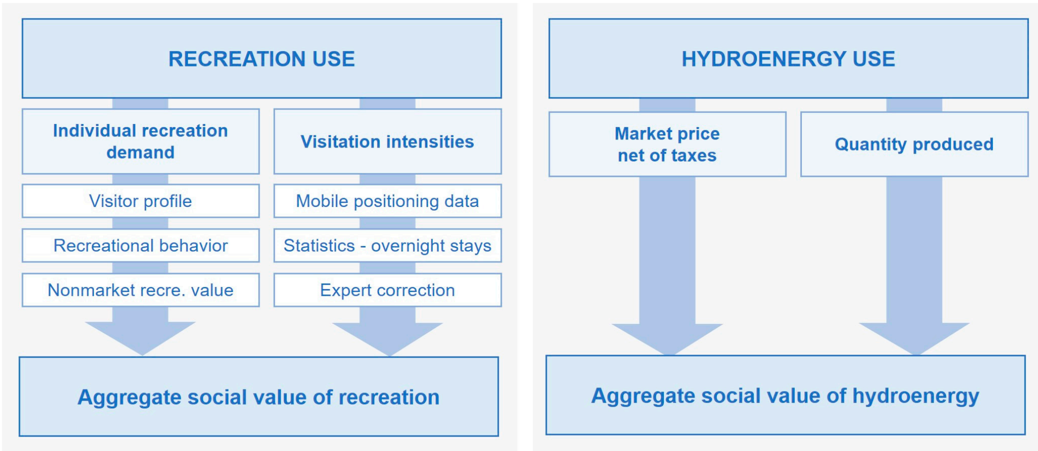

Figure 1. Flowchart of subsequent steps of the study.

2. Materials and Methods

2.1. Study Area

We tested the approach at the pilot area of the Vltava River, the longest river in the Czech Republic (430 km), and its cascade of dams. The Vltava River cascade consists of a system of nine artificial water dams that were built on Vltava River between the years 1930 and 1991. The cascade provides a multitude of functions to society: in addition to electricity production, water provision, flow regulation and flood defense, and it is perhaps the most important water-related recreation site in the country. The recreation function of this area has not been analyzed so far in any study, neither the biophysical indicator (visitation loads) nor the economic counterpart (recreation welfare) describing this ecosystem service. The existing biophysical data cover only part of the recreationists in the area: no. of guests at collective accommodation establishments (hotels, camps, etc.) are published by the Czech Statistical Office, and the no. of boats navigated through lock chambers are collected by Povodí Vltavy, a state enterprise. Both data sources suggest that the visitation pressure on the pilot area increases over time.

The pilot area is characterized by a variety of recreation uses, the particular composition of which locally differs. Traditionally, the area has been very popular for open-space recreation activities linked to water ecosystems, including bathing, swimming, fishing, adrenaline water sports, sailing in motorized boats and yachts, and hiking or biking along the river. Vltava is also popular for secondary housing which has a long tradition in the country—cottages and also houseboats are quite common in the pilot area. Most important for recreation are the largest dams Orlík (the largest hydraulic structure in the Czech Republic, 68 km long, with a water surface of 26 km^2, a storage capacity of 720 million m^3, and long-term average discharge of 83.5 m^3/s) and Slapy (44 km length, 14 square km, with a storage capacity 270 million m^3 and long-term average discharge of 84.7 m^3/s). The five other dams in the area are much smaller (3 to 21 million cubic meters of storage capacity).

The water dams and Vltava watercourse are owned by the state and are administered, managed, and maintained by the state enterprise Povodí Vltavy. Water prone areas are owned and managed by a variety of stakeholders, including private properties that operate the majority of the tourism-related services in the area, as well as municipalities and other public owners of land. Most of the river prone areas are freely accessible; sometimes a fee has to be paid to access a camp or a maintained beach. At some stretches along the river, the access to the riverbank is complicated due to the terrain morphology. Visitation loads are distributed quite unevenly. While the reservoirs (especially Lipno and Orlík) have been historically very popular particularly for summer recreation, river stretches further away from the dams on the downstream side are typically hardly frequented by visitors.

We look specifically at the patterns of water-based recreation in the middle and lower reaches of the cascade that cover the navigable part of the river (see Figure 2). The pilot area stretches 172 km from the Vraný dam (67th river kilometer) to the city of České Budějovice (239th river kilometer) and includes 7 dams. In this area, 59 municipalities (local administrative units—LAU in NUTS classification) are directly adjacent to the river. A total of 74 municipalities are located within a convenient walking distance (1 km) from the riverbank. In total, these LAUs cover the area of 1239 sq. km, and the area is populated by 53,000 inhabitants.

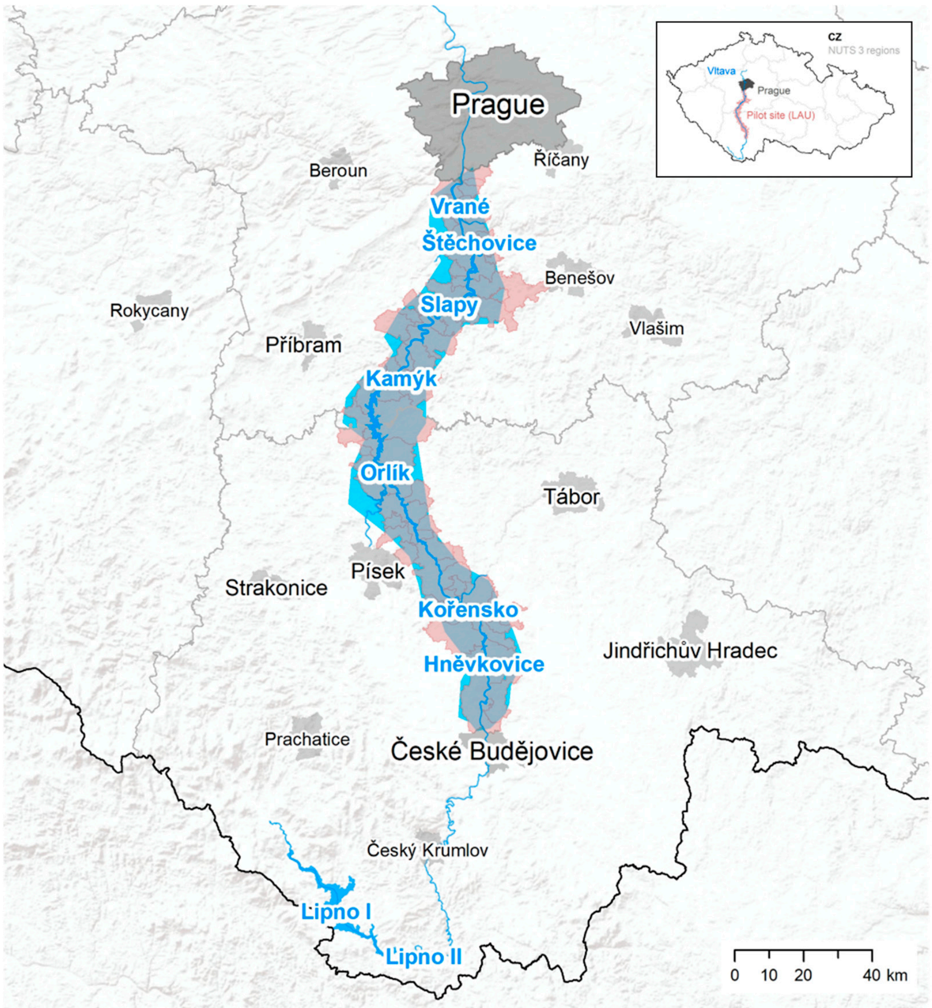

Figure 2. The Vltava River cascade and its dams and towns >10,000 inhabitants in the vicinity; pilot area definition (LAUs) and its location within the Czech Republic (inset). Borders of NUTS3 regions are shown in grey; CZ borders are shown in black. Sources: The Czech Office for Surveying, Mapping and Cadastre; T. G. Masaryk Water Research Institute; background map: Esri; USGS; NOAA.

2.2. Survey Method and Data Collection

An on-site survey of visitors was conducted to collect data on recreation behavior and preferences. The research and sampling design were administered by the Charles University Environment Centre; the data collection was administered by the professional market research agency Ipsos, s. r. o. The target population were Czech adult recreationists (aged 18+). The survey took place in August and September 2020 to cover the main (summer) recreation season and the low season. The recreationists reported on their actual visit to the pilot site and on their past recreation behavior during the last 12 months. To acquire a representative sample of visitors, a multistage quota sampling method was used. The sampling sites were chosen based on an expert evaluation of several site characteristics. The final set of sites represents areas with various levels of recreation use (high/low) and various mixes of recreation activities available and includes areas frequented by visitors with potentially different sociodemographic profiles (areas popular with inhabitants of the capital city Prague/areas characterized by visits from regional towns and the surrounding countryside).

All of the six sampling sites are located along the two largest reservoirs (Orlík and Slapy). These reservoirs are the main representants of a complete range of water-related recreation activities available at all dams in the pilot area and account for 100 river kilometers (60% of the river length in the pilot area). Within these areas, randomly chosen spots adjacent to water within a respective sampling site (beach, path, food truck or picknick area, fishing spot, marina and anchorage grounds, camping site, etc.) were chosen each day. A stratified random sampling of respondents was applied (sampling without replacement, max. 1 person from the visitor group surveyed). The respondents were approached using tablet-assisted personal interviewing (TAPI). The average time to complete the questionnaire was 13 min. Out of 543 administered surveys, a total of 460 visitors successfully completed the questionnaire survey (yielding a response rate of 85%).

2.3. Modelling Approach

The study employs a travel cost model to estimate the recreation demand for water-related activities at the pilot site [32,33]. The travel cost method has been applied successfully several times in the Czech Republic in the context of outdoor recreation not related to water ecosystems [30,34–36]; several travel cost studies worldwide have focused on water recreation activities at water bodies and dams, e.g., [5]. The analysis focuses on modelling the preferences of visitors that affect visitation of the pilot site using the recreation demand function. The demand function is further used to estimate the non-market value of recreation (recreation welfare associated with access to the pilot site accruing to visitors) in monetary units.

Specifically, an individual single site model is estimated. It is a multiple regression model that captures the relationship between visitation (measured by the number of visits by a given recreationist over a specified period of time) and the shadow price of the visits (valued by the direct cost of a trip to a recreation site and the opportunity cost of time spent travelling to the site and back home). Other demand-shifting variables that allow to control for differences in recreationists' preferences included in the multiple regression model typically encompass characteristics of the current or usual visit (trip duration distinguished usually by a 1-day trip and an overnight trip, recreation activity, travelling party size or other characteristics describing the group of visitors, type of accommodation, availability or shadow price of a substitute recreation site, etc.), socio-demographic characteristics of the visitor (gender, age, education, income, etc.), and potentially also technical variables to control for differences among particular survey sites, interviewers, or time periods of data collection [37]. The general model can be written as follows (Equation (1)):

$$y_i = x_i\beta = \beta_0 + \beta_{TC}(TC_i) + \sum_{j=1}^{m} \beta_j(TRIP_{ij}) + \sum_{g=1}^{n} \beta_g(SOCDEM_{ig}) + \sum_{h=1}^{p} \beta_h(TECH_{ih}) + \varepsilon_i \quad (1)$$

where y_i is the real number of trips realized by the visitor i, *TC* is the travel cost, *TRIP* are the trip-related variables, *SOCDEM* are the socio-demographic characteristics of the visitor, *TECH* are variables related to other technical issues, β represents the parameters of the model to be estimated, and ε is the error term.

In deriving the travel cost (*TC*), i.e., the shadow price of spending time at the recreational area, the following cost categories must be considered: direct travel expenditures (both ways, either with or without considering vehicle depreciation including parking fees), entry fees to beaches and fees for renting equipment (e.g., paddleboards), and the opportunity cost of the time spent travelling [21,33]. Other types of expenditure related to recreation experience that are not directly related to reaching the destination are typically not accounted for. Either due to their potential endogeneity or being an inseparable part of the recreational experience (opportunity cost of time spent at the site and the cost related to accommodation), due to non-conformity with economic welfare theory (the cost of food and drinks would have to be covered even under the status quo—if the recreation trip was not made and the respondent stayed at home), or due to problematic assignment of fixed costs to the particular one trip in question (cost related to acquisition of long-term recreational equipment and assets including boats). In addition, only trips motivated by the visit to the recreational area in question fully conform to the recreation welfare theory [38]. Four visitors who indicated that their only motive for visiting the pilot area was to visit friends or relatives or to work were not used in the recreation demand analysis, as their travel cost incurred to reach the site was not related to water recreation.

Nearly 90% of respondents travelled to the site by car or motorcycle, 10% travelled by public transport (bus, train, ferry, or boat), and three visitors reached the site on foot or by bicycle. The distance and duration of the trip was estimated based on a calculation provided by the Google Maps Distance Matrix API based on the recommended route between the start and end points indicated by the respondents in the survey, using the respective transport means (car/motorbike, walking, or cycling). For public transport, the duration of the ride and ticket prices were adjusted according to the Seznam.cz timetable (second fastest Friday afternoon service). For the car/motorbike mode, the travel costs are calculated as the sum of the cost of fuel consumed and the depreciation cost of the vehicle. We omitted two observations due to extreme and in the Czech context rather non-realistic values in the distance travelled (>450 km). Thus, the final sample size for recreation demand modelling consists of 454 out of 460 observations.

The opportunity cost of time was calculated as 1/3 of the average income of a respondent's household member following the usual practice [39], with imputation of missing income values (17% of the sample) based on a regression analysis of the remaining sample that accounted for region, education, and gender.

The value of access to the pilot site for recreation purposes is measured by consumer surplus, i.e., the difference between the recreationist's maximum willingness to pay to conduct the trips to the area (given by the shape of the recreation demand curve) and the shadow price of those recreation trips (travel cost). The recreation welfare therefore captures the 'extra' unpriced benefits or 'net' benefits accruing to recreationists, above the shadow price (travel cost) paid for their recreation trips. The consumer surplus associated with one recreation trip is given by in Equation (2).

$$CS = -1/\beta_{TC} \tag{2}$$

where β_{TC} is the estimated parameter of the travel cost variable.

Descriptive statistics of the set of the trip-related, sociodemographic, and technical variables used for the estimation of the demand model are shown in Table 1.

Table 1. Variables used in the recreation demand model and summary statistics (n = 454).

Variable	Definition	Mean	Median	Std. Dev.
	Characteristics of the visits			
trips	Number of trips to the area in the past year (dependent variable)	8.6	3.0	18.3
TC	Travel cost (in CZK)	590.6	484.2	435.5
substitute	Other Vltava dams visited in the past year (yes = 1/no = 0)	0.41	0	0.49
1daytrip	Duration of visit (1-day trip = 1/overnight trip = 0)	0.28	0	0.45
group_no	Number of people travelling in the recreation group (including children)	14.8	4	33.0
kids	Recreation group includes children (yes = 1/no = 0)	0.62	1	0.49
	Recreational activities during the current visit			
fishing	Fishing from the shore (yes = 1/no = 0)	0.19	0	0.39
swimming	Swimming (yes = 1/no = 0)	0.69	1	0.46
boat_kayak	Non-motorized boating or kayaking (yes = 1/no = 0)	0.13	0	0.33
walk_bike_attr	Walking or cycling or visiting tourist attractions (yes = 1/no = 0)	0.41	0	0.49
adr_sports	Adrenaline sport activities (water ski-ing, jet ski-ing, windsurfing, kiteboarding, etc.) (yes = 1/no = 0)	0.20	0	0.40
camping	Camping (tent, cabin, caravan, etc.) (yes = 1/no = 0)	0.51	1	0.50
houseboat_cruiser	Stay or cruise on a houseboat or a cabin cruiser (yes = 1/no = 0)	0.16	0	0.36
free_accom	Free private accommodation (cottage, houseboat, cabin boat, beneath the stars, etc.) (yes = 1/no = 0)	0.13	0	0.33
	Characteristics of the visitor			
gender	Gender (male = 1/female = 0)	0.55	1	0.50
age	Age in years	42.5	42.0	15.1
high_school	Highest level of education completed: high school with diploma (yes = 1/no = 0)	0.50	1	0.50
uni	Highest level of education completed: university degree (including higher vocational school) (yes = 1/no = 0)	0.21	0	0.41
	Technical variables			
sv_site	Surveyed at the site (Orlík dam = 1/Slapy dam = 0)	0.48	0	0.50

3. Results

3.1. Visitor Profile

The socio-demographic profile of the visitors shows that more than half (54.1%) of respondents were male, and the average age was 42.5 years. The middle age class dominated the visitor distribution, where 24.3% were in the age group of 18–30 years, 37.2% were 31–45 years old, 24.6% were in the age group of 46–60 years, and the remaining 13.9% of respondents were over 60 years of age. The highest level of education achieved by the visitors was for 21.5% a university degree (including higher vocational school), 50.2% reported to have finished high school with a diploma, and 26.1% completed high school without graduating (a diploma). The net monthly household income reported by the average visitor is EUR 2322 (CZK 39,400; all values in this study were converted to EUR using exchange rate adjusted for purchasing power parity published by EUROSTAT and are at the level of the year 2020).

During the past 12 months, the respondents visited the area on average nine times, ranging from 1 (present) visit to 181 visits. For a vast majority of the recreationists (74.6%), this was not their first trip to the respective water dam during this time period, and 40.1% of the respondents also visited another dam in the Vltava River cascade. Among the visitors to each of the dams, the second of the dams surveyed (Slapy—Orlík and Orlík—Slapy) is clearly the most popular, followed by the water dam Lipno (which is located outside the pilot area of this project). The other smaller dams were visited by only 1–6% of the respondents.

In terms of the actual visit to the pilot site, 28.3% of the trips made by the respondents accounted for one-day visits (without spending a night away from home) and 71.7% were overnight stays. The average distance travelled to the pilot site was 88 km, which corresponds to EUR 33.5 in 2020 (CZK 590.6 in 2020) of travel costs paid to travel to and from the recreation site (including the direct cost and the opportunity cost of his/her time spent travelling). The respondents usually engaged in several recreational activities during their actual trip (on average 2.6). Swimming was the most common recreational activity in the sample (68.3%), followed by hiking along the water (40.4%), and using a paddleboard or paddle boat (23.9%). The average visit to the pilot area lasted 11.9 days (16.2 days for an average overnight stay). On average, the longest stays across the recreational activities were recorded by cottagers (22.9 days) and campers (16.6 days). Over the whole analyzed time period (12 months from 2019 to 2020), the holidaymakers spent a total of 32.5 days on average in terms of their visits to the pilot site.

3.2. Recreation Demand for Water-Related Activities

A generalized negative binomial regression model was used to estimate an unbiased recreation demand function fitting the data characteristics [40,41] as is common in similar studies [5,38,42,43]. The approach is given by the specific nature of the visitation data which enter into the recreation demand model as its dependent variable. These are count data with truncation, as only positive integer values are observed and strong overdispersion of visitation data, the variance of which exceeds the conditional mean. In addition, the known problems related to on-site collection (endogenous stratification—i.e., more frequent visitors are more likely to be surveyed; Ibid.) affected the choice of the model.

This model outperforms the standard Poisson and negative binomial estimates that have been also tested but (similarly to other recreation demand studies) were found to overestimate the coefficients of the travel cost variable (which determines the demand slope). The modelling was undertaken using R software, version 4.0.3.

The recreation demand model is presented in Table 2. Three models were estimated to test the robustness of the demand and consumer surplus estimates with respect to the variables included. Model 1 represents the baseline model where the number of visits over the past year is explained only by the shadow price of a visit—travel costs. Model 2 includes variables that were identified as potentially significant predictors based on correlation analysis and univariate analysis of the relationship with the dependent variable. The complete set of all considered predictors (Table 1) is included in Model 3. The data sample for each model is based on 454 observations; all models are estimated omitting highly influential observations identified by Cook's distance.

Table 2. Recreation demand model for the Vltava cascade pilot area (explanatory variable: reported no. of visits during the past 12 months).

Variable	Model 1 (Baseline Model)	Model 2 (Final Model)	Model 3 (Full Set of Variables)
(Intercept)	2.150 ***	1.032 ***	0.185
TC	−0.001 ***	−0.001 ***	−0.001 ***
substitute		0.137	0.176 *
1daytrip			0.604 ***
group_no		−0.005 ***	−0.004 *
kids			0.249 **
fishing		0.538 ***	0.573 ***
swimming		0.216 **	0.211 **
boat_kayak			0.239 *
walk_bike_attr			0.152
adr_sports			−0.157
camping		−0.350 ***	0.079
houseboat_cruiser			−0.193
free_accom		0.472 ***	0.975 ***
gender		0.207 **	0.249 **
age		0.013 ***	0.014 ***
high_school			0.052
uni			0.119
sv_site		0.439 ***	0.529 ***
Model statistics			
No.of observations (*n*)	426	428	427
McFadden's pseudo R^2	0.030	0.095	0.095
AIC	2218.6	2183.4	2184.7
Overdispersion parameter α	0.723 ***	0.586 ***	0.576 ***

Note: Significance: *: α = 0.1, **: α = 0.05, and ***: α = 0.01.

As expected, all models exhibit significant overdispersion of the dependent variable. According to the overall model statistics (pseudo R2 and AIC), Model 2 is the best performing among all these model specifications. Adding further explanatory variables (Model 3) no longer improves the model fit to the data. Model 2 was therefore chosen to interpret the results and estimate the recreational benefits. The resulting pseudo R2 of ca. 10% is not uncommon among comparable analyses of individual recreational demand [5,19]; generally, well-performing cross-sectional data analyses exhibit an R2 of about 20–30% [41]. Several methodologically comparable studies report Log likelihood instead of R2, which cannot be directly compared across studies [21,44] or other less frequent measures of fit.

Travel cost *TC* is a highly statistically significant predictor of visitation in all models, which confirms the downward sloping recreation demand curve that conforms with the economic theory of demand. The effect (the slope of the demand curve) is stable across the models, irrespective of the fact of how many other variables are added to the model (Model 1 to Model 3). A positive sign on the substitute variable would indicate that the other Vltava dams are not substitute sites but in fact complements to recreation at the particular surveyed dam. Still, the effect is very weak—around the edge of 10% statistical significance. The evidence on substitution effects from other studies on water recreation is far from uniform, which reflects the unique geospatial conditions of particular valued sites and their surroundings [29]. Our results conform with the well-known fact that the potential to incorporate the often complex substitution patterns across recreation sites in single site recreation demand models is limited compared to travel cost models that incorporate multiple sites [30,33], which has surprisingly not been yet formally analyzed so far in any meta-analytic valuation study but is apparent, e.g., in study [30].

As expected, one-day recreationists take more trips to the area yearly compared to overnight visitors (Model 3). Interestingly, the most frequent trips to the area are made by overnight visitors who use free accommodation (*free_accom*) at secondary housing of their own or stay at their friends' or relatives' houses—trips of these visitors significantly outnumber even the average number of trips per year made by the one-day visitors (*1daytrip*). The yearly visitation rate of both these visitor categories is significantly higher than that of the overnight visitors in paid accommodation (the omitted baseline category).

The Vltava River cascade is characterized by several different segments of recreationists based on recreational activity, but only some are important demand shifters. Fishermen, followed by recreationists who came for swimming and bathing, are the segments that visit the pilot area most frequently. Campers return least frequently to the pilot area among all recreation activities (part of the reported camping sites are children's camps that are held 1–4 times a year; only adult camp instructors qualified by age were included in the sample). Other recreational activities—e.g., staying or cruising on a houseboat, adrenaline sports, hiking and biking along the water, boating or kayaking, and stays/cruises on a houseboat or cabin cruisers—do not further help shape the demand. When used (Model 3), they do not further add to the explanatory power of the model. For these activities, the trip frequencies vary neither from each other nor from the baseline category of other less frequent recreation activities. Small groups return more frequently than large groups of recreationists (*group_no*).

Inspecting the sociodemographic characteristics, the frequency of recreation visits is associated with age and gender (older people and men are likely to demand more trips to the pilot area) but not with education. We did not incorporate income variables as it has never played any significant role in demand modelling in any of the models tested. The only technical variable (see Equation (1)) using *sv_site* shows that the number of visits of an average respondent in the pilot area of the Vltava cascade was significantly higher for visitors surveyed at the Orlík dam than at the Slapy dam.

3.3. Estimates of the Economic Value of Recreation to Society

Regression estimates from Model 2 were further used to compute the net benefits associated with recreation at the pilot site (consumer surplus). Table 3 summarizes the results for one visit, one person–day spent at the site, and for the whole season (1 year).

Table 3. Recreational benefits of an average visitor associated with a visit to the Vltava cascade in EUR 2020 (CZK 2020).

Recreational Benefit for the Average Visitor (Consumer Surplus) in EUR (CZK)	Mean	95% Confidence Interval (CI)	
		Lower Bound	Upper Bound
One visit	55.7 (982)	45.0 (794)	72.4 (1279)
One-day visit (person–day)	4.9 (86)	4.0 (70)	6.4 (112)
1 year (12 months)	305.6 (5394)	247.2 (4364)	397.7 (7019)

Note: The values were converted from CZK to EUR 2020 using EU HICP and the exchange rate adjusted for purchasing power parity published by EUROSTAT.

The average non-market benefits of a recreation trip to the pilot site of the Vltava River cascade are estimated at EUR 55.7 in 2020 (95% confidence interval, EUR 45 to EUR A72.4). It need not be always valid to directly compare the values across different study sites or studies; moreover, as discussed earlier, no meta-analytic study has explained the central tendencies and the factors affecting the recreation value of water dams/water bodies yet in a plausible scope and detail.

However, the range of the estimates conforms with the few already existing on recreation at water bodies in Europe. The average recreation value of a trip to a blue-space site across Europe (including dams, but more frequently other types of areas such as ponds, rivers, streams, marinas, waterfalls, or sea shores) was estimated at EUR 42.2 (CI EUR 20.9–61.9) per person [20]. The average value of ecosystem services (not limited to recreation) provided by lakes at a global level was assessed at EUR 92.1 to EUR 121.6

and suggests that values associated with European lakes tend to be lower than of those in the USA [26]. A methodologically very similar study estimated the value of a recreation trip to Canton Lake in Oclahoma, USA, at EUR 75.5 (95% CI: EUR 59.7 and EUR 83.8) and reported that the values of lakeside recreation in other previous US studies tend to be rather lower than that. (All values from the original studies were converted to EUR 2020 using EU HICP, resp. the OECD consumer price index and exchange rates adjusted for purchasing power parity published by EUROSTAT.)

3.4. Aggregation of Values

Not many of the valuation studies on the recreation benefits of ecosystems proceed further above per person values and also attempt to aggregate the results over the population of recreationists. Such a task is more complicated for studies based on on-site data such as ours, as reliable information on the no. of unique visitors is very often missing [31]. This limits the use of the results of these valuation studies in practical decision-making and also hampers the use of the estimates in meta-analyses of non-market values and other methods of value transfer [28–30,45]. On the other hand, it is already quite well proven that the precision of data on visitation affects the aggregated recreation values even more than using reliable recreation welfare estimates [28,30,45] and can add much more uncertainty to the population welfare aggregates.

We employed a combination of two sources of data matched with the geographical definition of the pilot area at the Vltava River cascade (see Figure 1).

First, we used geolocation data from mobile operators provided by CE-Traffic and T-Mobile for two months representing the high season and shoulder season. Mobile positioning data are perhaps the most useful of the currently available sources of aggregate visitation data [46,47], as they cover a broad range of visits including one-day trips, enable non-visitors to be filtered (e.g., residents, commuters for work, etc.) and can be provided for a user-defined area. They are however not at all precise—e.g., visitors in secondary housing can be filtered out with residents—and more importantly, it is common all over Europe that the procedure of data management on the side of the data provider includes steps that are treated as business secrets and are not open to scientific debate [47,48] and that tend to be rather costly.

Second, we combined the geolocation data with monthly statistics on overnight stays in collective accommodation establishments provided by the Czech Statistical Office (CSO). These data are available for cadastral units (LAU) and cover overnight trips spent in establishments >5 rooms and >10 beds. We characterize the monthly trend over the whole year (including off-season) using CSO data and further employ the trend for extrapolation of the geolocation data to estimate the yearly visitation.

Three types of trends are calculated for sensitivity analysis. The trend with high seasonality directly stems from CSO data and suggests a significant drop in visitation in the off-season. Two further trends with expert-corrected seasonality are used in order to corrects for the fact that the no. of one-day trips in the off-season e.g., by fishermen and hikers do not decline so much between high season and off-season, while the CSO data (that refer to overnight trips only) would suggest that. The trend with medium seasonality is an expert-corrected trend of CSO by the ratio between the high/shoulder season from mobile data in the shoulder season and CSO+20% in the off-season, and the trend with low seasonality assumes there is still a large no. of one-day visitors even in off-season compared to trend suggested by CSO data (CSO+150% in the off-season). According to these particular extrapolation trends, the estimate of yearly visitation motivated by water recreation activities at the pilot site, the Vltava River cascade, is 5.6, 7.0 and 8.9 million person–days, respectively. A person–day is defined as a day in which the visitors spends at least 2 h in the pilot area (a one day trip or an overnight trip). The pilot area includes seven out of the nine dams in the whole cascade, which actually constitutes a continuous stretch of the river (Figure 1).

The aggregated recreational benefits for all recreationists and the year using the recreation welfare estimate and its 95% confidence interval for one person–day (Table 3) and three types of visitation trend are summarized in Table 4. The estimates range between EUR 28 and 43 million yearly (22 to 57 using the confidence intervals of recreation benefit estimate) and are centered around EUR 34 million.

Table 4. Aggregated recreational benefits for all visitors to the Vltava cascade and year in mil. EUR 2020 (mil. CZK 2020).

Extrapolation Trend/Aggregated Recreational Benefit (Consumer Surplus)	Mean CS	95% Confidence Interval	
		Lower Bound	Upper Bound
High seasonality	28 (489)	22 (395)	36 (636)
Medium seasonality	34 (604)	28 (489)	45 (786)
Low seasonality	43 (767)	35 (620)	57 (998)

Notes: The values were converted from CZK to EUR 2020 using EU HICP and the exchange rate was adjusted for the purchasing power parity published by EUROSTAT.

4. Discussion

4.1. Use of the Results

The Vltava River cascade is quite unique compared to the previously studied water bodies (particular lakes and dams) in several respects. It is a system of dams that have been officially declared as multi-purpose for the uses of society [49] and established as such for several decades. In practice, the prioritization of purposes is indicated by the order in which each purpose is listed in the complex handling regulations of the cascade (Ibid.).

The recreational function is one of the important purposes that the cascade fulfils for society, but the complex handling rules mentions this use far behind other more important functions such as minimum run-off, flood protection, hydropower, etc. At the same time, setting priorities among the different functions of the Vltava cascade is a matter of social consensus. The debate on the optimal setting of the individual functions, both in the long term (strategic) and in the short term (e.g., in case of a flood event), is far from over, as indicated by the long-standing discussions on the advisability of further increasing the retention vs. the storage function of the cascade.

The declared multi-purpose use combined with the current incomplete level of knowledge about the individual purposes complicates to some extent the handling of waterworks, especially during floods. Moreover, the prioritization of future use of the cascade is likely to evolve in line with expectations regarding changing climate conditions and their impact on the water regime in the Vltava cascade reservoirs as well as possible changes in societal needs.

The study translates the effect of the availability of the Vltava water ecosystems for recreation into economic terms, which stems into a wide range of further uses. Should the water-related recreation opportunities be affected due to climate change, droughts or floods and subsequent water management—and the recreationists—would have to substitute their trips with another recreational site outside the pilot area; the estimates are directly employable in cost–benefit analyses, analyses of climate change effects, etc. The results of this study are incorporated in this way into a software tool that is publicly available at https://shiny.fzp.czu.cz/kaskada-rekreace (accessed on 15 April 2023) (Czech version only).

The extent of the analysis and the incorporation of the aggregation method are reasonably designed and would be categorized as very reliable in international databases of visitor no. estimates [31] compared to many other estimates of recreation intensity used across valuation studies, which directs the results of this study into further meta-analytic and benefit transfer applications [28,29,45].

This study helps to clarify and materialize the up to now unspecific scope of recreation function for decision-making practice on the future use of the cascade so that it can be compared with other purposes of the waterworks' system.

4.2. Relative Comparison of Uses: Recreation and Hydro-Energy

Aggregate estimates of the social value of recreation at the Vltava River cascade of dams (Table 4) can be compared, e.g., to the social value of hydro-energy generated at the pilot site. Hydro power plants near the Vltava cascade participate significantly in regulating the power engineering system of the country and in generating inexpensive, environmentally clean peak-load electricity. The total yearly social value of the benefits related to hydro-energy production in water power plants located in the pilot area is based on the yearly retail price net of taxes/subsidies and is corrected for negative externalities related to energy production and potential market distortions (e.g., the monopoly structure of the market) [50–52]. For hydro-energy, we may rather plausibly assume that the market price of hydro-energy is not very far from its shadow value, including, e.g., externalities or market distortions [53–55].

The yearly production of hydro-energy in the pilot area during the last few years has been around 750 GWh (690 to 890) in total, 2/3 of which is generated by the Orlík and Slapy hydroelectric power stations. The 5-year average (2017 to 2021) market price of energy for CZ households and non-households excluding taxes reported by Eurostat [56] is 2.3–3.1 CZK/kWh. Another price estimate that is relevant for the social use of hydro-energy generated at the pilot site is the price of balancing energy, the 5-year average of which also fits into the range of the previously calculated pricing indicator: 2.6 CZK/kWh [57].

Using these data, we estimated the yearly value of hydro-energy generated by the pilot site at 1.7 billion CZK (range 1.5 to 2.3). The social value of hydro-energy therefore exceeds the medium value estimates of the social value of recreation by a factor of 3.1 (range 2.5 to 3.8). (Similar results are available for the Slapy hydroelectric power station vs. the recreation value of water-related activities at the Slapy dam). From this perspective, the actual relative prioritization of these two reservoir functions by Povodí Vltavy, a state enterprise that focuses on the complex handling regulations of the cascade [49], is confirmed by this study as quite rational—the actual recreation social benefits do not exceed the benefits gained from hydro-energy.

4.3. Research Limitations

An essential requirement for the use of the results drawn from the survey to guide water management policy in future years could be to test how robust the results are considering the COVID-19 pandemic. During the survey that was conducted in the year of 2020, no COVID-19 anti-epidemic measures were in place, but it is likely that Czech recreational areas including the Vltava Cascade were more frequented by domestic visitors than foreign recreationists compared to previous years. This does not affect the survey results as the survey focused on the Czech visitors only. To test whether the visitor composition shifted compared to recent years preceding the COVID-19 pandemic, the survey investigated whether the visitor would have been at the interview site at the time of the survey had the situation associated with the global pandemic caused by COVID-19 not occurred. Out of a total sample of 460 valid responses, only 24 respondents (5%) answered 'definitely not', while another 38 (8%) answered 'rather not'. The vast majority of the respondents did not change their recreation pattern in terms of realization of the actual visit to the pilot area. The study can thus be considered no less valid even for the following years hopefully characterized by a 'no pandemic scenario'.

For the practitioners, it is necessary to stress that the results on the comparison of the social value of water-related recreation to hydro-energy generation generated by the approach applied in our study are based on static cross-section data (comparing the yearly flow of both functions under previous conditions) and represent the current conditions. These results are the first available quantitative validation of the priorities on these two particular uses—most of the existing studies end in estimating the recreation value per one person (see the Section 1), which is useless for decision-making on water uses. The results presented in this study are relevant mostly for strategic management and for communication of the (relative) importance of particular uses. They are not valid for decision-making under changing conditions at reservoirs (e.g., climate change effects on water quality or water levels, new investment projects affecting the levels of one or both of the analyzed water uses, etc.) or for the operational (day-to-day) handling of water works, e.g., under flood events. For these types of decision-making, optimization techniques regarding these two and also other uses would better match the purpose, incorporating dynamic analysis which is out of the scope of this study. Recreation function parameters estimated by this study can, however, be used as an input into these.

4.4. Future Research

Future research will be most probably directed into reservoir optimization research, also describing the other functions of the Vltava River cascade and continuing the very inspirative previous studies, e.g., [1–3,7–10]. Attempting to cover the whole system of dams, not only one dam, into a multi-user model, will represent an interesting challenge, however, that may lead to necessary simplifications of the conditions for particular uses or reconsidering the geographical extent of the analysis.

To enable future comparisons with valuation and optimization studies on other water dams or dam systems, it is necessary to provide the following details on the functioning of the pilot site with respect to recreation and hydro-energy: the Vltava River cascade is operated as a whole system from the perspective of handling and manipulation (by Povodí Vltavy, státní podnik) and also from the perspective of hydro-energy generation that is managed by ČEZ, a. s. While the requirements for the recreational function and the use of the banks for recreation are more or less to maintain a minimum water level and stability, peak-load hydro-energetic use requires water level fluctuations. It must be noted that contrary to the study sites that comprise one dam [5], the recreation function of the Vltava cascade need not even be in direct contradiction with the hydro-energy requirements. In the case of the pumped-storage hydro-electric power stations that are located in the area, the effect on the water level need not be dramatic and need not match the daytime when recreationists are present. Other power projects (e.g., Orlík) operate with such a large body of the dam that the effect of fluctuations to ascertain a peak-load energy use on the water level can be negligible.

5. Conclusions

This study demonstrates a complex approach that follows applying a non-market valuation technique so that the results can be mainstreamed into water management. On the example of the large reservoir system at Vltava River in the Czech Republic, we shed light on who the beneficiaries of water-based recreation in the pilot area are and characterize their recreation behavior, assess the magnitude of non-market recreation benefits brought by the favorable conditions of the water bodies and waterfronts in the pilot area to its visitors, and aggregate them over the whole population of recreationists using reliable data on visitation rates. Furthermore, we compared the yearly aggregate recreation benefits to the other selected functions of the cascade: hydro-energy generation. Hydro-energy generation is an important water use, the monetary indicators of which are more readily available to the water management authority than the up to now unvalued recreation benefits. The results represent an important piece of information for strategic water management (prioritization of the multiple purposes of dams), a cost–benefit analyses on the availability of water bodies for recreation, communication of the importance of recreation among various water uses, and meta-analyses of the recreational values of nature (where there is still a lack of primary estimates for freshwater bodies worldwide). They are less relevant for decision-making under changing conditions and for dynamic decision-making on water use.

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