Status of and Perspectives on River Restoration in Europe: 310 000 EUR per Hectare of Restored River

Ewelina Szalkiewicz¹, Szymon Jusik² and Mateusz Grygoruk³,⁴*

¹ Poznań University of Life Sciences, Department of Hydraulic and Sanitary Engineering, ul. Piątkowska 94A, 60-649 Poznań, Poland; ewelszal@up.poznan.pl
² Poznań University of Life Sciences, Department of Ecology and Environmental Protection, ul. Piątkowska 94 C, 60-649 Poznań, Poland; jusz@up.poznan.pl
³ Warsaw University of Life Sciences – SGGW, Faculty of Civil and Environmental Engineering, Department of Hydraulic Engineering, ul. Nowoursynowska 166, 02-787 Warsaw, Poland.
⁴ European Centre for River Restoration, Polish National Centre.

* Correspondence: m.grygoruk@levis.sggw.pl; Tel.: +48 22 593-53-09

Abstract: The purpose of the present research was to analyze the available data on river restoration projects. As the framework of our study, we conducted a structured international survey. We asked selected entities and experts from among those responsible for river restoration in European countries about the details and costs of European Union river restoration projects. We examined 119 river restoration projects that were implemented in Europe between 1989 and 2016; some of the projects were still ongoing. We observed that the number of river restoration projects has been increasing since 1989, which expresses society’s growing interest in improving the quality of aquatic environments. We revealed that 56% of these European river restoration projects have been implemented by dedicated entities and stakeholders, not as part of any structured, larger-scale river restoration policy; this indicates that most European countries do not have integrated plans for river restoration. Our analysis showed that 52% of the projects analyzed have been designed and implemented without the participation of local stakeholders. It also showed that the budgets for river restoration projects did not differ significantly across various time horizons from 1981 to 2016.

In our study, the average cost of restoring 1 ha of an average European river was 310 000 EUR (or 195 000 EUR if 4 outlying values are excluded). Considering these projects’ permanent assets and including their amortization, for European river systems, we calculated the average unit price of a river restoration’s value in terms of ecosystem meta-service to be 7 757 EUR · ha⁻¹ · year⁻¹ (4 875 EUR · ha⁻¹ · year⁻¹ if 4 outlying values were excluded).

Keywords: river; restoration; ecosystem; management; water framework directive; ecosystem services

1. Introduction

The development of societies is expressed through increasing indices for growth, level of education and communication efficiency, as well as through a growing demand for a high-quality surrounding environment. Many suspect the latter to be the main driver of environmental restoration [1-3]. Some even deem the classic approaches such as process- and species-based conservation paradigms to lack resilience on a long time horizon, arguing that environmental restoration is the only way to reach sustainability goals [4]. As Suding stated, this situation and the increasing priorities on environmental issues provide exponentially more opportunities for the improvement of environmental quality and sustainable development than at any time before [1].

As synergies in environmental restoration result in measurable economic gains that follow restoration-induced improvements of ecosystems’ statuses [5-7], one may suspect that the scientific and political implementation consortia that are restoring various ecosystems worldwide are finally
able to provide comprehensive ecosystem restoration and to positively stimulate local economies and societies. However, the societal demand for high-quality environments remains spatially heterogeneous, as does the growth in environmental consciousness, education and emotions regarding nature [8-10]. That is why there are specific groups of interest, including people with various objectives and profiles who are responsible for the design and implementation of environmental restoration projects [11].

Unlike for other ecosystems, the restoration of rivers and wetlands remains a global issue [12-14]. These azonal ecosystems occur in every latitude of every continent. The problems related to riverine environments – including modifications in hydromorphology, flow velocities, and both longitudinal (upstream-downstream) and vertical (channel-floodplain lakes) connectivity – remain unrelated to climatic zones and thus are cited and reported on a universal basis [15]. Restoration of rivers and riparian wetlands still has great economic potential; the ecosystem services that these mesobiomes provide have been estimated to retain high economic value [16]. When well-planned, designed and -managed, restored river-wetland systems can mitigate the negative consequences of changing land uses and of climate extremes such as floods and droughts and can also help to sustain biodiversity [17-21]. Restoration of these systems is even more critical due to the fact that, among the ecosystems that Costanza et al. [22] evaluated, only two had decreasing economic unit values for the services they provide: namely freshwater wetlands and estuaries, both of which are related to – and dependent on – rivers and their valleys maintaining good status. Moreover, Costanza et al. also reported that the area of these ecosystems is decreasing on a global scale. Hence, the restoration of rivers and related riparian ecosystems may soon become an element of (inter)national strategy that is inherently included in water policies.

In the European Union (EU), the Water Framework Directive (WFD) [23] has regulated actions related to rivers and their ecosystems since 2000. This regulation promotes integrated water management. The WFD’s meta-goal is to maintain rivers’ good ecological states or at least achieve their good ecological potential. As riverine systems face existing pressures and most are in a deteriorating state, large-scale river restoration strategies seem to be the ultimate measure for fulfilling both the WFD’s requirements and the goals of other environmental regulations [24-25]. Therefore, especially from the EU’s perspective, the revision and general assessment of past and present river restoration projects – which so far has not been done – would (1) provide important information about these projects’ costs, results and future prospects and (2) help determine whether contemporary river restoration tends to involve strategic action or be reduced to the costly hobby of certain groups of stakeholders.

Our paper addresses the following research goals: (1) to quantify and assess the scale of particular river restoration projects in the EU; (2) to identify whether the reviewed river restoration projects remain individual, spontaneous actions or if they are now elements of more widely planned river restoration strategies; (3) to reveal the scale and share of EU and national funding spent on river restoration; and (4) to assess the approximate average cost of river restoration, as this reveals the value that societies are willing to pay to maintain healthy rivers.

2. Materials and Methods

Our study was based on a questionnaire (Tab. 1) that contained both open- and closed-ended questions. The open-ended queries focused on basic information (river, country, project’s start year and completion year) as well as on more detailed information such as budget and share of funding (if any) from the EU. If the budget for a given restoration project was not known or if the respondent did not wish to provide a detailed budget, he or she could select from ranges of costs. The questionnaire also included questions that addressed the issues of which entities were responsible for particular projects, the size and scope of those projects, the technical solutions applied in them, the level of the local communities’ participation, the monitoring of project results, and information regarding whether the project was part of a large-scale strategy or plan. The questionnaire was distributed to more than 300 European specialists involved in the implementation of or research on restoration for rivers and riparian ecosystems. Additionally, to obtain the broadest set of data
possible, we carried out a structured review of river restoration databases such as River Wiki [26] and Onema [27]. The River Wiki database is funded by the Environmental Agency (England) and administered by the River Restoration Centre (UK).

### Table 1. Closed questions asked in the questionnaire.

| Question                                                                 | Answers                                                                 |
|--------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Entity responsible for the project*                                      | a. nationwide authorities                                                |
|                                                                         | b. provincial/regional authorities                                       |
|                                                                         | c. association (NGO)                                                     |
|                                                                         | d. private investors                                                     |
|                                                                         | e. others                                                                |
| Scope of the project*                                                    | a. works within channel                                                  |
|                                                                         | b. works within floodplain                                                |
|                                                                         | c. works within catchment                                                |
| Size of the project                                                      | a. river reach length < 2 km                                              |
|                                                                         | b. river reach length > 2 km                                              |
|                                                                         | c. whole river                                                           |
|                                                                         | d. more than one watercourse                                              |
| Solutions which were used*                                               | a. removal of hydrotechnic structures                                    |
|                                                                         | b. deflectors                                                            |
|                                                                         | c. threshold                                                             |
|                                                                         | d. introducing of logs or other wood elements                            |
|                                                                         | e. biological strengthening of the banks                                 |
|                                                                         | f. preparing the spawning grounds                                         |
|                                                                         | g. constructing the fish ladders                                          |
|                                                                         | h. crosscut of the channel or other diggings                             |
|                                                                         | i. introducing of macrophytes                                            |
|                                                                         | j. others                                                                |
| Source of the project funding*                                           | a. government budget                                                     |
|                                                                         | b. EU funding                                                            |
|                                                                         | c. association or foundation funds                                       |
|                                                                         | d. private funds                                                         |
|                                                                         | e. others                                                                |
| Did the local community participate in the project?                      | Yes / No                                                                |
| Have the monitoring of the restoration project been performed?           | Yes / No                                                                |
| Was the project a part of the larger restoration plan (national, international)? | Yes / No                                                               |

*Questions with possibility to choose multiple answers.

The general analysis of the questionnaire consisted of summing up the answers for each query and conducting standard statistical analyses. The collected structured data allowed for rough calculations of the unit cost for river restoration in Europe, expressed in kEUR/ha. Although this information provides only a very general approximation, we found it critical, as it is the most accurate economic measure of a river’s aggregated ecosystem services. This cost refers to the amount of funds that stakeholders will pay to bring back a functioning riverine ecosystem that provides aesthetic value as well as services such as biodiversity, self-purification, and sustainable flood/drought mitigation.

### 3. Results

We obtained 105 questionnaire responses from 19 countries, of which 102 were reliable sources of data for the analysis. This is response rate of 36%, which we considered sufficient for purposes of our study. Altogether, we analyzed 119 river restoration projects in detail (Fig. 1). The collected
information about these projects is provided in the Supplementary Material. We are aware that other countries have implemented river restoration projects, but to ensure that the results correspond to the methodology, we did not count these countries’ projects in our analysis.

**Figure 1.** Number of surveys collected from each country.

![Image](image1.png)

**Figure 2.** Number of river restoration projects finalized in particular years analyzed.

![Image](image2.png)

We collated projects by the year when they were finished. The earliest project for which we have data is from 1989. The most recent year we considered was 2016, but some of the projects were still running and the end of that year. However, to keep the analysis clear, we assumed that, in such cases, 2016 was the terminal year for these restoration projects. Either way, the number of European river restoration projects in the countries for which we have data has clearly increased since the last two decades of the 20th century (Fig. 2).

In the next step, we analyzed the setup of the river restoration projects. We attempted to determine whether these projects analyzed were planned and implemented with the active participation of the local authorities; whether their results were monitored to allow for adaptive management; and whether the river restoration initiatives belonged to or result from any structured, large-scale river restoration strategy (e.g., a national river restoration plan). Less than a half of the projects included the active participation of local communities. Approximately 80% of initiatives included the monitoring of project efficiency (e.g., water level monitoring, river discharge measurements or ecological monitoring). Surprisingly, only approximately 44% of the projects were
part of large-scale (e.g., nationwide) river restoration policies, meaning that the majority of the EU river restoration projects comprised the individually planned actions of interested entities (Fig. 3).

**Figure 3.** Share of the projects analyzed with participation of local communities in project design/implementation, share of the projects which results were methodologically monitored and projects that remained a part of a larger (e.g. country-wide) river restoration strategy.

Regarding the main goals of the river restoration projects, we revealed that an increasing number of projects are oriented beyond the river channel (to include the floodplain and the whole catchment; Fig. 4). By time frame, the most comprehensive and abundant projects, including actions in the river channel, floodplain and catchment (or a mixture of these measures), occurred in 2016, the most recent time period (Fig. 4). This indicates that river restoration managers account for systematic solutions and address ecohydrological process at the catchment scale. The projects in the oldest time frame considered (1989-2000) did not include any actions oriented toward catchment-scale processes and instead concentrated mainly on the river itself, although a few floodplain-related measures were implemented (Fig. 4).

**Figure 4.** Share of the projects in selected time frames oriented at restoration measures in river channel, floodplain, whole catchment and complex projects including catchment-scale measures.

Among the river restoration projects analyzed, the majority (51%) were designed and implemented by regional authorities or by other entities working on a regional scale (Fig. 5). Nongovernmental organizations (NGOs) were reported to have participated in 13% of the projects (7% with the aid of national-scale institutions such as National Environmental Directorates and 6% run by NGOs on their own). The remaining projects were run by either national-scale entities or by other consortia (19% and 18%, respectively; Fig. 5). When analyzing the survey results, we observed that the numbers of projects designed and implemented by regional-scale authorities increased significantly from 1989 through 2015. The number of NGOs and national consortia implementing
river restoration projects did not increase in that time. No project run solely by NGOs were present before 2011 (Fig. 5), but they started to occur after that year. Because the time frame after 2016 was not fully reported, we do not draw conclusions about which authorities were implementing river restoration projects in this period. However, based upon the results of the survey, we observed that the number of NGO-run projects has increased, even as the number of projects implemented by national- or regional-scale entities remained the same or declined.

**Figure 5.** Types of entities responsible for the implementation of particular river restoration projects in particular time frames analyzed. The last time frame is shielded as it is still running and the results present only partial view.

**Figure 6.** Selected characteristics of river restoration projects analyzed: A – number of projects co-funded by the EU, B – average level of EU funding, C – average cost of river restoration project (kEUR per project). Box-plot charts (B and C): box represents the range from 25 to 75 percentile, x – average value, vertical line in the box – median, whiskers represent maximum and minimum values, dots represent outlying values.

Analysis of the funding sources for the river restoration projects revealed that approximately half of initiatives analyzed across all time frames were cofinanced, with the funds originating directly...
from EU subsidies (Fig. 6B). Moreover, 22.2% of the projects had nongovernmental funding, which proves that associations and groups of enthusiasts play an important role in river restoration in Europe. We observed (Fig. 6B) that the number of partially EU-funded river restoration projects has been continuously increasing (Fig. 6A). Among the projects in the 1989-2000 period, none were supported by EU funds (Fig. 6A and B).

The level of EU co-funding for river restoration projects has increased from 43% (in 2000-2005) to 65% (in 2010-2015). In the last time frame analyzed (2016 onward), the rate of EU co-funding decreased to 52%. However, the last time frame analyzed is still not complete, as it does not cover a full 5-year period. In the years analyzed, the total budgets for river restoration projects did not differ significantly (Fig. 6C and Tab. 2). There was only a significant difference between two periods, as the projects implemented in 2001-2005 were significantly more costly than those implemented in 2011-2015 (Tab. 2).

**Table 2.** *p*-values of the T-Test of the differences between total budgets of river restoration projects in different time frames analyzed. * - differences significant at the level of 0.05.

|      | 2000 and before | 2001-2005 | 2006-2010 | 2011-2015 | 2016 < |
|------|-----------------|-----------|-----------|-----------|--------|
| 2000 and before | -      | 0.108     | 0.934     | 0.631     | 0.473  |
| 2001-2005   | 0.108           | -         | 0.096     | 0.028*    | 0.303  |
| 2006-2010   | 0.934           | 0.096     | -         | 0.490     | 0.477  |
| 2011-2015   | 0.631           | 0.028*    | 0.490     | -         | 0.159  |
| 2016 <      | 0.473           | 0.303     | 0.477     | 0.159     | -      |

**Figure 7.** Distributions of unit costs of river restoration projects (kEUR/ha) in selected time frames. Box represents the range from 25 to 75 percentile, x – average value, vertical line in the box – median, whiskers represent maximum and minimum values, dots represent outlying values. kEUR stands for thousand of Euro.

Once considering the total budgets of the river restoration projects and the areas of their influence (lengths and widths restored), we calculated these projects’ average unit value per hectare of restored river (Fig. 7). We revealed that, on average, the cost of restoring 1 ha of river was 310 000 EUR (310 kEUR), with a range from 99 kEUR/ha (in 2000 and before) to 353 kEUR/ha (in 2006-2010; Fig. 7). After excluding 4 extremely outlying values (two Italian projects on the Draganziolo and Marzenego rivers, with unit restoration costs of 2000 and 4500 kEUR/ha, respectively; and two French projects on the Bievre and Petersbach rivers with unit restoration costs of 2600 and 5680 kEUR/ha, respectively), the average unit restoration cost was only 195 kEUR/ha (Fig. 7). Despite these outlying values, the differences in the unit river restoration costs across the time frames analyzed were not statistically significant (Tab. 3). This observation leads to the conclusion that the
unit cost of river restoration, although strongly variable from site to site and highly dependent on
the measures applied, remained at a similar level throughout the period from 1989 to 2016

Analyzing the unit costs of river restoration projects with respect to their spatial scales
(catchment; channel; floodplain; channel and floodplain together; or channel, floodplain and
catchment together; again, excluding the 4 outlying Italian and French restoration projects), we
found that the differences among these groups were more significant than those between the time
frames (Fig. 8.; Tab. 4).

In general, the unit costs of the catchment-scale river restoration projects (average: 32 kEUR/ha)
were significantly lower than for other types of projects. The highest statistical significance was
recorded for the difference between the catchment-scale projects and the joint channel- and
floodplain-oriented actions (average: 280 kEUR/ha). This observation is based on the types of actions

---

Table 3. p-values of the T-Test of the differences between unit costs of river restoration projects
(kEUR/ha) in different time frames analyzed.

|       | 2000 and before | 2001-2005 | 2006-2010 | 2011-2015 | 2016 < |
|-------|-----------------|-----------|-----------|-----------|--------|
| 2000 and before | - | 0.057 | 0.068 | 0.533 | 0.693 |
| 2001-2005 | 0.057 | - | 0.542 | 0.074 | 0.066 |
| 2006-2010 | 0.068 | 0.542 | - | 0.117 | 0.080 |
| 2011-2015 | 0.533 | 0.074 | 0.117 | - | 0.727 |
| 2016 < | 0.693 | 0.066 | 0.080 | 0.727 | - |

---

Table 4. p-values of the T-Test of the differences between unit costs of river restoration projects’
oriented at different spatial scales. * - differences statistically significant at the level of significance
0.05.

|       | Catchment | Channel | Floodplain | Channel & Floodplain | Catchment & Channel 
|-------|-----------|---------|------------|----------------------|---------------------|
| Catchment | - | 0.007* | 0.018* | 0.0001* | 0.083 |
| Channel | 0.007* | - | 0.660 | 0.095 | 0.327 |
| Floodplain | 0.018* | 0.660 | - | 0.260 | 0.220 |
| Channel & Floodplain | 0.0001* | 0.095 | 0.260 | - | 0.016* |
| Catchment & Channel & Floodplain | 0.083 | 0.327 | 0.220 | 0.016* | - |
implemented at the catchment-scale projects, which mostly involve planting trees and other low-cost actions (see Supplementary Material). The most expensive actions were implemented in the channel-floodplain and floodplain-only scales, and they included floodplain-lake reconnections and dyke relocations. As the number of projects varied strongly across the 19 countries (from 1 to 17), we decided not to differentiate the unit cost of river restoration at the country level.

4. Discussion

First and foremost, we are aware that the analyzed sample covers only a portion of river restoration projects implemented in European countries. The RiverWiki [26] and Onema [27] databases contain many more records. These databases showed that, of the countries in Europe, only the UK has hundreds of river restoration projects [28]. However, most of these projects lacked information about river lengths and project budgets, which prevented us from considering these data reliable enough for use in our study. Many projects related to the restoration of floodplain environments were also reported; they were oriented mainly at wetlands (e.g., ditch blocking) and as such, could not be analyzed. Bearing this issue in mind, however, the results presented in our analysis, which are based on 119 projects from 19 countries, reflected the most relevant, general advances in EU river restoration’s progress at the end of the 20th and start of the 21st century.

Our survey results tended to mirror the conclusions provided by Palmer et al. [15] and Wohl et al. [29]; for instance, the number of river restoration projects implemented in Europe continues to increase. In our analysis of the structure of river restoration projects, we noted that less than half of all the projects (42%) were part of a larger restoration strategy. Therefore, the majority of river restoration projects were designed and implemented on a site basis, driven by the river managers’ and stakeholders’ desire to improve the rivers. On the one hand, this can be considered a good prerequisite for river restoration in the future, as the pattern revealed shows that managers and stakeholders do not need special strategies or plans for their rivers. Their actions in the design and implementation of river restoration projects tend to reflect the growing societal demand for high-quality ecosystems, which Suding [1] foresaw as the main driver for environmental restoration in the 21st century. On the other hand, the lack of the comprehensive river restoration strategies in particular countries could remain an obstacle for certain projects that should be structurally implemented and that should not depend on the fluctuations of societal moods. One might expect that, if the availability of external funds for river restoration projects were to decline (e.g., due to the EU shifting its priorities away from environment and toward agriculture), then the lack of structured, national river restoration plans would inhibit the design of new projects. The number of EU-co-funded river restoration projects is increasing, and the cofinancing rate has reached 50-65% in most countries (or, in some cases, 95%; Fig. 6), which has led to enhanced cooperation between NGOs and regional (or national) official entities (Fig. 5). However, without structured strategies and planned cooperation between NGOs and national (or regional) authorities, river restoration projects will likely remain hobbyists’ activities rather than comprehensive country-level actions that would produce measurable improvements in degraded rivers’ statuses.

Although Wohl et al. [29] reported that most river restoration projects are oriented at one river only and that the measures applied remain limited to a single action (e.g., changing hydromorphology or opening migration barriers), we found this status to be changing. Starting in 2000, we observed an increasing heterogeneity of measures. These measures were formerly limited to the river channel and floodplain, but the set of actions that were undertaken in the most recent time frame had expanded to include the catchment and its integrated actions. The most significant shift in this manner occurred in 2011-2015 and from 2016 onward (Fig. 4). The growing scientific interest in river restoration meant that the vast majority (78%) of projects included structured before-and-after control-impact monitoring. Sadly, less than a half of the projects were designed and implemented with the active participation of local communities (Fig. 4). This status frequently led to conflicts between local stakeholders and implementing authorities [30]. Conflicts predominantly arose when the communication process began too late in a project’s life or failed to put the restoration project in a local context [31]. A higher level of participation from local communities and other
relevant stakeholders has already been determined to have a positive impact on environmental
management projects, and a special emphasis on ecological restoration has resulted in more
comprehensive measures, longer project life and longer-lasting results [32-33]. However, ensuring a
high level of stakeholder participation in a restoration project requires targeted communication, and
it is efficient only if the gaps related to the science-practice interface have been narrowed [31]. Either
way, those who wish to implement successful river restoration projects should foster the wider
involvement of stakeholders in the project's design and implementation and in measures that ensure
the sustainability of the projects' results.

We estimated the average unit costs for EU river restoration projects, expressed in EUR · ha⁻¹,
and although we calculated these values with a relatively small sample, there were few statistically
significant differences across temporal, spatial or technical scales (Tab. 2, Tab. 3 and Tab. 4). The lack
of information about some projects' longevity prevented us from defining the direct economic value
of the actions in each year, for comparison with the value of the ecosystem services for riparian and
riverine ecosystems, as other authors have calculated. Based on the collected answers from the
participants, we could not estimate the desirable persistence of the projects' ecological results over a
certain duration. Although the goal of a restoration project should be to enhance the existence of
resilient river systems, regardless of the duration [3,9,14-15,29], most restoration-related actions are
technical interventions (fish-ladder construction, floodplain-lake reconnection, etc.). Hence, these
projects could be considered permanent assets that undergo amortization (depreciation over time).
The annual depreciation (amortization) rate applied to the calculations made it feasible for us to
calculate the annual value of each river restoration per hectare. According to Poland’s legal
regulations [34], the amortization rate of permanent assets (hydrotechnical constructions, land
reclamation or drainage systems, weirs, spillways, etc.) is 2.5% per annum. This means that
permanent assets are designed and constructed to function for 40 years (1 year/2.5%). Assuming that,
due to legal accordance, similar levels of amortization apply to such assets throughout the EU, the
average cost of river restoration projects per hectare per annum would be 7 757 EUR · ha⁻¹ · year⁻¹ (310
kEUR · ha⁻¹ · 40 years⁻¹), which is equal to roughly 8 920 USD · ha⁻¹ · year⁻¹. Excluding the four outlying
values referred to above, the unit costs of river restoration were 4 875 EUR · ha⁻¹ · year⁻¹ (5 606 USD ·
ha⁻¹ · year⁻¹).

These values represent the price that European society wishes to pay (technically, has already
paid) to restore river functions. Hence, we consider this value to be the monetary dimension of
healthy rivers’ ecosystem meta-service. Due to each river restoration project’s complex aims and
measures, it is difficult to calculate the elementary values of a particular ecosystem’s services (e.g., a
restored river as a new habitat for fish), but the given annual unit cost of restoring 1 hectare of a river
system is likely to represent the average long-term value of that river’s services.

Interestingly, the calculated unit cost of river restoration may now be referred to as the value of
riverine ecosystem meta-service and is similar to the average worldwide unit value of ecosystem
services that de Groot et al. calculated for rivers and lakes combined [35] (4 247 USD · ha⁻¹ · year⁻¹;
ranging from 1 446 USD · ha⁻¹ · year⁻¹ to 7 757 USD · ha⁻¹ · year⁻¹). At the same time, the calculated
value is a bit higher than the quantities for some single-ecosystem services calculated in individual
studies (such as flood retention, as calculated by Grygoruk et al. [21] and priced at approximately 500
EUR · ha⁻¹ · year⁻¹ or 590 USD · ha⁻¹ · year⁻¹), but lower than the ones calculated by Costanza et al. (11
727 USD · ha⁻¹ · year⁻¹ for calculations published in 1997 [16] and 12 512 USD · ha⁻¹ · year⁻¹ for
calculations published in 2014 [36]). One might suspect that the differences shown above result from
the fact that both de Groot et al. [35] and Costanza et al. [16,36] used different calculation algorithms
and also dealt with lakes in addition to rivers. However, the river restoration projects that we
analyzed also referred to floodplains, which de Groot et al. [35] and Costanza et al. [16,36] listed in a
different category; the floodplain projects in these studies were priced much higher than average.
Despite these differences, all of the cited values have the same order of magnitude. This allows us to
hypothesize that the methodology we used to assess the unit value of the riverine ecosystems’ meta-

service (on the basis of river restoration costs), thus expressing societies’ willingness to pay for
healthy rivers, is a novel, comprehensive and reliable approach. One should be aware that every river
restoration project is strongly site-specific in terms of the river’s proportions (width, depth and stretch length), the project’s spatial scale (channel, floodplain or catchment) and the measures applied (from planting trees to heavy mechanical works in the channel). Moreover, labor and investment costs also were strongly variable across the set of countries analyzed. However, the general lack of statistical significance in the differences between the projects’ budgets across the 19 countries and the time frames analyzed (Tab. 2), with respect to the unit costs (Tab. 3), allow us to state that the calculated unit value of river ecosystems’ meta-service is reliable. As such, our results could be carefully applied in EU-scale studies and policies regarding the value of rivers.

Among the projects analyzed, relatively few dam-removal initiatives were reported. Some new initiatives are, however, being planned [37] and implemented [38], mainly in Western European countries; this allows us to suspect that the number of removed dams will increase across the continent. Similarly, observing advances in dam removal around the world, including the best documented dam removals in the U.S. [39], we foresee that the 21st century will include more ecosystem-economy-based discussions; our results, which are oriented at the calculation of healthy rivers’ services, may contribute to these discussions. The results of the research on dams’ downstream effects provides sufficient evidence that dam-reservoir-induced flow-regime changes and the related negative responses of humans and of riverine and riparian ecosystems must be addressed through (costly) mitigation measures [40-43].

On the other hand, even though the need for diverse, well-developed and resilient riverine ecosystems has been agreed upon for quite some time [44], in recent discussions, scholars have documented and even promoted ideas related to hard technical interventions (including the construction of new dams and hydrotechnical infrastructure) as a sine qua non for growth [45]. Muller et al. [45] hypothesized that humanity – for its own sake and benefit – is likely to continue degrading rivers by introducing newly built infrastructure than to restore the rivers’ environmental features. However, along with increases in sustainable growth and outstanding recent advances in ecological engineering, the awareness of the need for a high-quality environment will also rise [46-47], so we believe this negative scenario will not come to pass.

5. Conclusions

We analyzed 119 river restoration project from 19 EU countries, revealing that the number of river restoration projects has been increasing over the time frame analyzed (1989-2016). We also observed that the complexity of these river restoration projects has increased; in addition to the restoration measures in river channels and floodplains, more catchment-scale initiatives are now being implemented. We also revealed that majority of river restoration projects were not done in the framework of any larger (e.g., country-scale) policy, meaning that most are individual actions implemented by groups such as regional authorities. We also observed an increasing involvement of NGOs across the time frames. By analyzing the projects implemented in a variety of countries across multiple spatial and temporal scales, we revealed that the unit cost of river restoration does not change significantly across these scales. The average cost of restoring 1 ha of a river system was 310 kEUR (195 kEUR excluding four outlying values) and did not significantly change with respect to the scale of the project, the country of implementation or the measures applied. The EU’s average contribution to these projects’ budgets has also increased, reached a typical range of 50 to 60%. We concluded that the EU’s contributions and the implementation of the WFD significantly increased the number of river restoration projects. On the basis of the obtained data and our subsequent calculations, we estimated the average unit cost of river restoration per hectare to be 7 757 EUR · ha⁻¹ · year⁻¹ (8 920 USD · ha⁻¹ · year⁻¹). We stated that this value reflects society’s willingness to pay for a healthy river. Therefore, the calculated value can be referred to as monetary expression of river systems’ ecosystem meta-service, encompassing a range of individual services. This measure can be applied to European environmental policy to address the sustainable management of riverine ecosystems.

Based on our study’s results, we suggest that, to ensure the sustainable management of Europe’s rivers, certain countries should implement financial mechanisms that allow local
stakeholders (e.g., NGOs) to apply for external funds to pay for local river restoration initiatives. Such programs would broaden the involvement of local stakeholders and decentralize river restoration initiatives, thus enhancing local stakeholders' responsibility for their rivers. At the same time, countries should implement national programs to address river restoration on nationwide scales to provide planned and structured catchment-scale actions.

Acknowledgments: We sincerely thank all the experts from 19 European countries that participated in the survey.

Author Contributions: All authors contributed equally to manuscript preparation.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Suding, K.N. Toward an era of restoration in ecology: successes, failures and opportunities ahead. *Annual Review of Ecology, Evolution and Systematics* **2011**, *42*, 456-487.
2. Martinez, M.L.; Lopez-Barrera, F. Special issue: Restoring and designing ecosystems for a crowded planet. *Ecology* **2008**, *15*, 1-5.
3. Hobbs, R.H.; Harris, J.A. 2001. Restoration ecology: repairing the Earth’s ecosystems in the new millennium. *Restoration Ecology* **2001**, *9*, 239-246.
4. Choi, Y.D.; Temperton, E.B.; Allen, A.P.; Grootjans, M.; Halassy, M.; Hobbs, M.A.; Naeth, M.K.; Tokor, K. Ecological restoration for future sustainability in a changing environment. *Ecology* **2008**, *15*, 53-64.
5. Nielsen-Pincus, M.; Moseley, C. The economic and employment impacts of forest and watershed restoration. *Restoration Ecology* **2013**, *21*, 207-214.
6. Aronoson, J.; Blingnaut, J.N.; Milton, S.J.; Le Maître, D.; Esler, K.J.; Limouzin, A.; Fontaine, C.; De Wit, M.P.; Mugido, W.; Prinsloo, P.; Van Der Elst, L.; Lederer, N. Are Socioeconomic Benefits of Restoration Adequately Quantified? A Meta-analysis of Recent Papers (2000–2008) in Restoration Ecology and 12 Other Scientific Journals. *Restoration Ecology* **2010**, *18*, 143-154.
7. BenDor, T.; Lester, W.T.; Livengood, A.; Davis, A.; Yonavjak, L... Estimating the size and impact of the ecological restoration economy. *PLoS One* **2015**, PMC4470920.
8. Ehrenfeld, J.G. Defining the Limits of Restoration: The Need for Realistic Goals. *Restoration Ecology* **2000**, *8*, 2-9.
9. Jährig, S.C.; Lorenz, A.W.; Hering, D.; Antons, C.; Sundermann, A.; Jedicke, E.; Haase, P. River restoration success: a question of perception. *Ecological Applications* **2011**, *21*, 2007-2015.
10. Petursdottir, T.; Aradottir, A.; Benediktsson, K. An Evaluation of the Short-Term Progress of Restoration Combining Ecological Assessment and Public Perception. *Restoration Ecology* **2013**, *21*, 75-85.
11. Lave, R.; Doyle, M.; Robertson, M. 2010. Privatizing stream restoration in the US. *Social studies of science* **2010**, *40*, 677-703.
12. Grygoruk, M.; Acreman, M. Restoration and management of riparian and riverine ecosystems: ecohydrological tools, experiences and perspectives. *Ecohydrology & Hydrobiology* **2015**, *15*, 109-110.
13. Dynesius, M.; Nilsson, C. Fragmentation and flow regulation of river systems in the Northern third of the World. *Science* **1994**, *266*, 753-762.
14. Palmer, M.A.; Honda, K.L.; Koch, B.J. Ecological restoration of streams and rivers: Shifting strategies and shifting goals. *Annual Review of Ecology, Evolution and Systematics* **2014**, *45*, 247-269.
15. Palmer, M.A.; Bernhardt, E.S.; Allan, J.D.; Lake, P.S.; Alexander, G.; Brooks, S.; Carr, J.; Clayton, S.; Dahm, C.N.; Holliday, J.; Galat, D.L.; Loss, S.G.; Goodwin, P.; Hart, D.D.; Hassett, B.; Jenkinson, R.; Kondolf, G.M.; Lave, R.; Meyer, J.L.; O’Donnell, T.K.; Pagano, L.; Sudduth, E. Standards for ecologically successful river restoration. *Journal of Applied Ecology* **2005**, *42*, 208-217.
16. Costanza, R.; d’Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; Oeneil, R.V.; Paruelo, J.; Raskin, R.G.; Sutton, P.; van den Belt, M. The value of the world’s ecosystem services and natural capital. *Nature* **1997**, *387*, 253-260.
17. Brandyk, A.; Majewski, G.; Kiczko, A.; Boczoń, A.; Wróbel, M.; Porretta-Tomaszewska, P. Ground Water Modelling for the Restoration of Carex Communities on a Sandy River Terrace. *Sustainability* **2016**, *8*, 1324.
18. Cui, B.; Wang, C.; Tao, W.; You, Z. River channel network design for drought and flood control: a case study of Xiaolangdi River basin, Jinan City, China. *Journal of Environmental Management* **2009**, *90*, 3675-3686.
19. Erwin, K.L. Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and Management* 2009, 17, 71.

20. Grygoruk, M.; Bąkowska, A.; Jabłońska, E.; Janauer, G.A.; Kubrak, J.; Mirosław-Świątek, D.; Kotowski, W. Assessing habitat exposure to eutrophication in restored wetlands: model-supported ex-ante approach to rewetting drained mires. *Journal of Environmental Management* 2015, 152, 230-240.

21. Grygoruk, M.; Mirosław-Świątek D.; Chrzanowska, D.; Ignar, S. How much for water? Economic assessment and mapping of floodplain water storage as a catchment-scale ecosystem service of wetlands. *Water* 2013, 5, 1760-1779.

22. Costanza, R.; de Groot, R.; Sutton, P.; van der Ploeg, S.; Andresen, S.J.; Kubiszewski, I.; Farber, S.; Turner, K.R. Changes in the global value of ecosystem services. *Global Environmental Change* 2014, 26, 152-158.

23. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy.

24. Januer, G.A.; Albrecht, J.; Stratmann, L. Synergies and Conflicts Between Water Framework Directive and Natura 2000: Legal Requirements, Technical Guidance and Experiences from Practice [in:] Ignar, S.; Grygoruk, M. [eds.] Wetlands and Water Framework Directive: Protection, management and climate change. *Geoplanet: Earth and Planetary Sciences* 2015, Springer, Berlin-Heidelberg. ISBN 978-3-319-13764-3.

25. Ignar, S.; Grygoruk, M. Wetlands and Water Framework Directive: Protection, management and climate change. [in:] Ignar S.; Grygoruk, M. Wetlands and Water Framework Directive: Protection, management and climate change.*Geoplanet: Earth and Planetary Sciences* 2015, Springer, Berlin-Heidelberg. ISBN 978-3-319-13764-3.

26. https://restorerivers.eu (accessed on 14.10.2016)

27. http://www.river-restoration.onema.fr/ (accessed on 14.10.2016)

28. http://www.therrc.co.uk (accessed on 20.11.2017)

29. Wohl, E.; Angermeier, P.L.; Bledsoe, B.; Kondolf, G.M.; MacDonnel, L.; Merritt, D.M.; Palmer, M.A.; LeRoy Poff, N.; Tarboton, D. River restoration. *Water Resources Research* 2005, 41, W10301.

30. Mioduszewski, W.; Okruszko, T. Protection of natural wetlands – examples of conflicts. *Journal of Water and Land Development* 2012, 16, 35-42.

31. Grygoruk, M.; Rannow, S. Mind the Gap! Challenges for a science-based stakeholder dialogue in climate-adapted management of wetlands. *Journal of Environmental Management* 2017, 186, 108-119.

32. Muro, M.; Hartje, V.; Klapahke, A.; Scheumann, W.; Pilot Study in Identifying and Analysing Stakeholders for the Information and Consultation According to Art. 14 of the EU Water Framework Directive in a River Basin. 2007. Umweltbundesamt Texte 27-06. Dessau.

33. Carter, T.R.; Jones, R.N.; Lu, X.; Bhadwal, S.; Conde, C.; Mearns, L.O.; O’Neill, B.C.; Rousevell, M.D.A.; Zurek, M.B. New assessment methods and the characterisation of future conditions. In: Parry, M.L.; Canziani, O.F.; Palutikof, J.P.; van der Linden, P.J.; Hanson, C.E. (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. 2007. Cambridge University Press, Cambridge, UK, pp. 133-171.

34. Decree of the Minister of Finances of the Republic of Poland – Rozporządzenie Ministra Finansów of the Republic of Poland z dn. 20.01.1995 w sprawie amortyzacji środków trwałych oraz wartości niematerialnych i prawnych, a także aktualizacji wyceny środków trwałych. Dz. U. Nr. 7., Poz. 34.

35. De Groot, R.; Brander, L.; van der Ploeg, S.; Costanza, R.; Bernard, F.; Braat, L.; Christie, M.; Crossman, N.; Ghermandi, A.; Hein, L.; Salman, H.; Kumar, P.; McVittie, A.; Portela, R.; Rodriguez, L.C.; ten Brink, P.; van Beukering, P. Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem Services* 2012, 1, 50-61.

36. Costanza, R.; de Groot, R.; Sutton, P.; van der Ploeg, S.; Anderson, S.J.; Kubiszewski, I.; Farber, S.; Turner, K.R.; Changes in the global value of ecosystem services. *Global Environmental Change* 2014, 26, 152-158.

37. Press note of the Ministry of Ecology (Ministre de la Transition Écologique et Solidaire) of the Republic of France dated on 14.11.2017 (URL: www.ern.org/wp-content/uploads/sites/52/2017/11/20171114_cpm ministere_selune_dam_removal.pdf; accessed on 20.11.2017).

38. http://damremoval.eu/case-studies/ (accessed on 20.11.2017).

39. O’Connor, J.E.; Duda, J.J.; Grant, G.E. 1000 dams down and counting. *Science* 2015, 349, 496-497.

40. Dynesius, M.; Nilsson, C. Fragmentation and flow regulation of river systems in the northern third of the world. *Science* 1994, 266, 753-762.
41. Marcinkowski, P.; Grygoruk, M. Long-Term Downstream Effects of a Dam on a Lowland River Flow Regime: Case Study of the Upper Narew. *Water* 2017, 9, 783.

42. Magilligan, F.J.; Nislow, K.H. 2005. Changes in hydrologic regime by dams. *Geomorphology* 2005, 71, 61-78.

43. Cooper, A.R.; Infante, D.M.; Wehrly, K.E.; Wang, L.; Brenden, T.O.; Identifying indicators and quantifying large-scale effects of dams on fishes. *Ecological Indicators* 2016, 61, 646-657.

44. Naiman, R.J.; Decamps, H. The ecology of interfaces: Riparian zones. *Annual Review of Ecology, Evolution and Systematics* 1997, 28, 621-658.

45. Muller, M.; Biswas, A.; Martin-Hurtado, R.; Tortajada, C. Built infrastructure is essential. *Science* 2015, 349, 585-586.

46. Krueger, A.B.; Grossman, G.M.; Economic growth and the environment. *The Quarterly Journal of Economics* 1995, 110, 353–377.

47. De Bruyn, S.M.; van den Bergh, J.C.J.M.; Opschoorac, J.B. Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves. *Ecological Economics* 1998, 25, 161-175.