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Article

Influence of Small Hydroelectric Power Stations on River Water Quality

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Abstract: Hydropower electricity generation is considered one of the cheapest technologies regarding electricity generation costs, and it is the most traditional, clean, renewable energy source. However, despite the environmental benefits offered by hydropower, they also can have negative impacts and consequences in the environment affecting water quality and disrupting river ecology. We investigated the environmental effects of four small hydropower plants (SPH) in north-west Spain by looking at the water quality of the four river stretches where the SPH plants are located. The physicochemical and biological characteristics of the water streams were analyzed, as well as the riparian ecological quality. Results showed that the presence of the hydropower plants did not significantly influence the physical and chemical characteristics of the water. There were no alterations of the benthic macroinvertebrate community at any of the plants except for one, and the riparian habitat was in general classified as good quality or close to natural conditions for all plants.

Keywords: hydroelectric power; physicochemical parameters; Iberian Bio-monitoring Working Party index; riparian forest quality

1. Introduction

Between 2010 and 2040 energy demand is expected to increase by 56% worldwide [1], particularly, oil demand which is estimated to increase in countries, such as Brazil, China and India [2]. This is mainly due to the world's population unprecedented growth rate. According to the United Nations, by 2050, the world population will reach nine billion [3]. Fossil fuel combustion is currently the main source of energy production.

Two-thirds of the world's greenhouse gas emissions are produced by burning coal, natural gas and oil [4]. Anthropogenic greenhouse gas emissions are linked to climate change and human health problems [5]. Each year, more than 30 billion tons of carbon dioxide (CO_2) are released into the atmosphere [6], and around 65% of the world's excess mortality—The number of deaths caused by a specific condition or exposure to harmful circumstances is directly associated with fossil fuel-related emissions [5]. According to The Lancet Commission on Pollution and Health [7], 9 million premature deaths were associated with pollution in 2015, representing 16% of all deaths worldwide. Environmental problems, such as ozone depletion, forest destruction and acid precipitation are direct consequences of the use of fossil fuels [8]. As suggested by the 2015 Paris Agreement, the average global temperature increase should be limited to 1.5–2 °C above pre-industrial levels [9] to avoid dangerous climate change. This will require measures, such as the phase-out of fossil fuels and geoengineering methods, such as CO_2 removal [10]. These options, however, raise issues, such as the costs involved, the environmental consequences and the process effectiveness [11,12]. In addition, Raftery et al. (2017) [13], estimated that global temperature increase would be between 2.0 and 4.9 °C by 2100, with a 5% chance that it will be less than 2 °C, and 1% chance that it will be less than 1.5 °C.

In the European Union, where electricity demand is growing, 40% of total energy consumption comes from the electricity sector [14,15]. In Europe, there are 450 GW of fossil-fuelled power plants, 200 GW each of coal and gas, and 50 GW of oil. These plants supply 40% of Europe's electricity, but release 1.4 GT of CO_2 emissions each year, which account for 30% of Europe's total emissions [15]. In Spain, 70% of the total energy consumption comes from abroad, and half of the energy generated in the country is supplied by imported combustible fuels [16]. This high energy dependency can cause problems of energy supply and affect wholesale electricity prices as these are linked to international combustible prices.

Renewable energy has been of interest since the oil crisis in the early 1970s [8]. Renewable energy technologies produce energy by converting natural resources into different types of energy. These technologies use the energy inherent in sunlight and its direct and indirect impacts on the Earth, such as wind, falling water, heating effects, and plant growth, gravitational forces, such as tides, and the heat of the Earth's core as the resources from which they produce energy [17]. Renewable energies have a positive impact in issues, such as the depletion of non-renewable energy sources, environmental problems (e.g., acid rain, ozone depletion) and the increase of energy use in developing countries [18]. They can supply-two thirds of global energy demands, and in combination with higher energy efficiency, could deliver 94% of the greenhouse emissions reduction that is necessary to comply with the Paris Agreement [19]. Moreover, the ability to access affordable energy at any time in the future is one of the main drivers for sustainable energy [20]. Because of this, renewable energies play an important role by contributing to mitigate climate change and is regarded as a potential solution to the environmental problems caused by the use of fossil fuels. In Europe, renewable energy development has been part of energy policy since 1986 when the Council of Europe established as one of its main targets to promote renewable energy sources direct [21]. The TERES II report, which aims to provide an update on renewable energy in Europe, estimated that by 2020 renewable energy could contribute as much as 14% of Europe's primary energy, creating around 500,000 jobs [22].

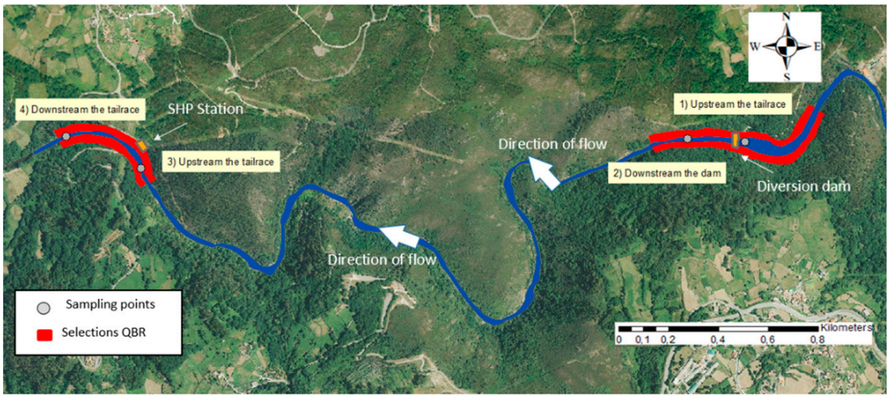
Hydroelectric power, known as hydropower, which is obtained by harnessing the power released when water passes through a vertical distance, has its origins in the pre-industrial revolution [23]. Hydropower electricity generation is considered one of the cheapest technologies regarding electricity generation costs [20], and it is the most traditional, clean, renewable energy source [24]. Hydropower plants have the capacity to respond to different energy demand fluctuations much faster than other systems, and they are able to convert direct mechanic work into electricity, making this technology highly efficient [20]. Hydropower is the leading source of renewable energy accounting for up to 70% of the world's supply [25]. However, despite the environmental benefits offered by hydropower, they also can have negative impacts and consequences in the environment, such as deforestation, aquatic and terrestrial biodiversity loss, affecting water quality and disrupting river ecology [26,27]. Yüksel [28] show that under the Renewables Scenario, 7250 MW of gas-fired capacity is substituted for 19,250 MW of wind and 1107 MW of small hydro over 2000–25. By 2025, all renewables combined (including large hydro) amount to more than 54 GW or 35% of installed capacity.

Although the energy industry in Galicia (Northwest of Spain) contributes to 8% of the region's gross domestic product (GDP) and is one of the main sources of employment, 77% of the region's primary energy is imported [29]. Due to its geographical location, Galicia has the potential to harness renewable energy through wind power, hydropower and biomass. In this work, we focus on hydropower and its effects in the ecosystem. Despite the environmental benefits of the small hydropower plants (SHP), they could negatively affect the ecosystem altering the natural hydrologic regime and the water quality, as well as the fish passage [24]. The aim of this study is, therefore, to investigate the environmental effects of four small hydropower plants (SHP) in north-west Spain by looking at the water quality of the four river stretches where the SHP plants are located. The physicochemical and biological (Iberian Bio-monitoring Working Party index) characteristics of the water streams of the SHP are analyzed, as well as the riparian ecological quality (QBR index). Based on the study of these two indices, it is intended to analyze how SPH affects the whole ecosystem in which they are found.

2. Materials and Methods

2.1. Study Areas and Parameters Studied

The SHP plants are located in the towns of San Xusto (UTM: 29T 539378.405; 4708387.927), Hermida (UTM: 29T 537226.719; 4716799.905), Touro (UTM: 29T 562005.977; 4742137.597), and Gomil (UTM: 29T 580284.87; 4786188.633), in the Lerez, Umia, Ulla and Mandeo rivers, respectively, all of them in Galicia (Figure 1).



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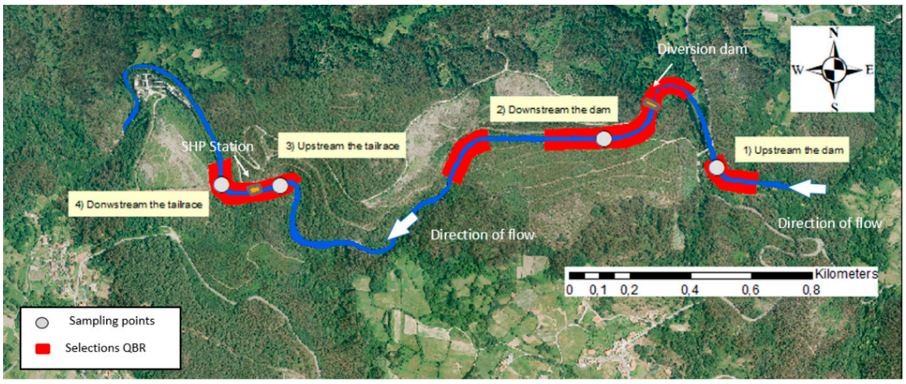

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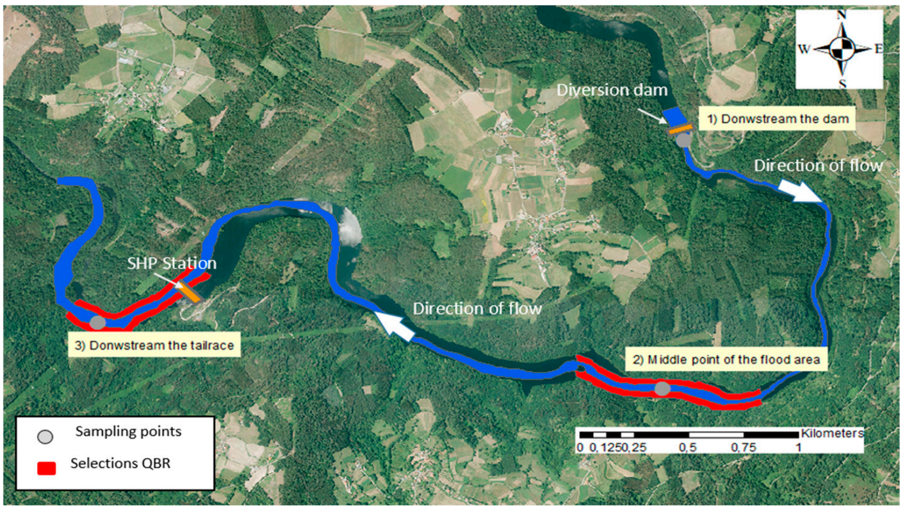

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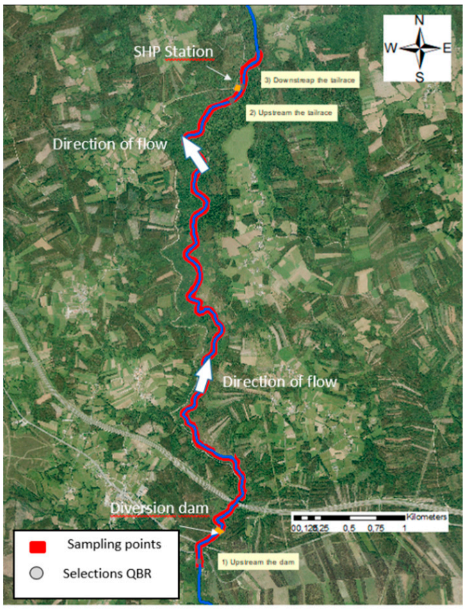

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Figure 1. Location of the sample points. (**a**) Lerez river (**b**) Umia river (**c**) Ulla river (**d**) Mandeo river. Environmental characteristics assessed, parameters and index used, and location of the sampling points (grey circles). Riparian habitat sections, where the QBR (riparian forest quality index) was calculated (red).

The SHP plants consist of a diversion dam that blocks the river and diverts the water, a pipeline that draws the water from a higher level to the powerhouse, a penstock and a powerhouse building. The total power production of the San Xusto, Hermida, Touro and Gomil plants is 11.81 MW, 2.916 MW, 12.81 MW and 9 MW, respectively. The total production of the San Xusto, Hermida, Touro and Gomil plants is 37.81 GWh/year, 9.14 GWh/year, 30.89 GWh/year and 22.82 GWh/year, respectively. The ecological status of the stream water around San Xusto was previously studied and analyzed in Valero [24], and it is included in this work for comparison with the other three SHP plants.

The Directive 2000/60/EC by The European Parliament [30], which establishes the framework in the field of water policy within the EU, was used in this work to assess the water status affected by the SHP plants. Thus, some of the water quality elements described in the directive were considered for this study. The physicochemical parameters taken into consideration were water temperature (T, °C), conductivity (mS/cm), dissolved oxygen (DO, mg/L) and pH (Figure 2).

The Iberian Biological Monitoring Working Party index (BMWP) score system was introduced in 1980 to provide an index of river water quality for England and Wales based on aquatic macroinvertebrates, was used to assess the biological quality of the water [31,32] (Figure 2). To do this, the taxa of macho-benthonic fauna found in the sampled areas were identified to the family level, a predefined score was allocated for each family, and the total BMWP score for a sample was the summation of the scores of all the families found. The scores of the BMWP (0–>100) were grouped in 5 quality classes [31]. In Ulla river, the Iberian Bio-monitoring Working Party index (IBMWP index) was applied in 1 and 3 sample sites because 2 and 4 were very deep waters, due to the embalming effect. The conditions are not suitable for collecting macroinvertebrates. IBMWP scores were then compared with conditions in Cantabric-Atlantic quality elements at high ecological status [33]. This index obtained optimal results in Thailand [34] United Kingdom [35], among others.

The Riparian Forest Quality index (QBR) was used to assess the ecological quality of the riparian habitats [36] (Figure 2). This index varies between 0 and 100, and it is based on four components of riparian habitat: Total riparian vegetation cover, cover structure, cover quality and channel alterations for the different geomorphology of the river from its headwaters to the lower reaches. After completing the analysis, the sum of scores for the four components gives the final QBR index. The QBR index, despite being developed for Mediterranean forests can be adapted to other types of riverside forests, as they have done in other studies [37–39].

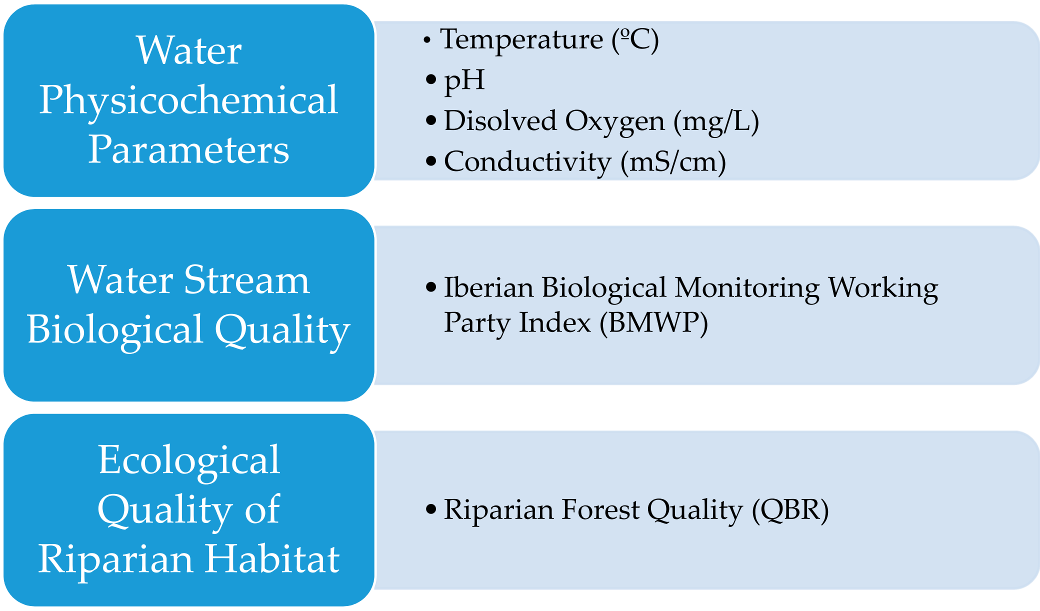


Figure 2. Schematic overview of the methodology.

2.2. Sampling

Four sample points each were selected at San Xusto and Hermida, and three sample points each were selected at Touro and Gomil. The points were selected in areas properly accessible and free of operational risks. A GPS GPSMAP 60CSx (Garmin, Olathe, KS, USA) was used to register the position of the sampling points.

The YSI 556 Handheld Multiparameter Instrument (YSI, Yellow Springs, OH, USA), was used to measure the water's physicochemical parameters in each sampling point. Different sensor types were used: The YSI Temperature Precision™ thermistor, the 4-electrode cell with auto-ranging, the steady-state polarographic, the platinum button, and the glass combination electrode. It was first submerged in the watercourse for twenty minutes for stabilization, and later left submerged (5 m deep) for another twenty minutes, while registering in order to obtain representative data. Measurements were made at the same time of the day.

To analyze the biological quality of the water using the IBMWP index, a 50 m radius from the points were sampled. Point 1 at San Xusto, and point 2 at Touro were not sampled, because it was not easy to obtain enough representative data. Pictures were taken of all the sampled areas and the locations were registered with a GPS. The different types of habitats were identified according to depth, flow velocity, substratum, and vegetation. Then, each habitat was sampled for benthic invertebrates, and captures were identified over a white tray on the field using an atlas and identification key. After the identification, specimens were released back into the river. Benthos which could not be identified in the field were kept in bottles with alcohol at 70% to be identified at the laboratory.

To calculate the QBR index, the Munné protocol [36] was followed, but with some modifications to be adapted to the tree species composition of our study area. A river stretch of 400 m around the dam, and another river stretch of 650 m around the SHP plant and tail race were selected. These reaches were divided into sections with similar characteristics, and the QBR was calculated for each one. Points between two sections with different QBR were located with GPS. We calculated one QBR index for each river bank. Based on the index, it is not necessary to apply it to all the banks, but it is recommended to choose strategic points according to their characteristics. In this study, the riparian vegetation was evaluated in the points where some direct affections were made (because of the construction phase). Intermediate points were considered in these cases where topographic conditions allow access to the river. In this last case, the embalming of the waters, due to the installation of the plants, will make the vegetation to change. However, it will be necessary for a considered period of time to evaluate these changes. The sampling period was carried out between December 2007 and November 2010. The physicochemical parameters and the biological quality of the water were sampled every three months, in March, June, September and December. Directed sampling has been performed—simple samples were collected in triplicate, and at the points already described. The samples were collected in amber borosilicate glass bottles previously washed with sample water. The QBR index was calculated every six months, in March and in September.

2.3. Analyses and Statistics

The software Ecowatch was used to download and process all the physicochemical data and mean, standard deviation, maximum and minimum were calculated. At the laboratory, the macroinvertebrates collected were identified using a glass Motic ST-37 20–80 × (Motic, Xiamen, China). Mean values of each physicochemical variable of the series registered in each sampling point, as well as the IBMWP index, were plotted over time to assess if their values stabilized themselves across time, as well as to observe differences between points. Differences between years and points, as well as differences between the four SHP plants, were analyzed using Kruskal-Wallis tests. Kruskal-Wallis is a nonparametric statistical test that assesses the differences among three or more independently sampled groups on a single, non-normally distributed continuous variable [40].

3. Results

The Kruskal-Wallis tests show no significant differences for the physicochemical parameters of pH, temperature, dissolved oxygen and conductivity between sampling points and years for any of the four plants, except for the temperature at the Touro plant (Table 1). No significant differences were obtained for the four water quality parameters, since the data do not present irregularities over time.

Table 1. Kruskal-Wallis results for each of the physicochemical parameters for each plant.

Plants	Temperature (n = 12)	pH (n = 12)	Dissolved Oxygen (n = 12)	Conductivity (n = 12)
San Xusto (Lerez)	0.249, $p = 0.969$	2.452, $p = 0.484$	3.557, $p = 0.313$	0.642, $p = 0.887$
Hermida (Umia)	2.176, $p = 0.537$	0.960, $p = 0.811$	0.281, $p = 0.964$	0, $p = 1$
Touro (Ulla)	2.573, $p = 0.276$	7.896, $p = 0.019$	0.412, $p = 0.814$	0.293, $p = 0.8634$
Gomil (Mandeo)	0.530, $p = 0.767$	1.794, $p = 0.408$	1.963, $p = 0.375$	0.0858, $p = 0.958$

This is in agreement with other studies, such as those from [41,42]. Jesus et al. evaluated the impact of an SHP plant over a period of two years on the water quality of the Ardena river in Portugal, and found the presence of the hydropower plant did not significantly influence the physical and chemical characteristic of the water. Santos et al. also studied the effects of SHP plants in central and north Portugal and found no significant difference between the physicochemical parameters at the different study sites.

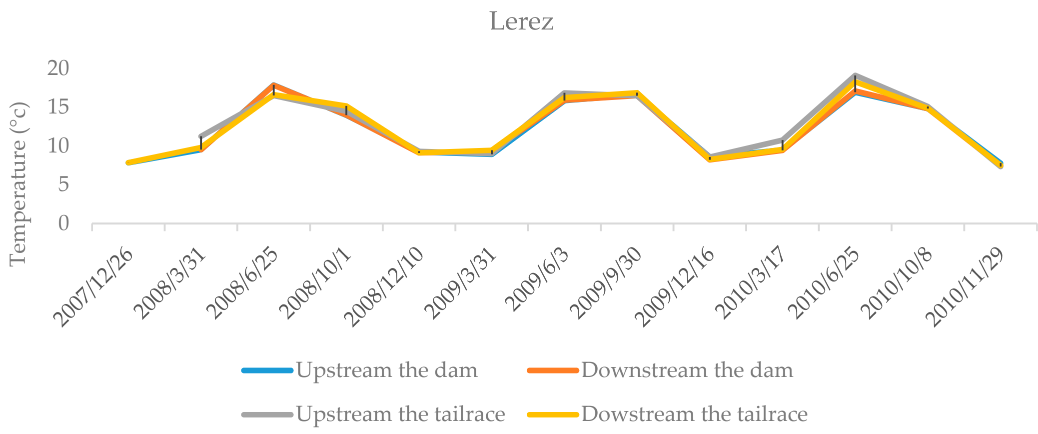
3.1. Temperature

Mean water temperature for the study period was 12.41 °C, 12.26 °C, 13.24 °C and 11.06 °C at San Xusto, Hermida, Touro and Gomil, respectively. Temperature values were in concordant with those from the Reference Condition in Cantabric-Atlantic siliceous rivers from IPH 2008 [43] (Table 2), where it is specified that the river's elements of this study belongs to the siliceous Cantabrian-Atlantic rivers.

Table 2. Reference Condition in Cantabric-Atlantic siliceous rivers.

Parameters	Reference Condition	Threshold Good/Moderate
Temperature (°C)	13.00	10.4–15.6
pH	7.00	6.0–8.4
Dissolved oxygen (mg/L)	9.00	6.7
Conductivity (mS/cm)	0.04	<0.03

These results also comply with the requirements of Directive 2006/44/EC [44] on the quality of freshwaters needing protection or improvement in order to support fish life, by which thermal discharges must not cause the temperature downstream of the point of thermal discharge to exceed 21.5 °C in salmonid waters. Temperature limits were not exceeded in any sampling point for any period in any of the plants (Figure 3). Directive 2006/44/EC also states that thermal discharges must not cause the temperature downstream of the point of thermal discharge to exceed 10 °C during breeding periods of salmonid species, which need cold water for reproduction and only to waters that contain such species. In Galician waters, the period when salmon breed extends from November to January [45]. Temperatures registered for all sampling points between November and January was below 10 °C at San Xusto, Hermida, and Gomil. The temperature at the Touro plant was above 10 °C in all points for two of the sampling periods. However, the Kruskal-Wallis test showed no significant difference between the temperatures recorded for all the points during the study period.



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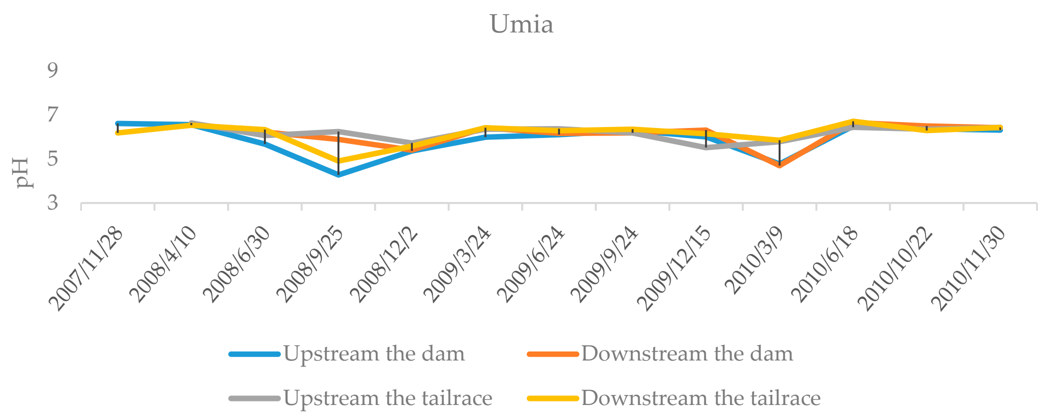

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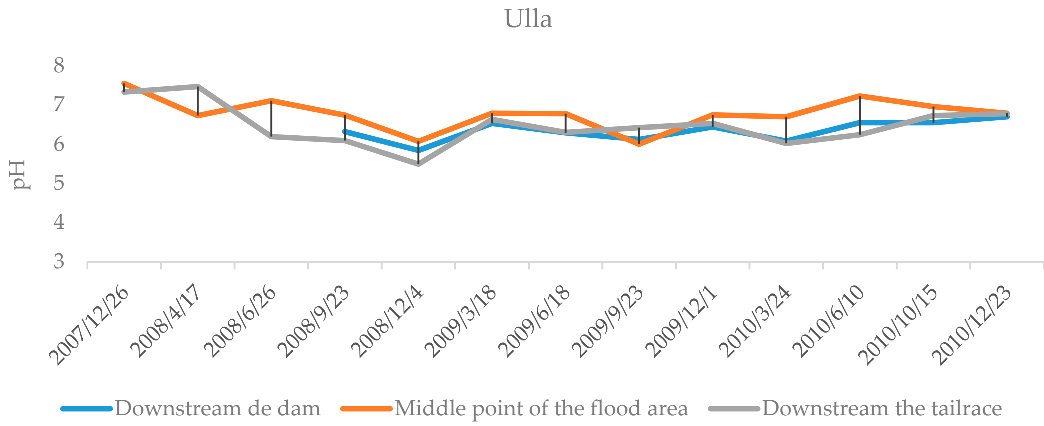

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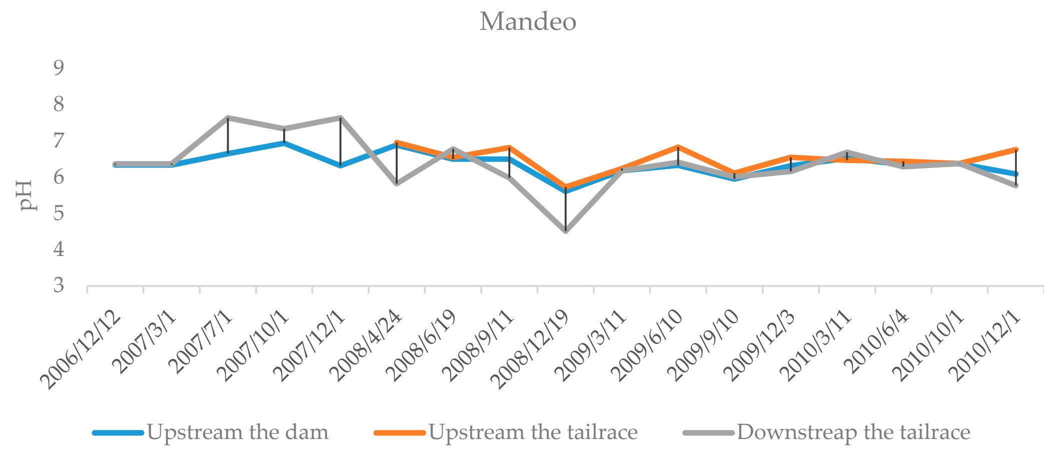

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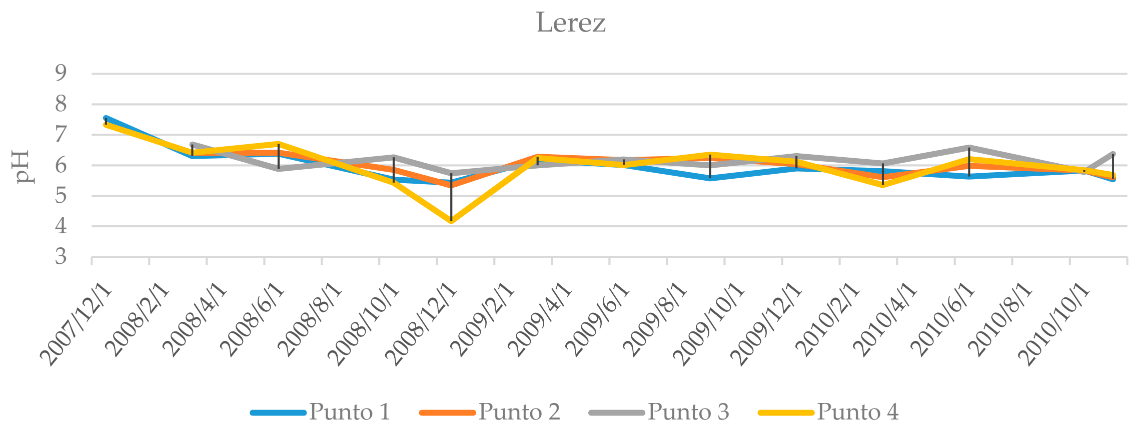
Figure 3. Temperature values measured during the survey period at (**a**) Lerez (San Xusto plant), (**b**) Umia (Hermida plant), (**c**) Ulla (Touro plant) and (**d**) Mandeo (Gomil plant).

3.2. pH

According to the Directive 2006/44/EC, artificial pH variations with respect to the unaffected values shall not exceed ±0.5 of a pH unit within the limits falling between 6.0 and 9.0 provided that these variations do not increase the harmfulness of other substances present in the water. At San Xusto and Hermida, low pH values were recorded in all four points close to the lower limit allowed for salmonid waters (Figure 4). However, mean pH values for all points for the sampling period was 6.02 and 6.09 at San Xusto and Hermida, respectively, which is within the limits established by the directive. In addition, there were no significant differences between all observations recorded in any of the two plants. Mean pH values for all points at Touro was 6.55, falling within the limits established by the Directive 2006/44/EC. There were only two observations at Touro, in points 1 and 3 recorded during the same period, where the pH value was below 6. Kruskal-Wallis test showed a significant difference between the sampled points. At Gomil, mean pH values for all points was 6.40, and there was no significant difference between the sampled points. However, some observations showed values below 6, but these were close to the limit allowed. According to Reference Condition (Table 2), the quality of the water for the four river starches can be classified as good/moderate.

The low pH values obtained for some of the points could be explained by the natural characteristics of the waters in Galicia, which are generally acidic [46].



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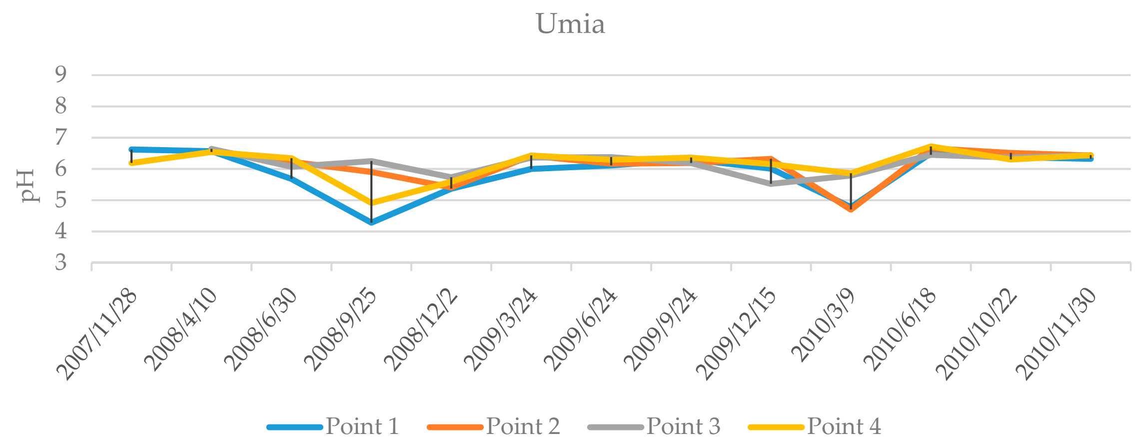

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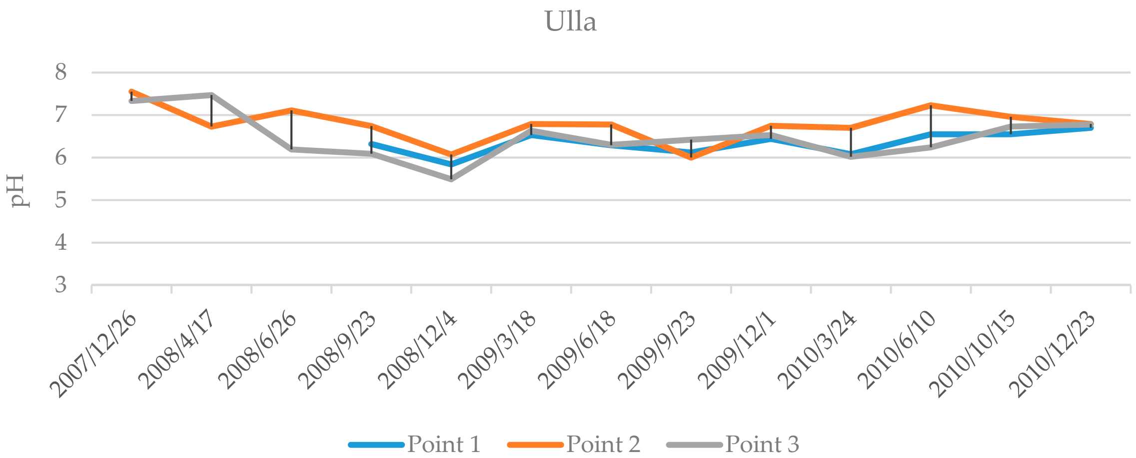

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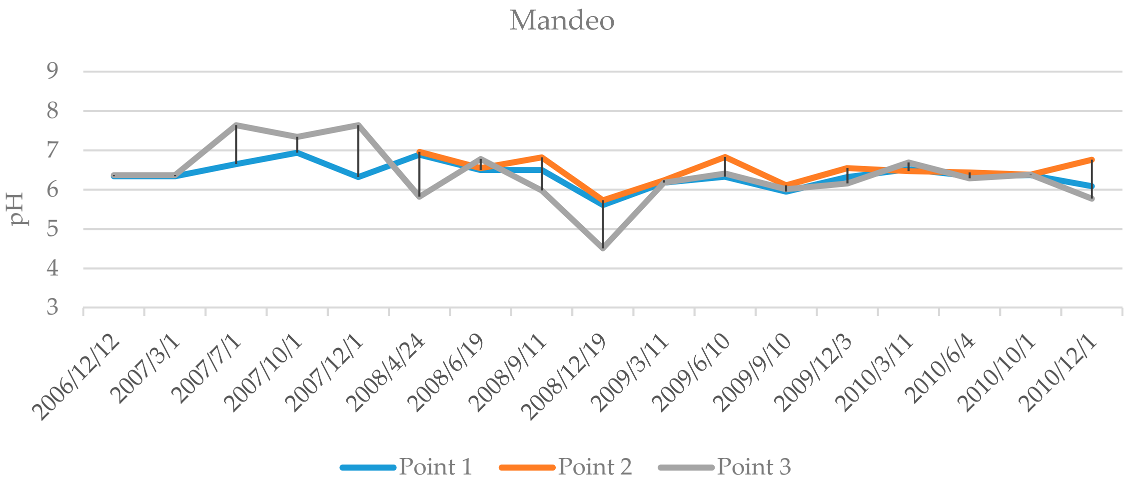

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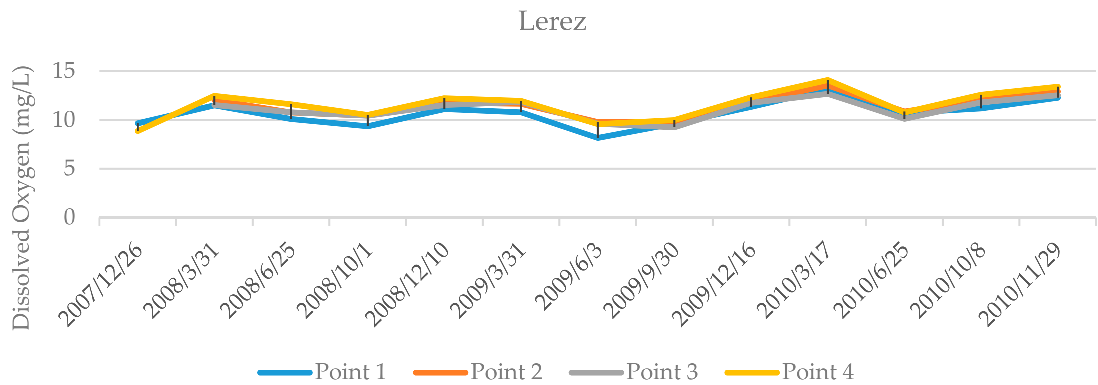
Figure 4. pH values measured during the survey period at (**a**) Lerez (San Xusto plant), (**b**) Umia (Hermida plant), (**c**) Ulla (Touro plant) and (**d**) Mandeo (Gomil plant).

3.3. Dissolved Oxygen

Mean dissolved oxygen values for the study period was 11.19 mg/L, 11.17 mg/L, 9.60 mg/L and 11.03 mg/L at San Xusto, Hermida, Touro and Gomil, respectively. These values were higher than the Reference Condition (Table 2). The results are in agreement with Directive 2006/44/EC, which states that the dissolved oxygen of 50% of the samples recorded must be equal or above to 9 mg/L. San Xusto plant had 96% of values above 9 mg/L, Hermida plant had 94% of values above 9 mg/L, Touro plant had 55% of values above 9 mg/L, and Gomil plant had 97.82% of values 9 mg/L (Figure 5). Results for the Kruskal-Wallis test show no significant difference between points during the study period for any of the plants. Dissolved oxygen concentration was inversely linked to temperature, which matches results from [41].



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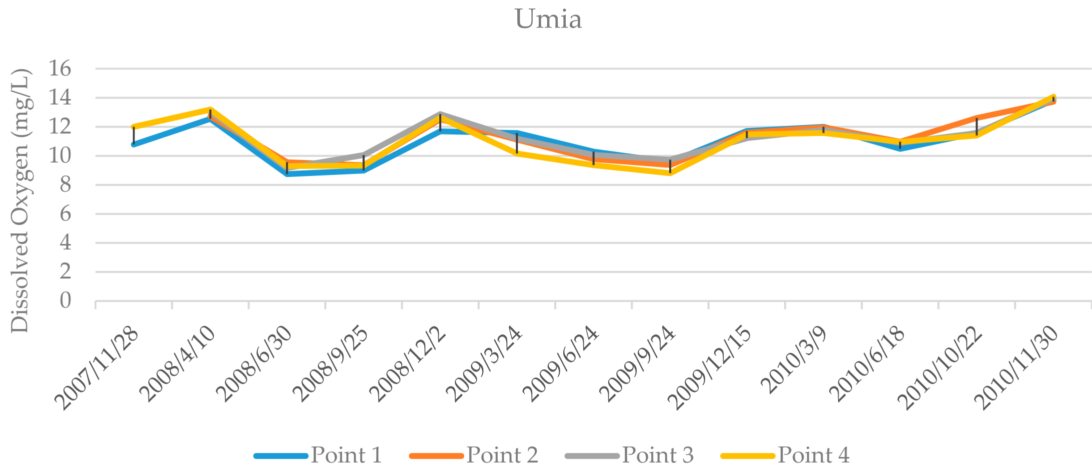

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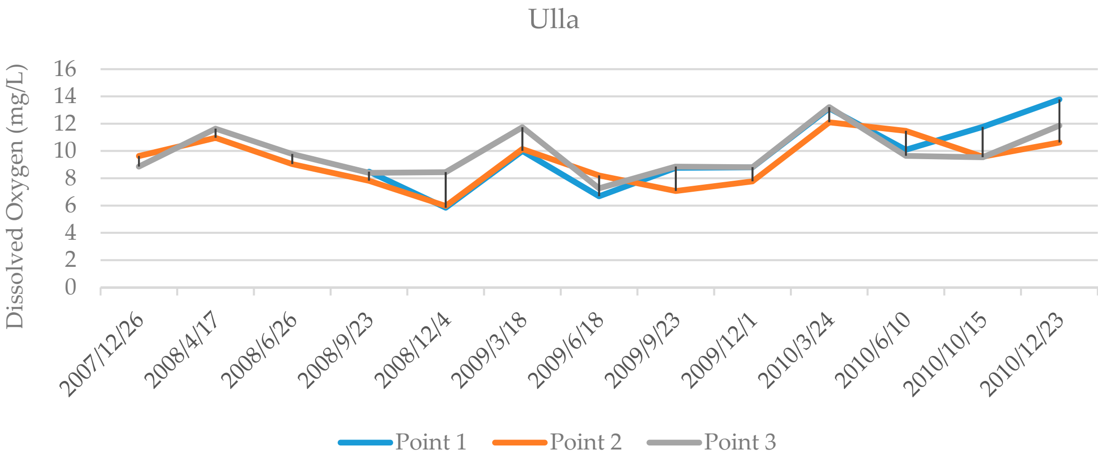

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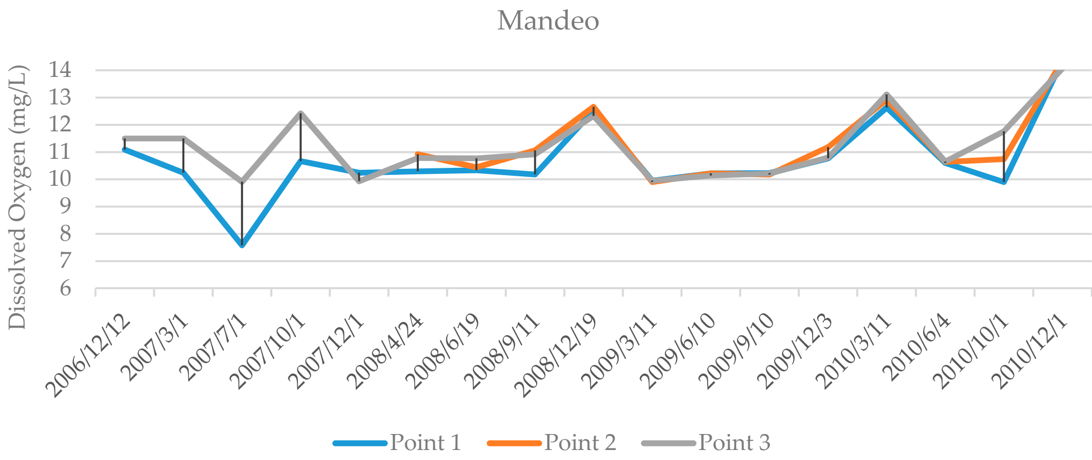

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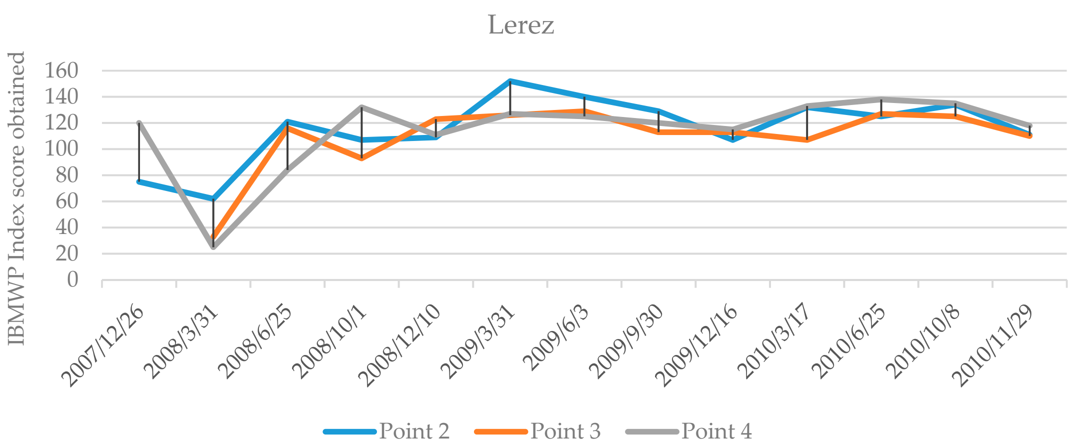
Figure 5. Dissolved oxygen values measured during the survey period at (**a**) Lerez (San Xusto plant), (**b**) Umia (Hermida plant), (**c**) Ulla (Touro plant) and (**d**) Mandeo (Gomil plant).

3.4. Conductivity

Mean conductivity values were 0.04 mS/cm at San Xusto and Hermida, 0.09 mS/cm at Touro and 0.07 mS/cm at Gomil. There were no significant differences between the points for any of the plants from the Kruskal-Wallis test. Our results are in compliance with the requirement from Reference Condition (Table 2) for San Xusto and Hermida, and are very close for Touro and Gomil. These results are also in agreement with previous studies from Costas et al. (2009) [47] and Ansemil and Membiela (1992) [46].

3.5. Biological Status of the Water

A total of 12 samples were collected for each river. At San Xusto, IBMPW index had a lower score at point 3, located upstream the power plant, than at points 2 and 4, although the Kruskal-Wallis test showed no significant differences between points (Kruskal–Wallis test = 1.756; df = 2; $p = 0.416$), and 86.84% of the scores fell within Quality I category (unpolluted or not consider altered water). At Hermida, Kruskall-Wallis test showed no significant differences between points (Kruskal-Wallis chi-squared = 3.800, df = 3, p-value = 0.283), and 95.91% of the scores fell within Quality I category. At Gomil, Kruskal-Wallis test showed no significant differences between points (Kruskal-Wallis chi-squared = 0.286, df = 2, p-value = 0.866), and 86.95% of the scores fell in the Quality I category. These results (Figure 6) are in agreement with some authors, such as Copeman (1997) and Almodóvar and Nicola (1999), [48,49], who found there were no alterations of the benthic macroinvertebrate community, due to small hydropower plants. At Touro, on the other hand, scores were very low, only 8.69% of them falling within Quality I category. Mann-Whitney test showed a significant difference between points ($p < 0.05$). In Point 1, all scores fell within Quality V category (waters highly contaminated), whereas, in point 3 most of the scores fell within Quality III category (evidence of some contamination). It is important to point out that the low scores obtained in point 1 are probably not, due to the low biological quality of the water, but rather to the lack of representative areas when the sampling was done.



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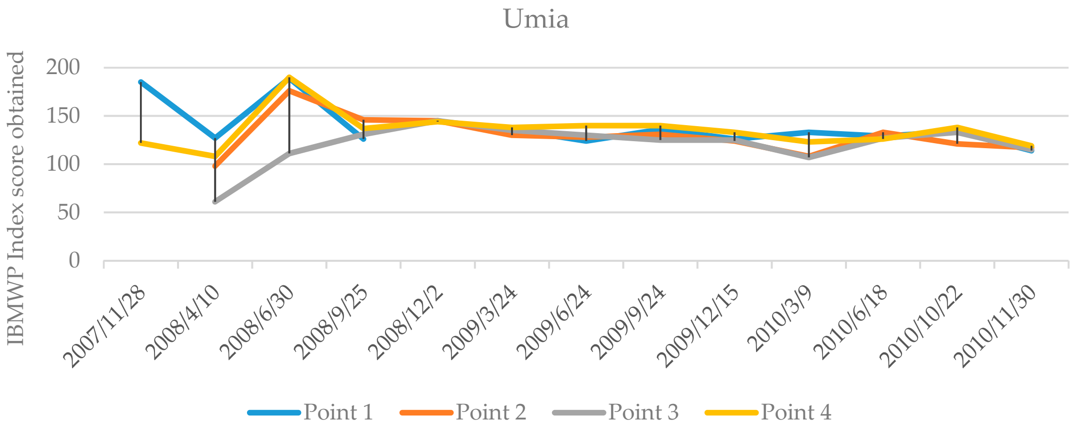

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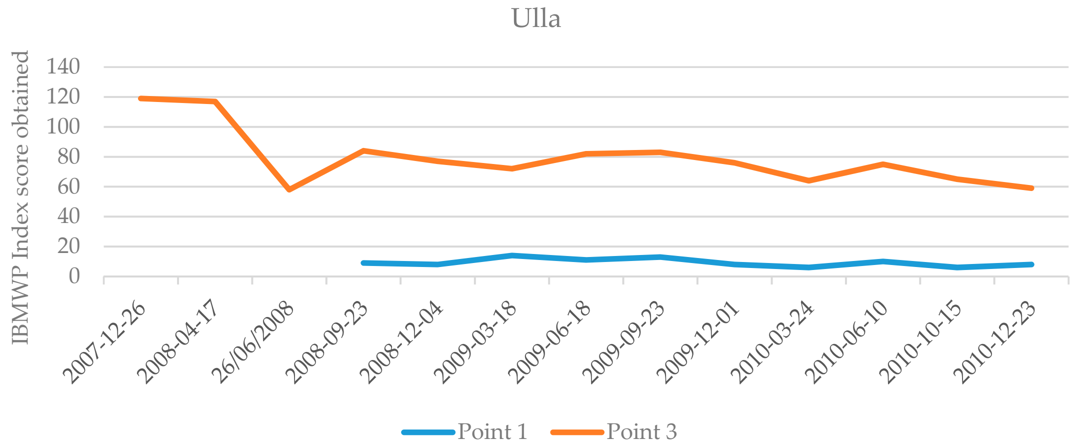

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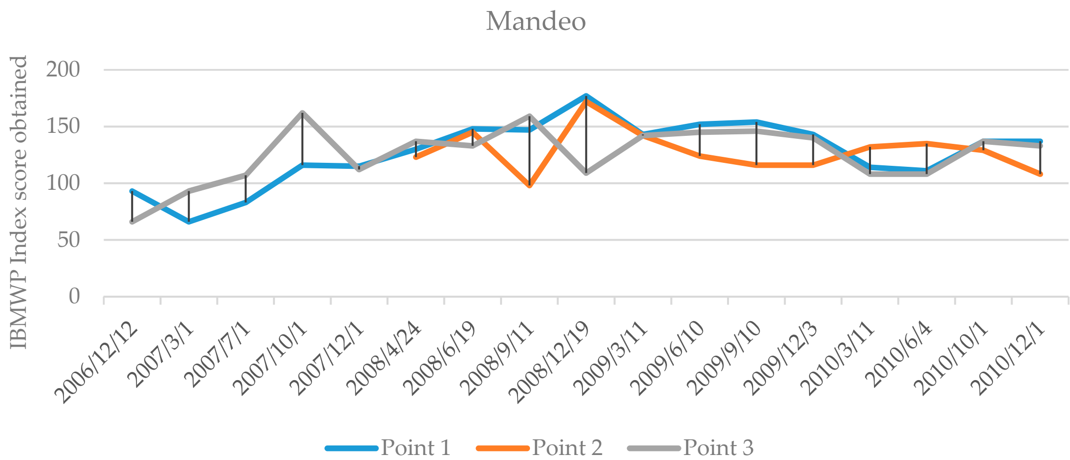
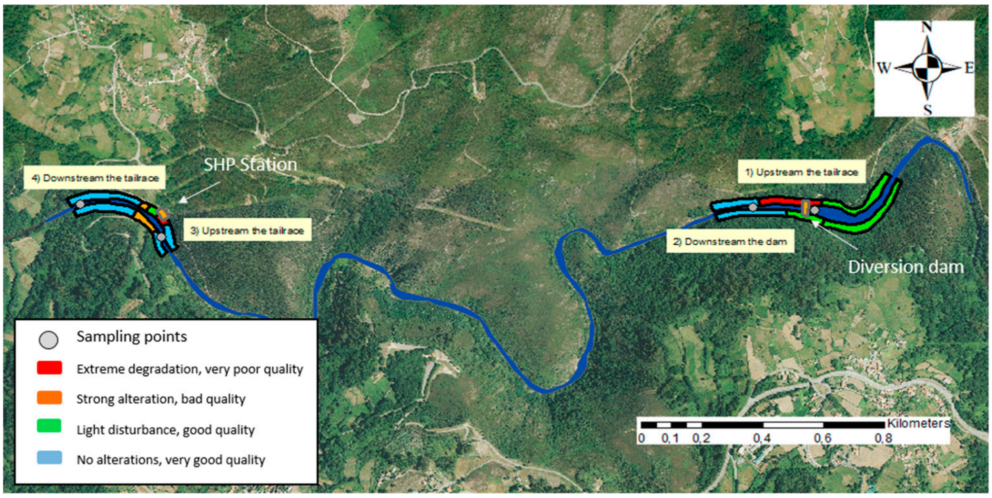


(**d**)

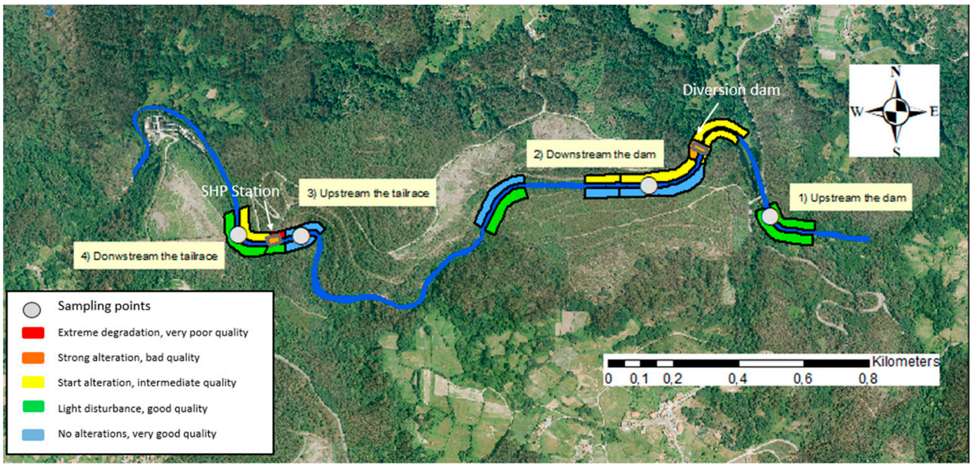
Figure 6. Evolution of the water biological quality index IBMWP during the period of study: I (>120) very clean waters; I (101–120) unpolluted or not considerably altered water; II (61–100) moderate effects of pollution are evident; III (36–60) polluted water; IV (16–35) very polluted water; V (<15) heavily polluted water, at (**a**) Lerez (San Xusto plant), (**b**) Umia (Hermida plant), (**c**) Ulla (Touro plant) and (**d**) Mandeo (Gomil plant).

3.6. Ecological Status of the Riparian Zones

A total of 7 samples were collected for each river. At San Xusto, the evaluation of the habitat according to the QBR index showed two river bank sections with extreme degradation and two with strong alteration, while in the remaining sections, the riparian habitat was classified as good quality or natural conditions (Figure 7). At Hermida, QBR index showed one section with extreme degradation, one section with strong alteration, while in the remaining sections, the riparian habitat was classified fair to good quality or even as having natural conditions (Figure 7). At Touro, the QBR index showed three sections with extreme degradation, while in the remaining sections, the riparian habitat was classified fair to good quality (Figure 7). At Gomil, the QBR index showed two sections with extreme degradation and four with strong alteration, while in the remaining sections, the riparian habitat was classified fair to good quality or even natural conditions (Figure 7).

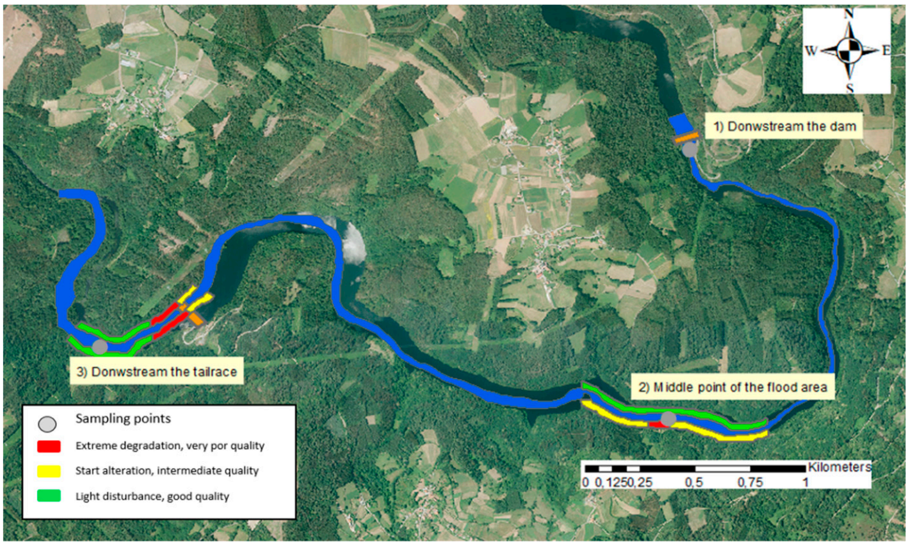


(**a**)

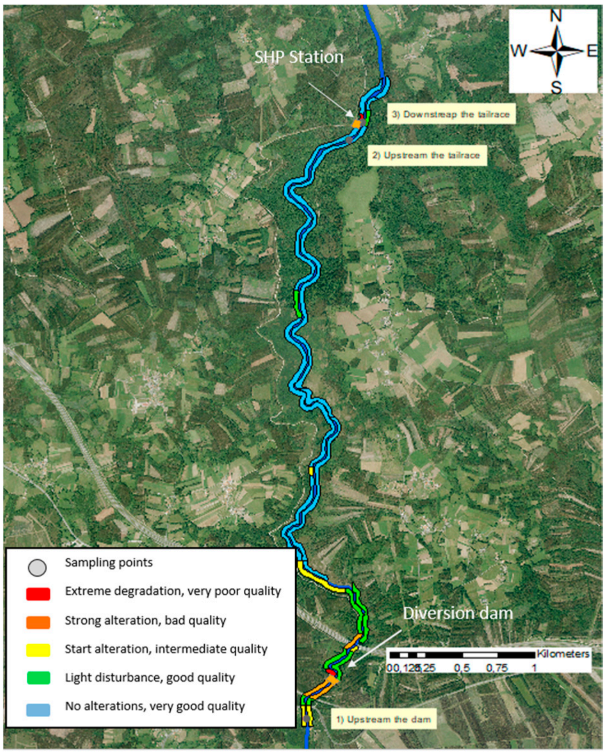


(**b**)

Figure 7. *Cont.*



(**c**)



(**d**)

Figure 7. Riparian habitat quality index QBR in the reaches of the rivers (**a**) Lerez, (**b**) Umia, (**c**) Ulla and (**d**) Mandeo.

3.7. General Discussion

Renewable energies, such as the one provided by SPH are a clean source of energy. Regarding the four plants studied in the present work, it must be taken into account that their installation in the last decades was done without prior planning, and without any specific studies and analyses on the ecological quality of the river environment. Therefore, without these previous studies, it is very difficult to predict and know what impacts these SPHs have on the ecosystem.

For better planning, the idea would have been to carry out studies prior to the construction, and also during the different construction stages to have a better understanding of the final impacts.

These studies should have been planned in four distinct phases corresponding to: Phase 0 (prior to construction), construction phase, exploitation phase, and abandonment or dismantling phase.

In this way, we would have had information on how the ecosystem would change from its original state (on a small scale and on a global scale). We would also be able to know what impacts the construction works generate. The construction can generate environmental problems, such as spills and reduction of flows, which can have specific effects on some species. Finally, we could have made an evaluation of the evolution of the ecosystem once the plant began to work, so the impact of the operation of the plant itself (water diversion, heating of the water, etc.) would have been known. In the case of the long-term impacts that SPHs can cause, analyses over several years would be recommended.

Small impacts have been detected with this study, but they are short term since the sampling data are from 2007 to 2010. This study focuses on the impacts that the SPHs operation may have on the ecological quality of water and riverbank vegetation in the short term. What we want to highlight is that there are impacts that occur in the aquatic ecosystem, therefore, it is important to know to what extent they occur. In this way, preventive measures would be taken from the knowledge that these analyses can generate. On the other hand, to know the extent of these impacts, it is very important to have a large-scale data collection. In this way, water managers, energy companies and users., can make changes in their trends, consumption and models.

4. Conclusions

Results showed uniformity of the data obtained. Temperature limits were not exceeded at any point in any of the plants. Temperatures registered during the salmon breeding period was below 10 °C for all the plants with the exception of Touro. San Xusto and Hermida plants showed low pH values. However, mean pH at all the plants fell within the limits established. The low pH values obtained for some of the points could be explained by the natural characteristics of the waters in Galicia, which are generally acidic [50]. Mean dissolved oxygen values for the study period were in agreement with Directive 2006/44/EC, which states that 50% of the samples must be equal to or greater than 9 mg/L. Mean conductivity samples were in compliance with requirements outlined in Reference Condition for San Xusto and Hermida, and were very close for Touro and Gomil. The IBMPW results showed no alterations of the benthic macroinvertebrate community at any of the plants except for Touro, where scores were very low, although this could be explained, due to the lack of representative areas when the sampling was done. The riparian habitat (QBR index) was in general classified as good quality or close to natural conditions for all plants. The lack of data prior to the construction of the power plants is, in many cases, a limitation when determining their effects. It would be adequate to do the analyses with this information to have a complete picture.

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References

1. Azad, K.; Rasul, M.; Khan, M.M.; Ahasan, T.; Ahmed, S. Energy Scenario: Production, Consumption and Prospect of Renewable Energy in Australia. *J. Power Energy Eng.* **2014**, *2*, 19–25. [CrossRef]
2. Osho, G.; Nazemzadeh, A.; Osagie, J.; Williford, R. Increased Demand for Oil in Developing Countries: Effects on the Global Oil Trade. *Southwest Rev. Int. Bus. Res.* **2005**, *15*, 221–231.
3. Lutz, W.; Samir, K.C. Dimensions of global population projections: What do we know about future population trends and structures. *Philos. Trans. R. Soc. B Biol. Sci.* **2010**, *365*, 2779–2791. [CrossRef] [PubMed]
4. Krane, J. Climate change and fossil fuel: An examination of risks for the energy industry and producer states. *MRS Energy Sustain.* **2017**, *4*, E2. [CrossRef]
5. Lelieveld, J.; Klingmüller, K.; Pozzer, A.; Burnett, R.T.; Haines, A.; Ramanathan, V. Effects of fossil fuel and total anthropogenic emission removal on public health and climate. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 7192–7197. [CrossRef]
6. Intergovernmental Panel on Climate Change. Summary for Policymakers. In *Climate Change 2007: Mitigation of Climate Change: Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2015; pp. 1–30.
7. Landrigan, P.J.; Fuller, R.; Acosta, N.J.R.; Adeyi, O.; Arnold, R.; Basu, N.N.; Baldé, A.B.; Bertollini, R.; Bose-O'Reilly, S.; Boufford, J.I.; et al. The Lancet Commission on pollution and health. *Lancet* **2018**, *391*, 462–512. [CrossRef]
8. Dincer, I. Renewable energy and sustainable development: A crucial review. *Renew. Sustain. Energy Rev.* **2000**, *4*, 157–175. [CrossRef]
9. Johnsson, F.; Kjärstad, J.; Rootzén, J. The threat to climate change mitigation posed by the abundance of fossil fuels. *Clim. Policy* **2019**, *19*, 258–274. [CrossRef]
10. Caldeira, K.; Bala, G.; Cao, L. The Science of Geoengineering. *Annu. Rev. Earth Planet. Sci.* **2013**, *41*, 231–256. [CrossRef]
11. Larkin, A.; Kuriakose, J.; Sharmina, M.; Anderson, K. What if negative emission technologies fail at scale? Implications of the Paris Agreement for big emitting nations. *Clim. Policy* **2018**, *18*, 690–714. [CrossRef]
12. Fuss, S.; Canadell, J.G.; Peters, G.P.; Tavoni, M.; Andrew, R.M.; Ciais, P.; Jackson, R.B.; Jones, C.D.; Kraxner, F.; Nakicenovic, N.; et al. Betting on negative emissions. *Nat. Clim. Chang.* **2014**, *4*, 850. [CrossRef]
13. Raftery, A.E.; Zimmer, A.; Frierson, D.M.W.; Startz, R.; Liu, P. Less than 2 °C warming by 2100 unlikely. *Nat. Clim. Chang.* **2017**, *7*, 637. [CrossRef]
14. Tzimas, E.; Georgakaki, A.; Peteves, S. *Future Fossil Fuel Electricity Generation in Europe: Options and Consequences*; Joint Research Center, European Commission: Petten, The Netherlands, 2009.
15. Green, R.; Staffell, I. Electricity in Europe: Exiting fossil fuels. *Oxf. Rev. Econ. Policy* **2016**, *32*, 282–303. [CrossRef]
16. Moreno, B.; García-Álvarez, M.T. Analyzing the impact of fossil fuel import reliance on electricity prices: The case of the Iberian Electricity Market. *Energy Environ.* **2017**, *28*, 687–705. [CrossRef]
17. Hartley, D. Perspectives on renewable energy and the environment. In *Energy and the environment in the 21st Century*; Tester, J., Wood, D., Ferrari, N., Eds.; MIT: Cambridge, MA, USA, 1990.
18. McGowan, J. Large-scale solar/wind electrical production systems-predictions for the 21st Century. In *Energy and the environment in the 21st Century*; Tester, J., Wood, D., Ferrari, N., Eds.; MIT: Cambridge, MA, USA, 1990.
19. Gielen, D.; Boshell, F.; Saygin, D.; Bazilian, M.D.; Wagner, N.; Gorini, R. The role of renewable energy in the global energy transformation. *Energy Strategy Rev.* **2019**, *24*, 38–50. [CrossRef]
20. Kaunda, C.S.; Kimambo, C.Z.; Nielsen, T.K. Hydropower in the Context of Sustainable Energy Supply: A Review of Technologies and Challenges. *ISRN Renew. Energy* **2012**. [CrossRef]
21. *Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 Concerning Common Rules for the Internal Market in Electricity*; Official Journal of the European Union: Brussels, Belgium, 1996.
22. Míguez, J.L.; López-González, L.M.; Sala, J.M.; Porteiro, J.; Granada, E.; Morán, J.C.; Juárez, M.C. Review of compliance with EU-2010 targets on renewable energy in Galicia (Spain). *Renew. Sustain. Energy Rev.* **2006**, *10*, 225–247. [CrossRef]
23. Sims, G.P. Hydroelectric energy. *Energy Policy* **1991**, *19*, 776–786. [CrossRef]
24. Valero, E. Characterization of the Water Quality Status on a Stretch of River Lérez around a Small Hydroelectric Power Station. *Water* **2012**, *4*, 815–834. [CrossRef]

25. Moran, E.F.; Lopez, M.C.; Moore, N.; Müller, N.; Hyndman, D.W. Sustainable hydropower in the 21st century. *Proc. Natl. Acad. Sci. USA* **2018**, *115*, 11891–11898. [CrossRef]
26. Ziv, G.; Baran, E.; Nam, S.; Rodriguez-Iturbe, I.; Levin, S.A. Trading-off fish biodiversity, food security, and hydropower in the Mekong River Basin. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 5609–5614. [CrossRef] [PubMed]
27. Benchimol, M.; Peres, C.A. Widespread Forest Vertebrate Extinctions Induced by a Mega Hydroelectric Dam in Lowland Amazonia. *PLoS ONE* **2015**, *10*, e0129818. [CrossRef] [PubMed]
28. Yüksel, I. Hydropower in Turkey for a clean and sustainable energy future. *Renew. Sustain. Energy Rev.* **2008**, *12*, 1622–1640. [CrossRef]
29. INEGA. Balance Enexetico de Galicia. 2007. Available online: http://www.inega.gal/publicacions/balanceenerxetico/publicacion_0017.html (accessed on 20 November 2019).
30. *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy*; Official Journal of the European Union: Brussels, Belgium, 2000.
31. Alba-Tercedor, J.; Sánchez-Ortega, A. A quick and simple method to evaluate biological quality of running fresh water based on Hellawell (1978). *Limnetica* **1988**, *4*, 51–56.
32. Alba-Tercedor, J.; Jáimez-Cuéllar, P.; Álvarez, M.; Avilés, J.; Bonada, N.; Casas, J.; Mellado, A.; Ortega, M.; Pardo, I.; Prat, N. Characterization of the ecological status of the Iberian Mediterranean rivers using the index IBWP (former BMWP'). *Limnetica* **2002**, *21*, 175–185.
33. Toro, M.; Robles, S.; Tejero, I.; Cristóbal, E.; Velasco, S.; Sáchez, J.R.; Pujante, A. Group 32. Ecological Type 21. Siliceous Cantabric-Atlantic Rivers. Preliminary Ecological Basis for Conservation of Habitat Types of Community Interest in Spain. Ministerio de Medio Ambiente y Medio Rural Marino: Madrid, Spain, 2009; Available online: http://www.jolube.es/Habitat_Espana/documentos/32%20T21.pdf (accessed on 19 November 2019).
34. Mustow, S.E. Biological monitoring of rivers in Thailand: Use and adaptation of the BMWP score. *Hydrobiologia* **2002**, *479*, 191–229. [CrossRef]
35. Paisley, W.J.; Trigg, M.F.; Walley, D.J. Revision of the biological monitoring working party (bmwp) score system: Derivation of present-only and abundance-related scores from field data. *River Res. Appl.* **2014**, *30*, 887–904. [CrossRef]
36. Munné, A.; Prat, N.; Solà, C.; Bonada, N.; Rieradevall, M. A simple field method for assessing the ecological quality of riparian habitat in rivers and streams: QBR index. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2003**, *13*, 147–163. [CrossRef]
37. Colwell, D.M.; Hix, S.R. Adaptation of the QBR index for use in riparian forests of central Ohio. In Proceedings of the 16th Central Hardwood Forest Conference, West Lafayette, IN, USA, 8–9 April 2008; pp. 331–340.
38. Tüzün, İ.; Albayrak, İ. The effect of disturbances to habitat quality on otter (Lutra lutra) activity in the river Kızılırmak (Turkey): A case study. *Turk. J. Zool.* **2005**, *29*, 327–335.
39. Miserendino, A.M.; Casaux, M.L.; Archangelsky, R.; di Prinzio, M.; Brand, C.Y.; Kutschker, C. Assessing land-use effects on water quality, in-stream habitat, riparian ecosystems and biodiversity in Patagonian northwest streams. *Sci. Total Environ.* **2011**, *409*, 612–624. [CrossRef]
40. McKight, J.; Najab, P.E. Kruskal-wallis test. *Corsini Encycl. Psychol.* **2010**. [CrossRef]
41. Jesus, T.; Formigo, N.; Santos, P.; Tavares, G. Impact Evaluation of the Vila Viçosa Small Hydroelectric Power Plant (Portugal) on the Water Quality and on the Dynamics of the Benthic Macroinvertebrate Communities of the Ardena River. *Limnetica* **2004**, *23*, 241–256.
42. Santos, J.; Ferreira, M.; Pinheiro, A.; Bochechas, J. Effects of Small Hydropower Plants on Fish Assemblages in Medium-Sized Streams in Central and Northern Portugal. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **2006**, *16*, 373–388. [CrossRef]
43. *ORDEN ARM/2656/2008, de 10 de septiembre, por la que se aprueba la instrucción de planificación hidrológica*; Boletín Oficial del Estado (BOE): Madrid, Spain, 2008; Available online: https://www.boe.es/buscar/doc.php?id=BOE-A-2008-15340 (accessed on 18 November 2019).
44. *Directive 2006/44/EC of the European Parliament and of the Council of 6 September 2006 on the Quality of Fresh Waters Needing Protection or Improvement in Order to Support Fish Life*; Official Journal of the European Union: Brussels, Belgium, 2006.

45. *Galician Plan of Management of Fish Resources and Continental Aquatic Ecosystems*; Xunta de Galicia: Santiago de Compostela, Spain, 2005; Available online: https://issuu.com/axentesforestais/docs/plan_galego_de_recursos_pisc_colas_e_ecosistemas_a (accessed on 21 November 2019).
46. Ansemil, E.M.; Membiela, P. The Low Mineralized and Fast Turnover Watercourses of Galicia. *Limnetica* **1992**, *8*, 125–130.
47. Costas, N.; ÁLvarez, M.; Pardo, I. Characterization of an Atlantic salmon *Salmo salar* stream at the southern limit of its eastern Atlantic distribution. *J. Fish Biol.* **2009**, *75*, 2552–2570. [CrossRef]
48. Copeman, V.A. The Impact of Micro-Hydropower on the Aquatic Environment. *Water Environ. J.* **1997**, *11*, 431–435. [CrossRef]
49. Almodóvar, A.; Nicola, G.G. Effects of a small hydropower station upon brown trout *Salmo trutta* L. in the River Hoz Seca (Tagus basin, Spain) one year after regulation. *Regul. Rivers Res. Manag.* **1999**, *15*, 477–484. [CrossRef]
50. Vázquez, F.M.; de Anta, R.C. Niveles Genéricos De Referencia De Metales Pesados Y Otros Elementos Traza En Suelos De Galicia. *Xunta Galicia* **2009**. [CrossRef]