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Coarse fishway assessment to prioritize retrofitting efforts: a case study in the Duero River basin

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ABSTRACT

Restoring the longitudinal connectivity of rivers is one of the main objectives of environmental European directives and policies. Fish passes or fishways are one of the most common actions for its restoration. Despite the great number of fish passes constructed during the last two decades to comply with these policies, few of them have been assessed and their suitability for fish movements is unknown. There are different options to assess fish passes, but time and economic costs frequently limit their application. Coarse fishway assessment methods (CFAMs) are an easy, fast and economic alternative for this purpose. This study aims to display the potential of CFAMs to evaluate a large number of fishways, to show the actual status of fishways in an Iberian representative river basin, and to diagnose their suitability and problems. For this, the Spanish Duero River Authority promoted the assessment of 64 stepped fishways in the Duero River basin (Spain) using the AEPS methodology. The results were analyzed considering the four stages that a fish must overcome in a fishway (attraction, entry, passage and exit), the fishway type and the construction period. Among others, results show that 50 % of the assessed fishways allow the free movement of fish. However, this percentage could have been greater applying an adequate monitoring program for the fishway design and construction. Furthermore, the diagnosis by stages of the AEPS methodology allowed to identify the attraction and passage as the most problematic stages and also helped to define specific retrofitting solutions for each fishway. The study concludes that the application of CFAM during fishway design, construction and first operation stages can increase their effectiveness and, thus, the number of fish passes that contribute to the restoration of the longitudinal connectivity of rivers.

Keywords: fishway evaluation, AEPS methodology, fish migration, river connectivity.

1. INTRODUCTION

Since the earliest human settlements, rivers have been sources of food, energy, transport and protection. This has generated many alterations in freshwater ecosystems together with many positive and negative environmental impacts all over the world (Dudgeon et al., 2006). One of the most harmful impacts is the rupture of river longitudinal connectivity by cross-sectional barriers (Nilsson et al., 2005). Among other consequences, these obstacles (e.g. dams, weirs, etc.) directly affect to fish fauna by hindering or preventing their natural movements to find suitable habitats for their reproduction, feeding and/or refuge (Lucas et al., 2001; Wofford et al., 2005). This has cause the reduction and the disappearance of many fish populations worldwide (Hall et al., 2011; Porcher and Travade, 2002; Doadrio et al., 2011).

One of the main objectives of environmental European directives and policies is to enhance the longitudinal connectivity of rivers to improve and recover their biodiversity [e.g. Habitats Directive and Water Framework Directive (WFD)]. This has led to the accelerated adoption of actions to restore the fluvial connectivity. These actions range from the removal of the in-stream barriers to the capture and transport of fish. Nevertheless, the most common alternative is the construction of fish passes (also named as fishways) (Clay, 1995; FAO/DVWK, 2002; M. Larinier, 2002), being stepped fishways the most widespread solution around the world (Noonan et al., 2012). A stepped fishway consists on a succession of cross-walls in a sloped channel, connected by slots, notches and/or orifices, that divide the total height of the obstacle (H) in smaller drops (ΔH) to ensure that the hydraulic conditions inside are in the range of the physical capacities of fish fauna and, thus, enable their passage (Fuentes-Pérez et al., 2017).

However, inadequate designs or negligent constructions can lead to the inefficiency of fish passes. Thus, building a fishway does not guarantee that fish fauna can overcome an obstacle (Castro-Santos et al., 2009; Roscoe and Hinch, 2010) and their assessment becomes vital to ensure that they really help to the restoration of river connectivity as well as to identify possible operating problems. Nowadays, a small number of fishways has been assessed worldwide, obtaining despair and in many cases negative results (Bunt et al., 2016, 2012).

The methods for fishway assessment can be classified in two major groups: biological and hydraulic (Sanz-Ronda et al., 2013). Biological methods study the fish that are using a fishway in order to assess its performance. They can be (1) qualitative studies, which assess the effectiveness, determining if a fishway is able or not to allow the fish passage, generally by visual inspection, video recording, samplings, traps, etc.; and (2) quantitative studies, which assess the efficiency, calculating the proportion of fish that locate, entry and overcome a fishway (Bunt et al., 2012; Castro-Santos and Haro, 2010; Larinier, 2001), generally by means of passive integrated transponders (PIT), acoustic or radio telemetry (King et al., 2016; Roscoe and Hinch, 2010).

On the other hand, hydraulic methods compare geometrical and hydraulic characteristics of the fishways with the physical capacities of fish (e.g. swimming or jumping capabilities, turbulence tolerance, etc.), in order to assess the effectiveness of the fish pass via qualitative indicators (Barry et al., 2018; Baudoin et al., 2015). These procedures are usually named as coarse fishways assessment methods (CFAM) and they are very practical because of their fast, simple and inexpensive application (*i.e.* Armstrong et al. 2004; Solà et al. 2011; Towler et al. 2013). There are some general experiences (CHE et al., 2011; Santos et al., 2012) and several standardized protocols of this type of hydraulic assessments: SNIFFER (2010), ICF (Solà et al., 2011), ICE (Baudoin et al., 2015) or AEPS (CHD, 2016). SNIFFER and ICF compare values of water level differences, depths and/or velocities inside the fishway with the fish ability to overcome certain thresholds, complemented by expert opinions. ICE and AEPS, besides the above, also include physical characteristics of the fish passes (e.g. pool dimensions, power dissipation, etc.), and they are conceptually objective. In the specific case of AEPS, besides the fish passage, it also considers the attraction, entry and exit from the fishway. Furthermore, it takes into account some outcomes and conclusions of several previous biological assessments (Bravo-Córdoba et al., 2018b; Sanz-Ronda et al., 2019, 2016) to increase confidence in the estimation of effectiveness.

Despite biological assessment methods provide richer information, their application is more expensive than hydraulic methods as they require more time together with specialized equipment and users (Barry et al., 2018). Therefore, hydraulic based methods as CFAM are more useful to carry out large scale fishway assessments. In addition, CFAM can also be used to detect fishway potential problems and to provide specific solutions for its retrofitting.

In this paper, the use of CFAMs for assessing fish passes and identifying their problematic aspects is analyzed. For this, the AEPS methodology is applied to 64 stepped fishways constructed from the mid-1990s to 2019 in the Duero River basin (Spain). This work aims to (1) highlight the usefulness of CFAM methods for assessing the effectiveness of fishways, and as tool for detecting errors and possible retrofitting actions, (2) show the actual status of the fishways in the Duero River basin, and (3) identify their main potential problems. In addition, the analysis revealed interesting information about evolution of fishways over the last years, their main problems, and the possible influence of recent regulations in their construction. This paper provides a clear example to managers, engineers and biologists on the usage of CFAMs to assess and improve the existent and future fishways and to decide how to prioritize efforts during river restoration.

2. MATERIAL AND METHODS

To achieve the proposed objectives, the AEPS methodology has been applied to asses 64 step-pool fishways. Herein this section, we start by presenting briefly the AEPS methodology (section 2.1) followed by a description of the study cases (section 2.2), and data collection procedure (section 2.3). Finally, we present the data treatment and statistical analyses (section 2.4) in order to obtain comprehensive and statistically relevant results about the ascent stages through fishways (attraction, entry, passage and exit), the type of fishway, its physical and hydraulic parameters, and its construction period.

2.1. DESCRIPTION OF THE AEPS METHODOLOGY

The AEPS methodology (CHD, 2016) is a CFAM for stepped fishways evaluation developed by the Spanish Duero River Authority (Confederación Hidrográfica del Duero-CHD) in 2016 (www.gea-ecohidraulica.org/AEPSv1.pdf). The acronym

AEPS derives from the Spanish names of the four stages that fish must overcome in their ascent through a fish pass (Castro-Santos et al., 2009): attraction, entry, passage and exit. These stages are assessed studying twenty variables of easy measurement (table 1 and figure 1).

Table 1. Variables included in the assessment of the four stages that the AEPS methodology considers (see Figure 1).

STAGE	VARIABLES (ABBREVIATION)
Attraction	Relative flow of attraction ($Q_{attraction}$)
	Location of the fish entrance (L_E)
Entry	Water level difference at the entrance (ΔH_E)
	Water depth at the entrance (D_E)
	Width of the entrance (b_E)
	Water depth before the entrance (D_{prevE})
	Orientation of the entrance respect to the river (Ort_E)
	Type of entrance (T_E)
Passage	Water level difference between pools (ΔH_{Ps})
	Volumetric power dissipation (N)
	Mean water depth in the pool (D_{med})
	Water depth between pools (D_{Ps})
	Width between pools (b_{Ps})
	Type of connection between pools (T_{Ps})
Exit	Water level difference at the exit (ΔH_S)
	Water depth at the exit (D_S)
	Width of the exit (b_S)
	Water depth after the exit (D_{postS})
	Orientation of the exit respect to the river (Ort_S)
	Type of exit (T_S)

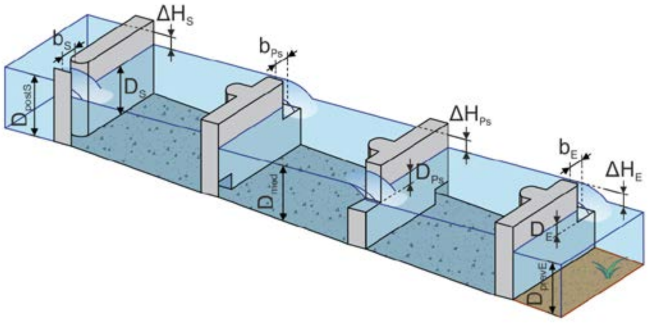

Figure 1. Variables to be measured in a fishway according to AEPS methodology (*ΔH* – water level difference; *D* – water depth; *b* – width for fish passage; D_{prevE} – water depth before the entrance; D_{med} – mean water depth in the pool; D_{postS} – water depth after the exit; $_E$ – entry; $_{Ps}$ – passage; $_S$ – exit) (see table 1).

Each variable is graphically or categorically scored from 0 (very unsuitable for the ascent of the target fish fauna) to 10 (very suitable) (figure 2). The graphical and categorical scoring systems of AEPS are based on the recommendations of specialized literature, laboratory studies and field experiences. The AEPS methodology is focused on the main potamodromous fish species of the Duero River basin: the brown trout (*Salmo trutta,* Linnaeus 1758) and two rheophilic cyprinids: the Iberian barbel (*Luciobarbus bocage*i, Steindachner 1864) and the northern straight-mouth nase (*Pseudochondrostoma duriense*, Coelho 1985), because they are the most relevant species in terms of biomass and distribution in the basin. However, using the same scores, it can be applied to other species with similar capacities and requirements, or it can be adapted to other species modifying the scoring values.

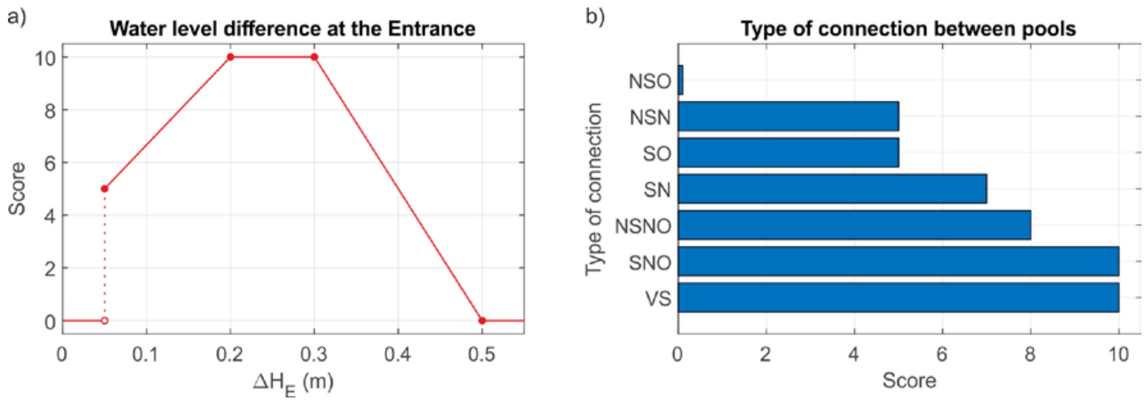

Figure 2. Scoring systems for two variables considered in the AEPS methodology: (a) graphical scoring system for the water level difference at the entrance (based on: Armstrong et al., 2004; Larinier, 2002b), (b) and categorical scoring table for the type of connection between pools (based on: Baudoin et al., 2015; Clay, 1995; FAO and DVWK, 2002) (*NSO* – non-submerged orifices; *NSN* – non-submerged notches; *SO* – submerged orifices; *SN* – submerged notches; *NSNO* – non-submerged notches and orifices; *SNO* – submerged notches with orifices; *VS* – vertical slots) (see the original reference (CHD, 2016) for more information).

The score of each stage (attraction, entry, passage and exit) is obtained by geometric means of the scored variables (eq. 1 to eq. 4, see notation section for further clarification). The geometric means allow to classify a whole stage as unsuitable if at least one of its variables is also unsuitable.

$$\text{Attraction} = (Q_{attraction} \cdot L_E)^{1/2} \qquad \text{(Eq. 1)}$$

$$\text{Entry} = (\Delta H_E \cdot D_E \cdot b_E \cdot D_{prevE} \cdot Ort_E \cdot T_E)^{1/6} \qquad \text{(Eq. 2)}$$

$$\text{Passage} = (\Delta H_{Ps} \cdot N_{Ps} \cdot t_{med} \cdot D_{Ps} \cdot b_{Ps} \cdot T_{Ps})^{1/6} \qquad \text{(Eq. 3)}$$

$$\text{Exit} = (\Delta H_S \cdot D_S \cdot b_S \cdot D_{postS} \cdot Ort_S \cdot T_S)^{1/6} \qquad \text{(Eq. 4)}$$

The methodology classifies the suitability of each stage, as well as the suitability of each variable, as: Highly Suitable or *HS* (8 < Score ≤ 10), Suitable or *S* (6 < Score ≤ 8), Unsuitable or *U* (4 < Score ≤ 6), and Highly Unsuitable or *HU* (0 ≤

Score ≤ 4). This discretization of the scores allows to define potential problems of the fishway and their specific solutions. Finally, the lowest value of the four stages is considered as the overall score for the whole fishway.

2.2. STUDY CASES

All the studied fishways are located in the Duero River basin, the largest basin of the Iberian Peninsula. It is a transboundary system of 97,290 km^2 shared by Portugal (19 %) and Spain (81 %) (CHD, 2020) (figure 3). Most of the Spanish side is under Mediterranean-continental climate, with a mean annual precipitation of 612 mm, and a contribution to rivers and underground systems of 15,000 hm^3 per year (CHD, 2020).

The AEPS methodology was applied to 64 stepped fishways associated to hydropower plants located in the Spanish side of the Duero River basin (figure 3). Priority for the evaluation was given to those fishways located in sensitive zones, in the mainstem of the Spanish side of the Duero River and the lower parts of its tributaries. However, these fishways are about the 50 % of the existing stepped fish passes in the whole basin and more than 75 % of those built since the implementation of the WFD in 2000 (CHD, 2019a).

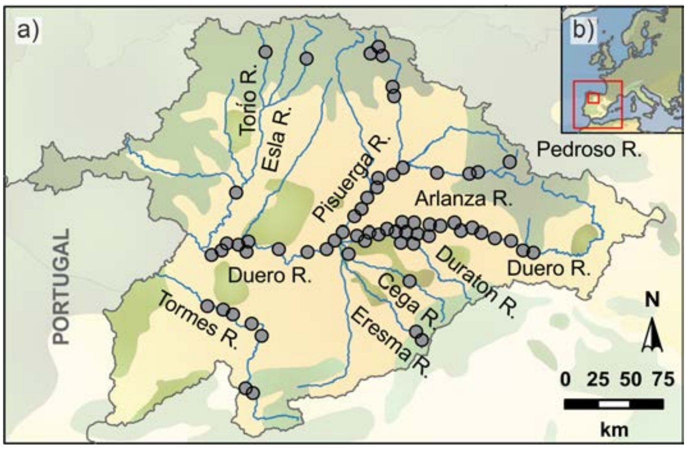

Figure 3. Study area. (a) Location of the assessed fishways in the Spanish side of the Duero River basin (R. – river), (b) northwest of the Iberian Peninsula, southern Europe.

2.3. DATA COLLECTION

Data collection was carried out when the river flow of each study site (obtained from SAIH real time gauging stations (CHD, 2019b)) was similar to the one during the reproductive migration of the target species (public database of CEDEX (CEDEX, 2019)). The northern straight-mouth nase and the Iberian barbel usually perform reproductive migrations from April to June, while the brown trout from November to January in the Iberian Peninsula (Doadrio et al., 2011; García-Vega et al., 2017; Kottelat and Freyhof, 2007).

Water levels and height differences in the fishways were measured with a topographic total station Leica TC307 (± 1 cm). Geometrical characteristics of the fishways were measured with metal rulers to the same precision level. Based on the previous information, the discharges through the fishways were estimated using the formulation for stepped fishways proposed by Fuentes-Pérez et al. (2017).

2.4. DATA TREATMENT

The collected information in each fishway was processed following the AEPS methodology, obtaining the scores for the twenty variables (table 1), the four stages (eq. 1-4) and the overall score and suitability category (*HS*, *S*, *U* or *HU*) for each assessed fishways. Furthermore, the suitability categories of AEPS methodology were gathered in two final groups of effectiveness: favorable (*HS* and *S*) and unfavorable to fish movements (*HU* and *U*)

The evaluated stepped fishways were classified in five groups according to their connections between cross-walls: vertical slots (*VS*), submerged notches (*SN*), submerged notches with orifices (*SNO*), non-submerged notches (*NSN*) and non-submerged notches with orifices (*NSNO*) fishways. To study the relation among variables, stages and the type of stepped fishways, linear mixed models of analysis of variance were used. Mixed models relate a response or dependent variable (type of stepped fishways) with one or more explanatory or independent variables (stages and variables), considering the possible existence of correlated observations or with heterogeneous variability linked to the presence of random factors.

To identify which were the most problematic variables and/or stages, a frequency analysis of the suitability categories by variable, stage and the overall performance of the evaluated fishways was performed, by type of stepped fishway and construction period. For this purpose, two periods were considered, from the mid-1990s to 2009 and from 2010 to 2019. The division by construction period was considered to assess the possible impact of the implementation of the

WFD is the Duero basin. The Chi-squared test was used to evaluate if there were significant differences in effectiveness between both construction periods.

All the statistical analyses were performed using SAS® and Statgraphics Centurion.

3. RESULTS

Half of the assessed fishways showed a favorable effectiveness (29.7 % *S* and 20.3 % *HS*), meanwhile the other half showed problems related to the design, construction or operation (10.9 % *U* and 39.1 % *HU*) (figures 4a and 4b) (see appendix A). Most of the problems were identified at the Attraction and Passage stages, where almost the third part of the fishways were classified as unfavorable (figure 4b). The mean score of the Attraction was significantly lower than the scores of the rest of the stages (7.05 ± 0.37; $p < 0.05$; table 2).

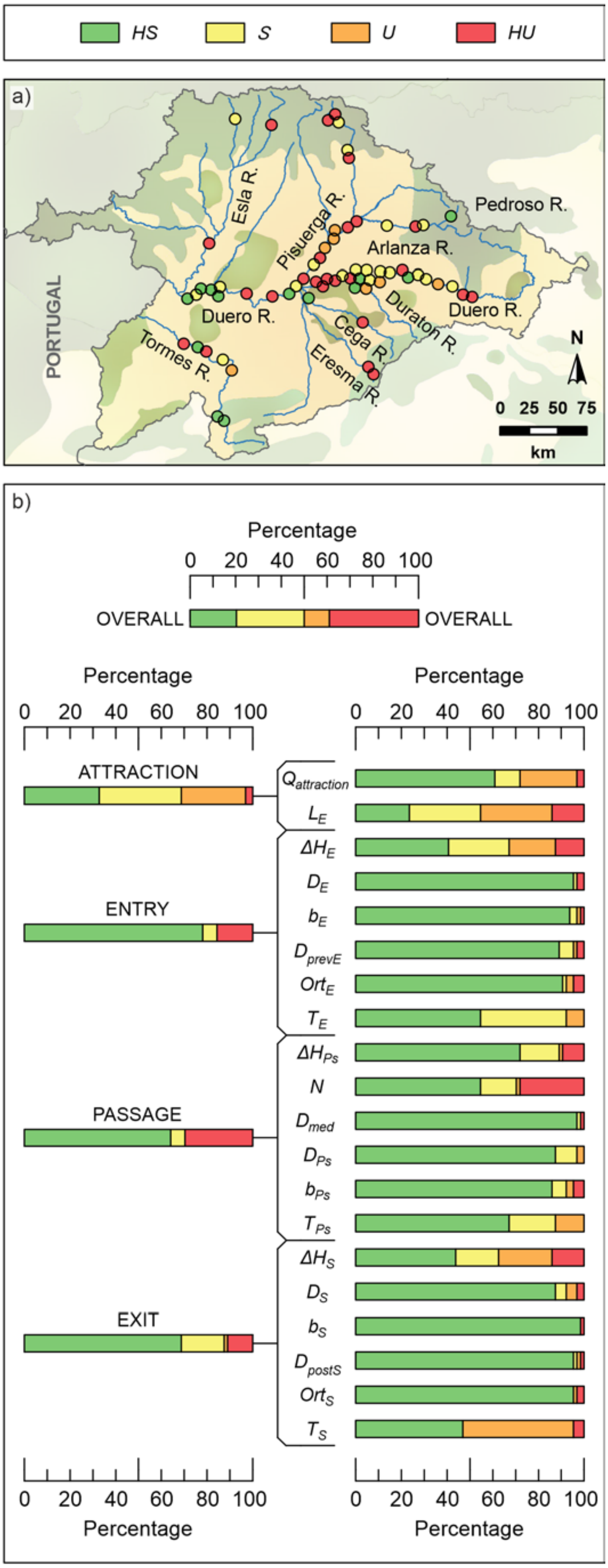
HS
S
U
HU
a)
PORTUGAL
Esla R.
Pisuerga R.
Pedroso R.
Arlanza R.
Duero R.
Duero R.
Duraton R.
Cega R.
Eresma R.
Tormes R.
N
0 25 50 75
km
b)
Percentage
0 20 40 60 80 100
OVERALL
OVERALL
ATTRACTION
ENTRY
PASSAGE
EXIT
$Q_{attraction}$
L_E
ΔH_E
D_E
b_E
D_{prevE}
Ort_E
T_E
ΔH_{Ps}
N
D_{med}
D_{Ps}
b_{Ps}
T_{Ps}
ΔH_S
D_S
b_S
D_{postS}
Ort_S
T_S

Figure 4. Effectiveness of the studied fishways according to the AEPS methodology: (a) location of the studied fishways in the Duero River basin and their overall classification (R. – river), (b) percentage of fishways in each suitability category (*HS* – Highly Suitable; *S* – Suitable; *U* – Unsuitable; *HU* – Highly Unsuitable), in total (overall) and by stages and variables (see table 1 for abbreviation description).

Attraction problems were mainly caused by an inadequate location of the fish entrance (L_E) (45.3 %), rather than by an inefficient attraction flow ($Q_{attraction}$) (28.1 %) (figure 4b). These inefficient flows were caused by fishway discharges that, although they ranged from 150 L/s to 500 L/s and in general were about 300 L/s, they were lower than 3.0 % of the usual river flow during the migration season.

For the Passage stage, an excesive volumetric power dissipation (N) was the main source of low suitability. This variable is calculated from others such as ΔH_{Ps} and D_{med} (Towler et al., 2015), which were favourable in a greater proportion of cases (89.1 % and 98.4 %, respectively), than N (70.3 %) (figure 4b).

In the Entry and Exit stages, the variables lower scored were those related to a poor adjustment between the water level in the river and the water level in the fish entrance or exit pools (ΔH_E and ΔH_S). The Exit stage was also very conditioned by the type of connection between the upper pool and the river (T_S), where in many cases were free overfalls (figure 4b).

According to the type of stepped fishway, *VS* were the most effective, with 81.8 % classified as favorable and displaying the greatest score (9.39 ± 0.17; $p < 0.05$). Secondly, *SNO* showed a score of 8.89 ± 0.18 and 63.6 % of favorable cases, meanwhile *NSNO* and *NSN* types obtained the lowest scores (figure 5 and table 2).

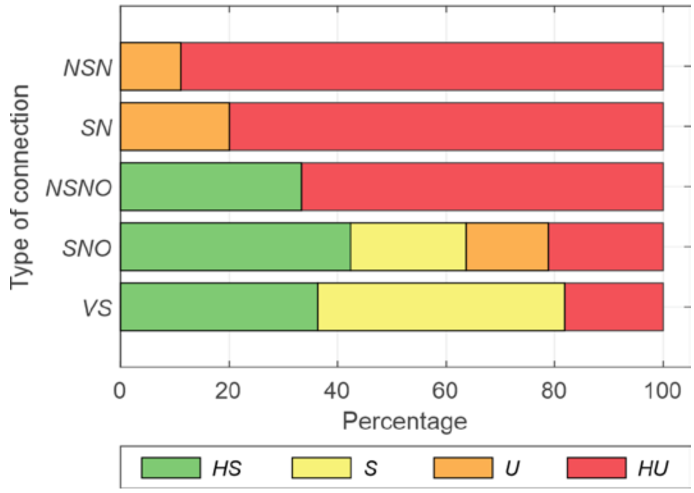

Figure 5. Studied fishways in each suitability category by type of stepped fishway according to AEPS methodology (*HS* – Highly Suitable; *S* – Suitable; *U* – Unsuitable; *HU* – Highly Unsuitable; *NSN* – non-submerged notches; *SN* – submerged notches; *NSNO* – non-submerged notches and orifices; *SNO* – submerged notches with orifices; *VS* – vertical slots).

Table 2. Linear mixed model outcomes: mean score and standard error for each type of stepped fishway by stage and overall. Different uppercase or lowercase letters over the mean values show significant differences between stages or types, respectively (α = 0.05) (*VS* — vertical slot fishways; *SN* — submerged notches; *SNO* — submerged notches with orifices; *NSN* — non-submerged notches; *NSNO* — non-submerged notches and orifices; *n* — number of fishways).

TYPE	*n*	STAGE				ALL STAGES
		ATTRACTION	ENTRY	PASSAGE	EXIT	
VS	11	C a	B a	A a	B a	a
		(8.21 ± 0.65)	(9.46 ± 0.30)	(9.91 ± 0.12)	(9.17 ± 0.39)	(9.39 ± 0.17)
SN	5	C c	A bc	B c	B bc	c
		(5.08 ± 1.47)	(8.93 ± 0.26)	(7.28 ± 0.65)	(8.49 ± 0.53)	(7.92 ± 0.31)
SNO	33	B b	A ab	A b	A ab	b
		(7.38 ± 0.46)	(9.05 ± 0.35)	(9.15 ± 0.37)	(8.98 ± 0.27)	(8.89 ± 0.18)
NSN	9	C c	A d	B c	A bc	d
		(5.83 ± 0.44)	(7.84 ± 0.97)	(6.59 ± 0.52)	(8.24 ±0.63)	(7.38 ± 0.39)
NSNO	6	A abc	A cd	A c	A abc	cd

TYPE	***n***	**STAGE**				**ALL STAGES**
		ATTRACTION	**ENTRY**	**PASSAGE**	**EXIT**	
		(6.54 ± 2.44)	(7.89 ± 1.04)	(7.37 ± 1.12)	(7.53 ± 2.43)	(7.49 ± 0.91)
ALL TYPES	64	B (7.05 ± 0.37)	A (8.83 ± 0.25)	A (8.61 ± 0.24)	A (8.73 ± 0.29)	

Most of the evaluated fishways (62.5 %) were constructed or modified during 2010-2019. In addition, there was a variation in the election of type of stepped fishway over time (table 3a). During the period from the mid-1990s to 2009, the most constructed type was *NSN* (37.5 %) whereas during 2010-2019 it was *SNO* (67.5 %) (table 3a). *NSN* and *SN* fishways were exclusively constructed during the first period, whereas *VS* in the second one. The effectiveness of all assessed stages increased significantly in the last period ($p < 0.05$; table 3b). In general terms, fishways constructed from 2010 had a significantly greater effectiveness than those built before 2010 (16.7 % vs. 70 % of favorable cases; $p < 0.05$) (figure 3b).

Table 3. Changes over time of effectiveness (favorable – fishways classified as *HS* and *S*; unfavorable – fishways classified as *HU* and *U*) by (a) type of stepped fishways (*VS* – vertical slots; *SN* – submerged notches; *SNO* – submerged notches with orifices; *NSN* – non-submerged notches; *NSNO* – non-submerged notches and orifices) and (b) stages according to AEPS methodology (*n* – number of fishways).

a) EFFECTIVENESS BY TYPE OF STEPPED FISHWAY

	VS		***SN***		***SNO***		***NSN***		***NSNO***	
	1990-2009	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**
Favorable	-	81.8%	0.0%	-	50.0%	66.7%	0.0%	-	25.0%	50.0%
Unfavorable	-	18.2%	100%	-	50.0%	33.3%	100%	-	75.0%	50.0%
n	-	11	5	-	6	27	9	-	4	2

b) EFFECTIVENESS BY STAGE

	ATTRACTION		**ENTRY**		**PASSAGE**		**EXIT**		**OVERALL**	
	1990-2009	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**	**1990-2009**	**2010-2019**
Favorable	41.7%	85.0%	70.8%	92.5%	37.5%	90.0%	79.2%	92.5%	16.7%	70.0%
Unfavorable	58.3%	15.0%	29.2%	7.5%	62.5%	10%	20.8%	7.5%	83.3%	30.0%
n	24	40	24	40	24	40	24	40	24	40

4. DISCUSSION

Since the application of the European policies in the last two decades, a large number of fish passes have been constructed in European rivers (Barry et al., 2018). Therefore, it is essential to find methods to assess the efficiency of these devices in a reliable, fast and economical way. The application of the AEPS methodology, a hydraulic based CFAM, has allowed to describe the individual and global status of a large number of fish passes in a wide geographic area, and to detect fish passes with operational problems, with a lower investment and a faster and easier application than biological assessment methods. In general, for biological efficiency studies, a minimum of 3 months (usual period of active migration) is required to obtain reliable data, whereas CFAM, as AEPS, can be applied in less than one day per fishway.

In this study, the usefulness of hydraulic based methods (AEPS methodology) is demonstrated by assessing 64 stepped fishways in the Duero River basin. The evaluation of fishway effectiveness by means of suitability scores and categories provides a tool to prioritize actions and to distribute the resources for river restoration and management. Likewise, the discretization of the scores by ascent stages (attraction, entry, passage and exit) allows to diagnose possible problems in each fish pass and to propose specific solutions for their retrofitting.

4.1. GLOBAL STATUS

Regarding the global status of the studied fishways, results show that 50 % of assessed fishways are potentially suitable to allow the movements of main fish species of the Duero River basin. This percentage rises to 70.3 % if only Passage stage is considered. Close results were obtained in other Iberian regions, as Catalonia 55 % (Ordeix et al., 2011; Solà et al., 2011) and Portugal 49 % (Santos et al., 2012). In contrast, in a study developed in the Ebro River basin (one of the largest rivers in Iberia), where 131 fish passes were evaluated, only 17.8 % showed favorable results (CHE et al., 2011). The construction year (before 2011) of the fishways included in that study may explain the observed differences. Our results show that fishways constructed before 2010 displayed lower scores (higher unsuitability) than fishways constructed after this year. This could be explained by several reasons: (1) an increase in the knowledge of fishway design (e.g. Fuentes-Pérez et al., 2017; Quaresma et al., 2018), (2) a better fit between physical capabilities of fish and designs (*e.g.* Romão et al. 2012; Sanz-Ronda et al. 2015), (3) a consolidation of the European guidelines (*e.g.* FAO/DVWK 2002; Larinier 2002b) and (4) a greater concern of Water River Authorities which control and regulate more severely the construction process (Sanz-Ronda et al., 2013).

The study also shows an evolution over time toward streaming connections such as *VS* and *SNO*, together with an increase of the scores, which seems to indicate a better performance of these type of fishways. During last years, specialized literature has pointed out that streaming connections are preferable than plunging ones as they usually demand less effort for fish and do not require jumping between pools; consequently they seem to be more suitable for rivers with fish with wide morpho-ecological traits (Branco et al., 2013; Sanz-Ronda et al., 2016; Silva et al., 2009). Furthermore, *VS* and *SNO* fishways have demonstrated good performance for the passage of Iberian cyprinids as well as brown trout (Bravo-Córdoba et al., 2018a; Sanz-Ronda et al., 2016, 2019). In addition, *VS* and *SNO* present better self-regulation of the hydraulic variables than other fishway types, which compensate possible construction errors and water level oscillations (Fuentes-Pérez et al., 2016, 2014). Therefore, it seems that *VS* and *SNO* are the preferable options for new constructions or retrofitting old ones.

Some of the studied *SN* fishways were working close to plunging regimens, that is to say, with a low submergence in the notch (< 10 cm). One of the reason could be that despite they were designed to operate in streaming regimens, i.e. as *NSN*, the river dynamics or the lack of discharge management through the structures favoured an operation in plugging regimen, i.e. as *SN*. Due to the multiple benefits of streaming regimens (Branco et al., 2013; Sanz-Ronda et al., 2015a; Silva et al., 2009) the operation under plugging regimens is penalized by AEPS.

4.2. DIAGNOSIS OF THE STUDIED FISHWAYS

The most frequent causes of fish pass failure include the lack of attraction flow, inadequate location of the entrance, absence of maintenance and inadequate hydraulic conditions (e.g. flow patterns, velocities or turbulence) inside the fishway for the target species (FAO/DVWK, 2002; Larinier, 2001; Silva et al., 2018; Williams et al., 2012). In this study, Attraction and Passage were the two stages with the lowest scores. For Attraction stage, the location of the fish entrance is essential. The optimal location is as close as possible to the most upstream part of the barrier, adjacent to its base and/or to the exit of the turbines in case of a powerhouse (M Larinier, 2002; Williams et al., 2012). Furthermore, an attraction flow near the fish entrance is desirable to create a detectable flow pattern not masked by other flows (Burnett et al., 2017; FAO/DVWK, 2002; M. Larinier, 2002). 45.3 % of the studied fishways had an incorrect fish entrance location and 28.1 % lacked an appropriate attraction flow in their surroundings. A large number of works (e.g. Bunt et al., 2012; Larinier et al. 2005; Williams et al. 2012) identify these two variables as the main cause of inadequate operation of the fishways. Once these problems have been identified, it is possible to implement specific solutions for each case. For example, Bunt (2001) showed a positive effect of approaching the fish entrance to the spillways.

Regarding the Passage, results show that it was negatively influenced by both high water drops between pools (ΔH_{PS}, in 10.9 % of the fishways) and small size of the pools. This caused an excessive volumetric power dissipation within pools (*N,* in the 29.7 % of the fishways). *N* is directly related to turbulence levels inside the pools, which can disorient the fish (Clay, 1995; M. Larinier, 2002) and increase the cost of swimming performance (Enders et al., 2005). Likewise, *ΔH* is related to the water velocity and, when it exceeds fish swimming or jumping capacities, the fish cannot pass the notches or slots (M. Larinier, 2002; Sanz-Ronda et al., 2016). The correction of these deficiencies is usually challenging, and some alternatives can be, for instance, the increase of the water volume in the pool (by increasing the sill elevation in the notches, and thus, the water depth in the pool) or the addition of extra pools and cross-walls in order to share the excessive drops among them. If the failure is localized in a specific pool, this can be retrofitted by modifying the successive cross-walls (Fuentes-Pérez et al., 2016).

The water drop is usually a conflictive variable also in the Entry and Exit stages. Despite the overall better results of these two stages (favorable > 80 %), in both cases *ΔH* was the variable with the lowest score. Failures in this variable are usually linked to (1) not considering the water level oscillations related to changes in river discharge during the migration season in the design and operation of the fishway, (2) a wrong on-site layout during the construction process or (3) the modification of the river control sections during the construction. Although high water level differences or plunging flows at the entrance can be related to a better attraction (Williams et al., 2012), they can also exceed the swimming and/or jumping capacities of fish (Ruiz-Legazpi et al., 2018; Sanz-Ronda et al., 2015b). Likewise, small differences in water levels or excessive submergence can reduce the velocity and turbulence at the entrance, affecting negatively to Attraction. Larinier (2002b) recommends a minimum velocity of 1 m/s and a maximum of 2.4 m/s at the entrance. Excessive water level differences at the fish entrance can be solved, for example, by installing a set of pre-barrages; meanwhile, the small water drops can be corrected by increasing the sill elevation of the most downstream notch or slot (Fuentes-Pérez et al., 2016).

4.3. OTHER CONSIDERATIONS

In general, the overall passage problems identified in this study can have two main origins: (1) not considering the recommended criteria for fishway design or (2) unsupervised modifications during the construction with respect to the original project. Although the former is difficult to solve if there is not a project control agent with advanced knowledge in the fishway design field, the latter could be avoided with an adequate in-site inspection during the construction process (Mallen-Cooper and Brand, 2007; Sanz-Ronda et al., 2013). An inspection based on hydraulic evaluation methods (e.g. AEPS), after construction and prior to the machinery retreat, could have solved the possible deficiencies, increasing the percentage of favorably scored fishways.

In addition, the inspection process also allowed the identification of maintenance problems (also considered in the AEPS methodology (CHD, 2016)). The 32.8 % of the studied fishways presented problems due to obstructions (debris, branches, leaves and other drifts). The fishways were cleaned before measuring the variables needed for the application of the methodology. In absence of this previous cleaning phase, the final scores could had been lower as these obstructions may modify the hydraulics inside the fishway. Therefore, although the first action to restore the longitudinal connectivity of a river stretch is the fishway construction and its evaluation, the second one is the implementation of a maintenance schedule adapted to the river dynamics in order to ensure its adequate operation. Lastly, the final action is the application of a periodical and effective control plan by the water authorities.

5. SUMMARY AND CONCLUSIONS

This paper analyses the functionality of AEPS as a coarse fishway assessment method. The application of CFAM or hydraulic methods is in general a faster, less expensive and simpler option than biological assessment methods, mainly due to the nature of the variables to measure and the necessary tools for their application. However, the uncertainties in these methods are greater than in biological assessments due to the absence of fish monitoring. The easy and simple application of the AEPS methodology has made possible to assess a large number of fishways in a wide geographic area. Its application has also demonstrated the need of an assessment after construction of any fishway, as most of the assessed structures require retrofitting actions to ensure their adequate operation.

The application of AEPS showed that 50 % of assessed fishways are potentially suitable for fish movements and that *VS* and *SNO* fishway types were the most effective ones. The research also revealed that fishway design improved their effectiveness over time, probably due to an increase of knowledge of native fish species and the consolidation of European regulations.

Attraction and Passage were the two stages with lower suitability scores. Most relevant failures for the attraction were a poor location of the device and low attraction flows, whereas for the passage, they were high water drops between pools and small size of the pools. Fishways design and construction processes were identified as the key causes of those defects, thus the control during these processes have to be guaranteed, together with periodical inspections to ensure a correct maintenance.

CFAMs seems a valid tool to handle the assessment of all the constructed fishways. However, further research is necessary. Specifically, it is necessary the improvement of CFAMs through their direct comparison with results from biological methods, to relate them to biological efficiencies, and to incorporate other fish species as well as other types of fish passes. Until then, we can conclude that AEPS methodology and CFAMs in general, provide a systematic tool to managers, engineers and biologist to identify and solve problems and correct deviations by its application during design, construction and operation phases of the existent and future fish passes.

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Notation

The following symbols and abbreviations are used in this paper:

ΔH = water level difference or drop (m)

ΔH_E = water level difference at the entrance (m)

ΔH_{Ps} = water level difference between pools (m)

ΔH_S = water level difference at the exit (m)

b_E = width of the entrance (m)

b_{Ps} = width between pools (m)

b_S = width of the exit (m)

CFAM = coarse fishway assessment method

D_E = water depth at the entrance (m)

D_{med} = mean water depth in the pool (m)

D_{postS} = water depth after the exit (m)

D_{prevE} = water depth before the entrance (m)

D_{Ps} = water depth between pools (m)

D_S = water depth at the exit (m)

H = total height of an obstacle (m)

HS = highly suitable

HU = highly unsuitable

L_E = location of the fish entrance

n = number of fishways

N = volumetric power dissipation (W/m^3)

NSN = non-submerged notch with orifice fishway

NSNO = non-submerged notch and orifice fishway

NSO = non-submerged orifice fishway

Ort_E = orientation of the entrance respect to the river

Ort_S = orientation of the exit respect to the river

$Q_{attraction}$ = relative attraction flow (%)

S = suitable

SN = submerged notch fishway

SNO = submerged notch with orifice fishway

SO = submerged orifice fishway

T_E = type of entrance

T_{Ps} = type of connection between pools

T_S = type of exit

U = unsuitable

VS = vertical slots fishway

WFD = water Framework Directive (2000/60/EC)

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APPENDIX A

Table A.1. Scores of the assessed variables for the studied stepped fishways in the Duero River basin (*VS* – vertical slots; *SN* – submerged notches; *SNO* – submerged notches with orifices; *NSN* – non-submerged notches; *NSNO* – non-submerged notches and orifices; $Q_{attraction}$ – relative flow of attraction; L_E – location of the fish entrance; ΔH – water level difference; *D* – water depth; *b* – width for fish pass; *Ort* – orientation respect to the river; *T* – type of element for fish pass; D_{prevE} – water depth before the entrance; *N* – volumetric power dissipation; D_{med} – mean water depth in the pool; D_{postS} – water depth after the exit; $_E$ – entry; $_{Ps}$ – passage; $_S$ – exit).

	ID. CODE	**RIVER**	**TYPE**	**OVERALL**	**ATTRACTION**			**ENTRY**							**PASSAGE**							**EXIT**							**DATE OF CONSTRUCTION**
					STAGE	$Q_{attraction}$	L_E	**STAGE**	ΔH_E	D_E	b_E	D_{prevE}	Ort_E	T_E	**STAGE**	ΔH_{Ps}	N	D_{med}	D_{Ps}	b_{Ps}	T_{Ps}	**STAGE**	ΔH_S	D_S	b_S	D_{postS}	Ort_S	T_S	
1	**PE1**	Pedroso	*VS*	8.7	8.7	10	7.5	9.5	10	10	7.5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2010-2019
2	**AR1**	Arlanza	*VS*	6.9	6.9	9.5	5.0	9.4	10	10	10	10	10	7.0	9.4	9.4	8.9	8.7	10	9.3	10	7.7	4.2	10	10	10	10	5.0	2010-2019
3	**AR2**	Arlanza	*VS*	0.0	8.7	10	7.5	0.0	0.0	10	10	10	4.0	10	9.9	10	10	10	10	9.5	10	9.7	8.2	10	10	10	10	10	2010-2019
4	**AR3**	Arlanza	*SNO*	7.1	7.1	10	5.0	9.9	9.3	10	10	10	10	10	10	10	10	10	10	10	10	9.7	8.3	10	10	10	10	10	2010-2019
5	**AR4**	Arlanza	*VS*	0.0	10	10	10	9.4	7.0	10	10	10	10	10	10	10	10	10	10	10	10	0.0	0.0	10	10	10	10	10	2010-2019
6	**AR5**	Arlanza	*SNO*	0.0	10	10	10	9.4	7.0	10	10	10	10	10	9.6	9.7	8.1	10	10	10	10	0.0	0.0	10	10	10	10	10	2010-2019
7	**CE1**	Cega	*SNO*	0.0	8.7	10	7.5	7.9	2.4	10	10	10	10	10	0.0	0.0	0.0	10	10	9.9	9.8	9.4	8.3	10	8.5	10	10	10	2010-2019
8	**CE2**	Cega	*NSNO*	8.7	8.7	10	7.5	9.2	8.4	10	8.9	10	10	8.0	8.8	8.1	8.2	10	10	8.9	8.0	8.9	10	10	10	10	10	5.0	2010-2019
9	**DU1**	Duero	*SNO*	6.6	6.6	5.8	7.5	9.1	6.7	10	8.8	10	10	10	10	10	10	10	10	10	10	8.4	7.0	10	10	10	0.0	10	1990-2009
10	**DU2**	Duero	*VS*	6.6	6.6	5.7	7.5	9.3	6.3	10	10	10	10	10	10	10	10	10	10	10	10	9.5	7.3	10	10	10	10	10	2010-2019
11	**DU3**	Duero	*NSNO*	0.0	5.1	0.0	5.0	0.0	6.0	8.5	0.0	10	10	10	0.0	5.8	0.0	10	10	2.3	7.4	0.0	1.0	0.0	0.0	0.0	10	5.0	1990-2009
12	**DU4**	Duero	*SNO*	8.7	8.7	10	7.5	8.8	5.0	10	10	10	10	7.0	9.9	9.3	10	10	10	10	9.9	9.5	7.3	10	10	10	10	10	2010-2019
13	**DU5**	Duero	*SNO*	7.1	7.1	10	5.0	9.4	7.0	10	10	10	10	10	10	10	10	10	10	10	10	7.6	2.5	7.5	10	10	10	10	2010-2019

	ID. CODE	RIVER	TYPE	OVERALL	ATTRACTION			ENTRY							PASSAGE							EXIT							DATE OF CONSTRUCTION
					STAGE	$Q_{attraction}$	L_E	STAGE	ΔH_E	D_E	b_E	D_{prevE}	Ort_E	T_E	STAGE	ΔH_{Ps}	N	D_{med}	D_{Ps}	b_{Ps}	T_{Ps}	STAGE	ΔH_S	D_S	b_S	D_{postS}	Ort_S	T_S	
14	**DU6**	Duero	*SNO*	7.7	8.2	10	6.7	7.7	6.0	10	10	10	5.0	7.0	9.8	10	8.6	10	10	10	9.8	10	10	10	10	10	10	10	2010-2019
15	**DU7**	Duero	*SNO*	0.0	6.7	5.5	8.4	0.0	0.0	10	10	10	10	10	9.3	9.9	8.0	10	8.2	10	10	10	10	10	10	10	10	10	2010-2019
16	**DU8**	Duero	*SNO*	0.0	10	10	6.7	9.4	6.8	10	10	10	10	10	0.0	0.0	0.0	10	9.3	9.6	9.4	0.0	0.0	10	10	10	10	10	2010-2019
17	**DU9**	Duero	*VS*	7.6	7.6	10	5.9	9.5	8.9	10	8.5	10	10	10	9.7	10	10	10	10	8.5	10	9.1	5.6	10	10	10	10	10	2010-2019
18	**DU10**	Duero	*SNO*	5.2	5.2	8.0	3.4	7.5	6.0	10	10	10	3.0	10	9.3	9.9	10	10	6.5	10	10	8.9	10	10	10	10	10	5.0	2010-2019
19	**DU11**	Duero	*NSN*	4.9	4.9	5.7	4.2	8.1	10	10	5.5	10	10	5.0	6.2	8.5	2.5	10	10	5.5	5.0	8.9	10	10	10	10	10	0.0	1990-2009
20	**DU12**	Duero	*VS*	7.9	7.9	8.3	7.5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
21	**DU13**	Duero	*SNO*	7.9	7.9	8.3	7.5	10	10	10	10	10	10	10	9.8	9.7	8.7	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
22	**DU14**	Duero	*SNO*	7.4	7.4	6.8	9.2	9.7	10	10	10	10	10	10	9.7	9.2	7.4	10	10	10	10	8.9	9.7	10	10	10	10	10	2010-2019
23	**DU15**	Duero	*SNO*	8.9	9.6	10	9.2	9.7	10	10	10	10	10	10	9.7	10	10	10	10	10	10	8.9	9.7	10	10	10	10	10	2010-2019
24	**DU16**	Duero	*SNO*	8.5	8.5	8.4	9.2	9.7	10	10	10	10	10	10	9.4	10	10	10	10	10	10	8.9	9.7	10	10	10	10	10	2010-2019
25	**DU17**	Duero	*NSN*	0.0	5.8	5.8	5.9	9.4	9.7	10	10	10	10	7.0	0.0	7.3	0.0	10	10	5.8	5.0	7.9	5.0	10	10	10	10	5.0	1990-2009
26	**DU18**	Duero	*SNO*	6.5	6.5	5.7	7.5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
27	**DU19**	Duero	*SN*	0.0	5.3	5.5	5.1	9.0	7.7	10	10	10	10	7.0	0.0	7.7	0.0	10	7.5	10	7.0	7.9	6.5	7.5	10	10	10	5.0	1990-2009
28	**DU20**	Duero	*SN*	0.0	6.7	6.0	7.5	8.8	6.7	10	10	10	10	7.0	0.0	6.5	0.0	10	5.5	10	7.0	8.9	10	10	10	10	10	5.0	1990-2009
29	**DU21**	Duero	*NSN*	0.0	3.6	5.1	5.0	7.8	5.3	10	8.3	10	10	5.0	7.4	9.0	6.3	10	9.3	6.2	5.2	0.0	5.0	10	8.3	10	10	0.0	1990-2009
30	**DU22**	Duero	*NSN*	0.0	6.4	5.4	7.5	0.0	0.0	10	10	10	10	10	7.1	8.8	5.2	10	10	10	5.0	0.0	5.0	10	10	10	10	0.0	1990-2009
31	**DU23**	Duero	*SNO*	7.0	7.0	9.9	5.0	9.7	8.1	10	10	10	10	10	9.8	10	10	10	9.0	10	10	7.1	5.0	10	10	10	5.0	5.0	2010-2019
32	**DU24**	Duero	*SNO*	8.2	8.2	10	6.7	9.1	8.3	10	10	10	10	7.0	9.1	9.7	10	10	6.2	9.9	9.7	8.5	7.4	10	10	10	10	5.0	2010-2019

	ID. CODE	RIVER	TYPE	OVERALL	ATTRACTION			ENTRY							PASSAGE							EXIT							DATE OF CONSTRUCTION
					STAGE	$Q_{attraction}$	L_E	STAGE	ΔH_E	D_E	b_E	D_{prevE}	Ort_E	T_E	STAGE	ΔH_{Ps}	N	D_{med}	D_{Ps}	b_{Ps}	T_{Ps}	STAGE	ΔH_S	D_S	b_S	D_{postS}	Ort_S	T_S	
33	**DU25**	Duero	*NSN*	0.0	5.8	5.0	6.7	8.8	6.7	10	10	10	10	7.0	0.0	9.2	0.0	10	10	10	5.0	8.9	5.0	10	10	10	10	10	1990-2009
34	**DU26**	Duero	*NSNO*	0.0	8.6	9.8	7.5	0.0	5.4	0.0	10	7.5	10	5.0	0.0	7.5	0.0	9.8	10	2.5	8.0	7.9	5.0	10	10	10	10	5.0	1990-2009
35	**DU27**	Duero	*VS*	7.5	7.5	5.1	10	9.1	10	10	10	10	10	8.0	10	10	10	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
36	**DU28**	Duero	*VS*	8.9	10	10	10	9.1	10	10	10	10	10	8.0	10	10	10	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
37	**DU29**	Duero	*VS*	8.8	8.8	7.6	10	9.1	10	10	10	10	10	8.0	10	10	10	10	10	10	10	8.9	10	10	10	10	10	5.0	2010-2019
38	**DU30**	Duero	*SNO*	7.6	7.6	6.3	9.2	8.9	5.0	10	10	10	10	10	9.7	10	8.5	10	8.5	8.5	8.5	8.2	7.0	10	10	10	10	5.0	2010-2019
39	**DU31**	Duero	*SNO*	8.2	8.7	8.2	9.2	8.6	10	10	10	10	4.0	10	10	10	10	10	10	10	10	8.2	7.0	10	10	10	10	5.0	2010-2019
40	**DU32**	Duero	*SNO*	8.2	8.2	7.3	9.2	8.8	7.5	10	10	10	7.0	10	10	10	10	10	10	10	10	8.2	7.0	10	10	10	10	5.0	2010-2019
41	**DT1**	Duratón	*SNO*	4.3	4.3	10	2.5	8.7	5.3	10	9.2	9.0	10	10	9.1	10	8.3	10	7.5	9.2	10	8.2	6.0	10	10	10	10	5.0	2010-2019
42	**ER1**	Eresma	*NSNO*	0.0	4.2	7.2	2.5	0.0	0.0	10	9.4	8.4	10	8.0	0.0	8.0	7.7	0.0	8.1	9.1	7.7	8.9	5.0	10	10	10	10	10	2010-2019
43	**ER2**	Eresma	*SNO*	0.0	5.8	10	3.4	8.8	5.0	10	10	10	10	7.0	0.0	8.0	0.0	10	9.8	7.8	8.0	8.6	6.7	10	10	5.9	10	10	2010-2019
44	**ES1**	Esla	*SNO*	0.0	6.5	10	4.2	8.5	5.0	10	10	7.5	10	10	0.0	0.0	0.0	10	10	9.9	9.8	7.9	5.0	10	10	10	10	5.0	1990-2009
45	**ES2**	Esla	*SN*	0.0	5.0	10	2.5	8.5	7.3	7.3	10	10	10	7.0	0.0	6.2	0.0	10	7.5	10	7.0	7.3	8.3	5.0	10	7.5	10	5.0	1990-2009
46	**PI1**	Pisuerga	*NSN*	0.0	6.5	10	4.2	0.0	0.0	9.5	10	5.0	10	5.0	0.0	0.0	0.0	7.9	10	10	5.0	5.6	1.0	2.0	10	10	10	5.0	1990-2009
47	**PI2**	Pisuerga	*NSN*	0.0	4.1	10	1.7	0.0	5.0	0.0	10	0.0	5.0	7.0	0.0	0.0	0.0	8.1	10	10	5.0	7.7	8.3	5.0	10	10	10	5.0	1990-2009
48	**PI3**	Pisuerga	*SNO*	7.6	7.6	10	5.9	9.7	10	10	8.3	10	10	10	10	10	9.9	10	10	10	10	8.9	8.3	6.0	8.8	10	10	10	2010-2019
49	**PI4**	Pisuerga	*SNO*	0.0	4.1	10	1.7	0.0	0.0	10	7.5	0.0	10	5.0	0.0	6.3	0.0	10	10	10	10	10	10	10	10	10	10	10	1990-2009
50	**PI5**	Pisuerga	*SNO*	6.2	6.2	9.3	4.2	9.2	8.2	10	10	7.5	10	10	9.1	8.4	7.7	10	9.5	9.6	9.4	8.9	5.1	10	10	10	10	10	1990-2009
51	**PI6**	Pisuerga	*SNO*	6.0	6.0	10	7.5	8.4	5.0	10	10	10	10	7.0	9.5	10	9.6	10	10	7.7	9.8	8.9	10	10	10	10	10	5.0	2010-2019

	ID. CODE	RIVER	TYPE	OVERALL	ATTRACTION			ENTRY							PASSAGE							EXIT							DATE OF CONSTRUCTION
					STAGE	$Q_{attraction}$	L_E	**STAGE**	ΔH_E	D_E	b_E	D_{prevE}	Ort_E	T_E	**STAGE**	ΔH_{Ps}	N	D_{med}	D_{Ps}	b_{Ps}	T_{Ps}	**STAGE**	ΔH_S	D_S	b_S	D_{postS}	Ort_S	T_S	
52	**PI7**	Pisuerga	*SN*	4.6	4.6	5.0	4.2	8.4	5.0	10	10	10	10	7.0	8.1	10	6.7	10	6.0	10	7.0	8.5	10	7.5	10	10	10	5.0	1990-2009
53	**PI8**	Pisuerga	*SNO*	5.1	5.1	5.0	5.0	9.5	7.3	10	10	10	10	10	9.9	9.7	9.6	10	10	10	10	8.9	10	10	10	10	10	5.0	1990-2009
54	**PI9**	Pisuerga	*NSNO*	0.0	7.7	10	5.9	8.7	6.3	10	10	10	10	7.0	0.0	0.0	7.9	10	9.2	8.4	6.9	0.0	0.0	10	10	10	10	10	1990-2009
55	**PI10**	Pisuerga	*SNO*	7.2	8.7	10	7.5	9.9	9.7	10	10	10	10	10	8.0	6.5	7.3	10	6.1	9.4	9.3	7.2	3.0	10	10	10	10	5.0	2010-2019
56	**PI11**	Pisuerga	*NSN*	0.0	5.5	5.1	5.9	0.0	0.0	10	10	10	10	7.0	0.0	6.2	0.0	9.2	10	6.2	5.3	8.9	10	10	10	10	10	5.0	1990-2009
57	**TI1**	Torío	*SNO*	7.1	7.1	10	5.0	9.1	8.0	10	10	10	10	7.0	9.4	9.2	7.8	10	10	10	9.4	7.6	5.0	10	10	10	4.0	10	1990-2009
58	**TO1**	Tormes	*SNO*	8.4	10	10	10	9.9	10	10	10	10	10	10	9.5	9.2	10	10	8.5	8.4	10	8.4	7.0	10	10	10	10	5.0	2010-2019
59	**TO2**	Tormes	*NSNO*	8.4	10	10	10	9.9	10	10	10	10	10	10	8.9	10	8.6	10	10	9.2	8.0	8.4	7.0	10	10	10	10	5.0	1990-2009
60	**TO3**	Tormes	*SNO*	4.3	4.3	5.6	3.4	9.3	6.3	10	10	10	10	10	9.6	10	7.9	10	10	10	10	9.4	7.1	10	10	10	10	10	2010-2019
61	**TO4**	Tormes	*SNO*	7.2	7.2	6.2	8.4	9.4	10	10	10	10	10	7.0	10	10	10	10	10	10	10	9.7	8.3	10	10	10	10	10	2010-2019
62	**TO5**	Tormes	*NSN*	0.0	4.1	10	1.7	8.3	7.2	8.7	10	7.5	10	7.0	0.0	7.1	0.0	9.8	10	4.0	8.0	9.0	5.2	10	10	10	10	10	1990-2009
63	**TO6**	Tormes	*VS*	8.7	8.7	10	7.5	9.6	7.7	10	10	10	10	10	10	10	10	10	10	10	10	8.9	5.0	10	10	10	10	10	2010-2019
64	**TO7**	Tormes	*SN*	0.0	0.0	0.0	5.0	9.2	8.8	10	10	10	10	7.0	0.0	9.7	0.0	10	10	10	7.0	7.8	2.3	10	10	10	10	10	1990-2009