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ORIGINAL ARTICLE

Construction of a typology system for rivers in Chile based on the European Water Framework Directive (WFD)

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Abstract To assess the current status of surface waters, it is necessary, as a first step, to have a system that includes a set of criteria for classifying and describing each existing surface water body. In this article, a new river typology system for Chile based on the Water Framework Directive of the European Union is shown. This system was created following a top down and a priori approach and was based on an accurate review of scientific literature, interviews and workshops with experts in Chilean aquatic ecosystems. The system consisted of five ecoregions (large areas with homogenous hydrological and climatic conditions) and a set of abiotic criteria with their classes. It was assumed that each abiotic criterion was a control factor for freshwater ecosystems. It is expected that this system will organise knowledge about the biocenosis distribution of the Chilean freshwater ecosystem and also provide an operative tool for water quality monitoring based on biological indicators.

Keywords Typology system · Water bodies · Water resources management · Rivers

Introduction

In Chile, several interventions over continental surface waters have triggered major modifications in their physical, chemical, and biological characteristics (e.g. Soto and Campos 1997; Habit and Parra 2001; Oyarzún and Huber 2003; Parra et al. 2003; Goodwin et al. 2006; Habit et al. 2006a, 2007, 2010; Barra et al. 2009), as it is not always possible to determine what the original and natural conditions quality of those water bodies. However, Chilean institutions do not have sufficient knowledge about aquatic ecosystems (Habit et al. 2006b; Hauenstein 2006; Jara et al. 2006; Rivera 2006; Villalobos 2006; Ortiz and Díaz-Páez 2006) to improve policies concerning the conservation and/or restoration of these ecosystems (Peredo-Parada et al. 2009). These institutions are taking important steps toward the elaboration of management tools to evaluate the state of aquatic ecosystems based on the experience of countries that have already applied these methods (e.g. Germany, Spain). In this context, it is important to indicate the development of a set of norms called Normas Secundarias de Calidad Ambiental (Secondary Norms for Environmental Quality or NSCA; CONAMA 2004). One of the approaches adopted to develop new evaluation tools is the EU Water Framework Directive (WFD; European Parliament and Council 2000), which consists of a program that establishes guidelines and obligations to control, protect, and restore the structure and function of aquatic ecosystems. To achieve such a goal, the WFD has delineated a methodological framework to categorise and characterise the different water bodies (rivers, lakes, transitional waters, coastal waters, and artificial waters or modified waters), which defines the reference conditions of the original state in which the water bodies should be without anthropic intervention. Thus, it is possible to establish the current ecological quality of these water bodies (Verdonschot and Nijboer 2004). Therefore, having a typology of water bodies based on their morphological, physical, chemical, hydrological, and biological characteristics (Logan and

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Furse 2002) constitutes a solid base of knowledge in order to recognise the body types that are part of this typology and, therefore, provides a referential framework about the most relevant water body properties, which is useful for different goals related to water resources management. These goals are as follows: (a) the protection of water bodies, (b) the restoration of water bodies to their natural state, and c) the conservation of biodiversity (Pottgiesser and Sommerhauser 2008). In fact, during the WFD implementation, the use of water body types has been shown to be a simple and appropriated tool for managers to better understand the natural differences in the biocenosis and consequently differences in the restoration targets (Hering et al. 2010). However, having a typology in itself is not enough for water resource management, even though this typology constitutes an important tool for decision makers to create plans, programs and policies considering the purposes for which they were created.

Several comparable methods are available to generate typologies and classify water bodies (Ferreól et al. 2005), among which the most commonly used are (a) those that are based on similar abiotic aspects [top–down approach from Verdonschot and Nijboer (2004); Sánchez-Montoya et al. (2007)] (b) those based on similar biotic aspects [bottom–up approach from Hering et al. (2004), Lorenz et al. (2004)]. In general, the typologies that are generated using top–down approaches have been adjusted and corrected by applying bottom–up approaches (Böhmer et al. 2004; Hering et al. 2004; Lorenz et al. 2004).

In this paper, a system is proposed that classifies the types of water bodies in Chile following a priori and top–down methods based exclusively on geomorphologic, hydrologic, physical, and chemical criteria that are recognised as the most relevant factors that control the biocenosis of rivers throughout the country. The primary aim of this study was to generate a typology system at a general scale starting with physical variables, which were in agreement with a local scale and with biological information based on expert reasoning.

Methodology

Study area

The spatial domain of this study was the continental territory of Chile between 17°30′S and 56°32′S. According to surface runoff, the study area are divided into three main hydrological regions (Niemeyer and Cereceda 1984): the endorheic region (approximately between 17°30′S and 23°S), the arheicregion (between 23°S and 27°S) and the exorheic region (between 27°S and 54°S). While the exorheic region is characterised by having permanent surface runoffs that reach the Pacific Ocean, the endorheic region has closed drainage basins with no outflow to the ocean. In the endorheic region, the low annual precipitation, which is concentrated in the summer season (January–March), and the high evapotranspiration rates, especially in the Altoandean zone, determine an extremely arid climate and the existence of rivers and streams with high saline concentrations, especially of sulphates, carbonates and chlorides (Vila et al. 2006).

The rivers and streams of the exorheic region are classified into four categories based on their hydrological regime (Niemeyer and Cereceda 1984):

1. *Fast-flowing rivers with mixed regimen* (~27°S to ~32°S). These water bodies are located in the arid zone and are characterised by having flows with high seasonal and inter-annual variability. The highest flow rates occur in the winter and summer due to high precipitation and snow and ice melting, respectively.
2. *Fast-flowing rivers in the sub-humid zone* (~32°S to ~39°S). These rivers include large rivers of Andean origin with mixed-regimen. The highest flow rates occur in the raining season in the winter and in the spring and during the onset of summer due to snow melting. Four longitudinal natural sections can be distinguished: (a) upper reach with steep slopes and coarse substrates; (b) upper-middle reach with a deep riverbed and mid-coarse substrates; (c) middle-lower reach with clean waters and broad and shallow riverbeds; and (d) the river mouth.
3. *Slow-flow rivers in the humid zone* (~39°S to ~45°S). These rivers are born in lakes and have marked potamonic and ritronic areas and wetlands.
4. *Patagonian high-flow rivers* (~45°S to ~54°S). These rivers are born in glaciers that are located in the eastern part of the Andes and have high contents of particulate material.

Table 1 shows the mean flow rates of some representative rivers in each category.

Construction of the typology system

The construction of this typology system to classify water bodies was carried out following the WFD guidelines (European Parliament and Council 2000) considering its implementation in Germany (Pottgiesser and Sommerhauser 2008). To obtain a water typology based on the WFD, it was necessary (a) to define the freshwater ecoregions in Chile; (b) to identify the water bodies (i.e. rivers) that must be classified; (c) to establish classification criteria with their respective ranges; (d) to confirm and validate the aforementioned steps with expert opinions, including the distribution of the biocenosis to adjust the limits; and (e) to

Table 1 Representative rivers of the exorheic region of Chile

River type	River	Location[a]	Catchment size (km^2)[a]	Flow rate (m^3 s^{-1})[b]
Fast-flowing rivers with mixed regimen	Huasco	28°30′S–29°40′S	9.850	3.62[c]
	Choapa	31°10′S–32°15′S	8.124	0.2–93.4[d]
Fast-flowing rivers in the sub-humid zone	Aconcagua	32°55′S	7.163	8.87–33.2[d]
	Bio Bio	36°42′S–38°49′S	24.264	279–1.823[d]
Slow-flow rivers in the humid zone	Valdivia	39°52′S–40°10′S	10.275	683[c]
Patagonian high-flow rivers	Aysén	45°S–46°16′S	11.456	628[c]

[a] *Source* CADE-IDEPE (CADE-IDEPE 2004)

[b] *Source* Vila et al. (2006); TWINBAS (2007)

[c] Mean flow rate

[d] Minimun and maximum mean flow rate, respectively. Rivers located in the arid and sub-humid zone presents high flow rate variability within the year

process and analyse the data to establish the different types that would be part of the typology of the continental waters. As mentioned above, this typology system was generated following an a priori and a top–down methodology. This work did not address this last step, leaving open the future development of a typology for Chile.

Identification of ecoregions

To define the water body typologies, it is necessary to first establish the freshwater ecoregions, which are homogenous geographic units at a macro scale level that share common species and similar ecological dynamics (Abell et al. 2008). As a starting point, the map of freshwater ecoregions of the world that was published by Abell et al. (2008) was used. This map distinguishes six ecoregions for Chile (Titicaca, Atacama, Mar Chiquita y Grandes Salares, Pendientes del Pacífico Sur Andino, Lagos Valdivianos and Patagonia), which are defined according to the distribution and composition of endemic ictic fauna in freshwater. Because the freshwater ecoregions that were proposed by Abell et al. (2008) were developed at a world scale, their limits were adjusted to a national scale. Therefore, the cartography was compared with the freshwater ecoregions that were developed for Chile by Dyer (2000), who determined and delineated each ecoregion by means of qualitative evaluations of similarity/dissimilarity of the basins in relation to the presence of endemic species. The limits of the Abell's ecoregions were modified using the differences that were identified in such comparisons. Finally, the limits of each ecoregion were adjusted, making an expert revision and analysis of the aquatic ecosystems as described further.

Identification of water bodies for classification

The WFD classification criteria consider the following water bodies: rivers, lakes, transitional waters, coastal waters and artificial or modified waters. For the purpose of this study, the identification of superficial water bodies considered only rivers. Therefore, the minimal unit of classification consisted of segments that were defined by third order basins because the Chilean official cartography differentiates among basins, sub-basins, and sub-sub basins, which corresponds to a similar definition that was established for the same purposes in Spain (González and García 2006). This classification does not consider the rivers that are categorised as brooks by the responsible Chilean government institution (Dirección General de Aguas, DGA), as this classification represents a level of detail that is difficult to address by means of this study and future monitoring systems.

Identification of the classification criteria with their respective ranges

The classification criteria with their corresponding river classes were based on the German experience in constructing typology systems for the classification of water bodies that was based, in turn, on the Annex II from the WFD and expert opinions of the scientific community. The criteria and ranges that were proposed by the WFD were modified based on a review of the scientific literature in order to make an adjustment of this system to the Chilean geographic reality. The selected criteria were analysed, discussed, and modified in two technical and scientific workshops in which experts in aquatic systems and decision-makers that were linked to water resources management participated. Once the typology system was defined, a validation process was carried out by means of semi-structured interviews (Hernández et al. 2006) and participative maps (e.g. Chambers 2006; Brown and Raymond 2014). The semi-structured interviews are a qualitative tool to gather information regarding the perception of the interviewees by means of a dialogue between the interviewer and the interviewee about the variables that the former

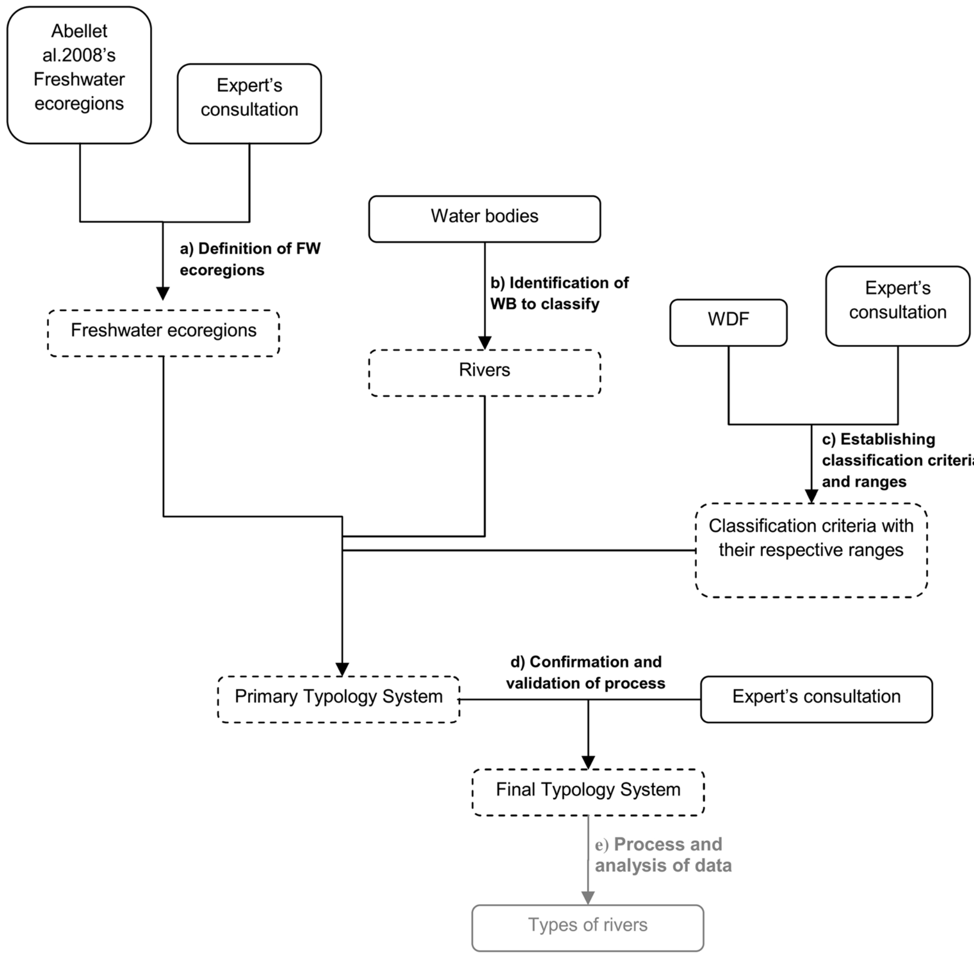

Fig. 1 Flow chart showing the main methodological steps to obtain a Typology System for Chile. The process and analysis of data to develop a system with "Types of rivers" should be addressed in future studies. *FW* freshwater ecoregions, *WB* water bodies

wants to know. However, participative maps are methodological resources that gather the spatial component of knowledge and are normally used to help the members of a community to visually illustrate how they perceive their territory (e.g. Chambers 2006; Brown and Raymond 2014). This tool defines the differentiated spatial units that are part of the expert comprehension of the territory that is dealt with, elaborating zoning plans or processes (Rambaldi et al. 2006). Both of these methodological tools were used by scientists (freshwater experts) from different regions of the country. During this validation process, three main dimensions were included in the interviews: (a) the relevance of the criteria ranges that were used to create the typology system; (b) the logic and foundations to redefine the criteria ranges according to local characteristics; and (c) the adjustment of the ecoregion boundaries.

The selection of experts in aquatic ecosystems to be interviewed was defined according to the national and international scientific publications that refer to studies that are linked to aquatic ecosystems, searching for the presence of renowned national experts of each studied ecoregion.

Figure 1 shows a flow chart describes the main methodological steps of this study:

Results

Ecoregions

The contrast between the ecoregions that were defined for Chile by Abell et al. (2008) and those that were proposed by Dyer (2000) indicated differences in the Atacama, Mar Chiquita and Grandes Salares, and Pendientes del Pacífico Sur Andino ecoregions. Therefore, Dyer (2000) did not include an arheic region between 23°S and 26°S, the Andean endorheic basins of the Mar Chiquita and Grandes Salares ecoregions and the Copiapó river basin within this classification due to the lack of information about the native ictic fauna in those areas. With this information and based on the expert criterion, the Abell et al. (2008) proposal was adjusted as follows:

1. The arheic zone between 23°S and 26°S, which is characterised by the absence of surface runoff, was included in the “Atacama” ecoregion due to its climatic and hydrologic characteristics.
2. The northern limit of the Pendientes del Pacífico Sur Andino ecoregion was changed from the coastal basins that are located in the La Negra and Pan de Azúcar brooks (approximately 24.7°S) to north of the Copiapó river basin (approximately 26°S). This ecoregion was denominated the Mediterranean ecoregion.
3. The Copiapó river basin was included in the Mediterranean ecoregion due to its exorheic condition and its mixed regime, which are typical of the semiarid zone between Copiapó (approximately 26.7°S) and La Ligua (approximately 32.3°S; Niemeyer and Cereceda 1984).
4. Due to their climatic (Santibáñez et al. 2008) and hydrologic (Niemeyer and Cereceda 1984) characteristics, the Mar Chiquita and Grandes Salares ecoregions were merged with the Titicaca ecoregion,

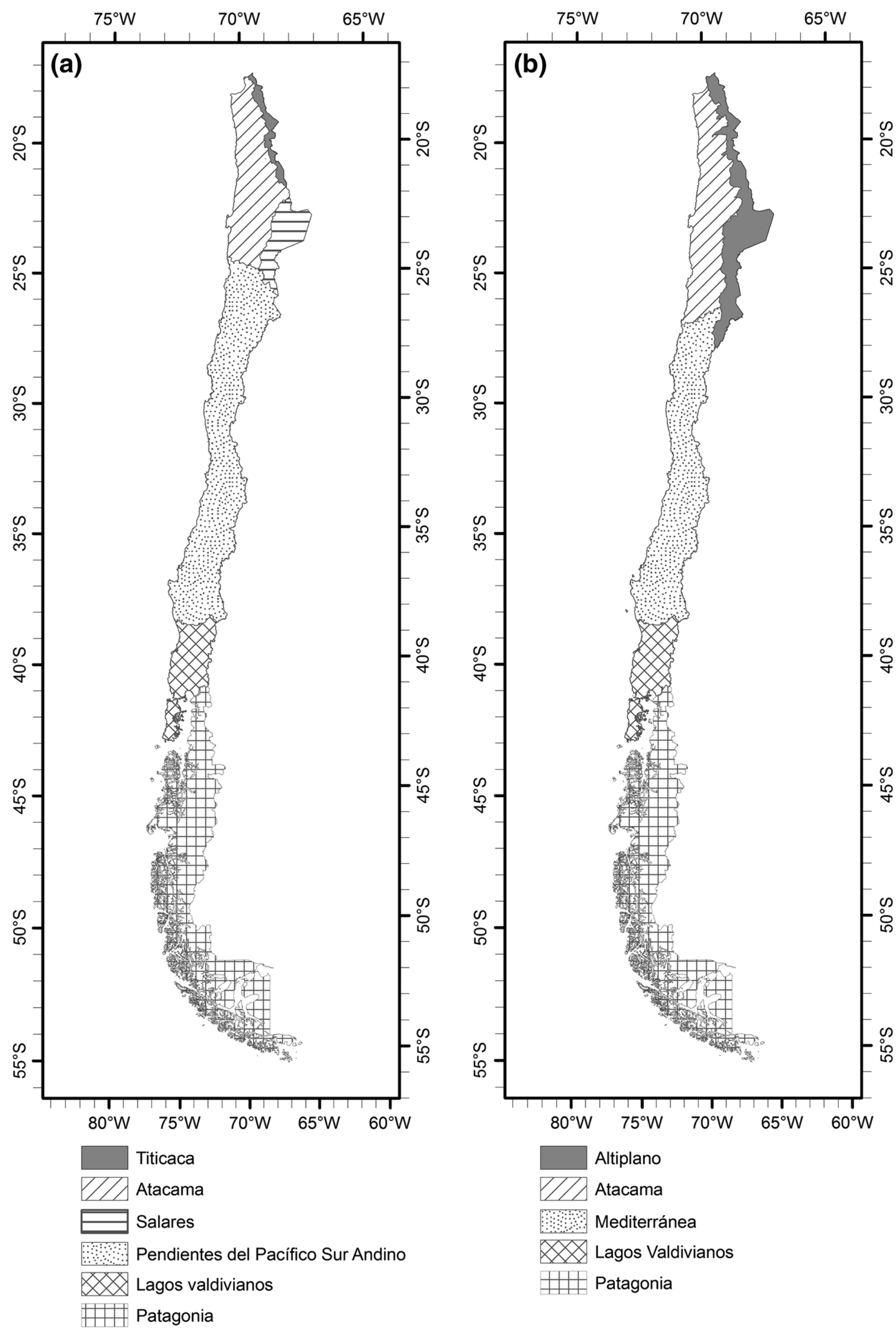

Fig. 2 Ecoregions from Abell et al. (2008) (**a**) and those defined in this work (**b**) *source* **a** Abell et al. (2008); **b** self-elaborated

forming the Altiplano ecoregion. This merge showed a discontinuity in the Loa River that divided this region into two units that were spatially separated. However, the interviewees suggested the fusion, following the natural limit for this ecological condition that corresponds to the high and flat zones that are located more than 3,500 m above sea level (m.a.s.l.; which is also in agreement with the results of Vila et al. (2007)). Finally, the interviewees decided to follow the limits of those sub-sub basins with heights >3,500 m.a.s.l.

A general description of each ecoregion is described in the Supplementary Material.

The five ecoregions that were redefined for Chile were adjusted to the limits of the country's hydrographic basins (Fig. 2).

Classification criteria for rivers

Based on their effects on both the water quality and quantity in the country, five criteria were selected:

1. *Altitude*. The choice of this criterion was based on the fact that altitude is a forcing factor of the temperature, precipitations, and vegetation patterns (Higgins et al. 2005), which directly influence the aquatic fauna (Carter et al. 1996; Jacobsen et al. 1997).
2. *Geology*. This criterion differentiates the natural or original conditions of the water quality according to its mineral content in a limnic system, as the human being cannot easily modify this system. Geology provides information about the natural content of the minerals on the rocks, which is associated with the nutrients in the water as well as high and low electric conductivity conditions. In fact, in Chilean rivers an important parameter of water quality closely related to geology is constituted by dissolved salts due to marine and/volcanic origin of the basins showing a pronounced north–south gradient (Peredo-Parada et al. 2011). In this regard, the electric conductivity was chosen as a key parameter by some experts; however, this criterion has been showed to be too variable in short periods of time and too sensitive to human disturbances in the country (expert opinion). It is important to point out that criterions selected for constructing a typology system need to be not very sensitive to human intervention. In this sense, most of the experts agreed to select geology as a good criterion that can explain satisfactorily the chemical properties in Chilean rivers.

Watershed geology also controls ground water storage capacity and transmissivity and thus is likely to be the dominant influence on base flow at mesoscale scale (Snelder and Biggs 2002). Therefore, different geology classes are expected to incorporate indirectly the groundwater-surface water interaction and its effect on flow.

The classes proposed correspond to an adaptation of the WFD proposal, in which the prevalence of silicates and carbonates with high or low levels of minerals is distinguished.

3. *Slope of the stream bed*. The slope is a decisive factor in rivers because it determines the hydraulic characteristics, the amount of oxygen, and the stream bed substratum. These elements influence the structure of the fluvial ecosystems (Allan and Castillo 2007). In Chile, where rivers are characterized by having drastic slope changes, the slope of the stream bed becomes a key controlling factor that is expected to discriminate specific ecosystem properties such us biological communities (Peredo-Parada et al. 2009)
4. *Dominant substratum*. The substratum is closely related to the abundance and richness of the aquatic flora and fauna (Mackay 1992; Allan and Castillo 2007). Taking into account the spatial scale of analysis and the minimum river classification unit the type of substratum correspond to the dominant one for a specific river unit.
5. *Mean annual discharge*. The criteria mean annual discharge in the natural regime explains the runoff

Table 2 Criteria and ranges from the system of typology of Chilean rivers

Criteria	Proposed ranges
Altitude (m.a.s.l.)	Class 1: very low (<100 msnm)
	Class 2: low (100–800 msnm)
	Class 3: medium (800–1,500 msnm)
	Class 4: high (1,500–3,500 msnm)
	Class 5: very high (>3,500 msnm)
Geology	Class 1: siliceous
	Class 2: calcareous
	Class 3: evaporitical and other minerals
Slope of the stream bed (%)	Class 1: low (<2)
	Class 2: medium (2–4)
	Class 3: high (>4)
Dominantsubstratum	Class 1: silt
	Class 2: sand
	Class 3: gravel
	Class 4: rock
Mean annual discharge in natural regime ($m^3 s^{-1}$)	Class 1: <5
	Class 2: 5 a 50
	Class 3: 50 a 200
	Class 4: >200

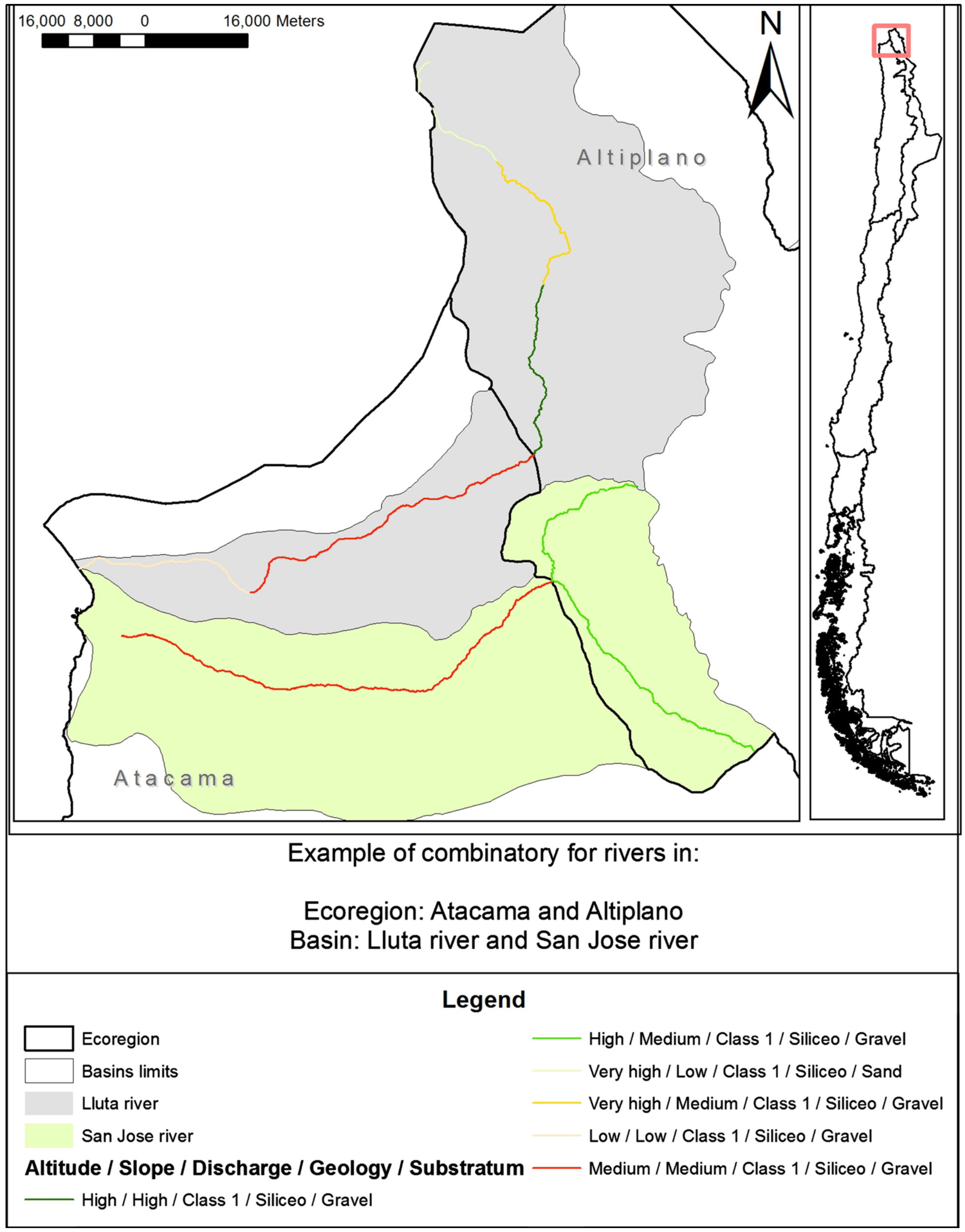

Fig. 3 Example of a criteria combinatory of rivers (Lluta and San José rivers), according to the system of typology for Atacama and Altiplano ecoregions

conditions, the humidity, the amount of sediment and the concentration of ions, among others, determining the biological and physical properties of the stream bed (Snelder and Hughey 2005; Vila et al. 2006; Allan and Castillo 2007). For example, mean annual discharge has been showed to be a predictor of the fish species richness with fish species richness values positively associated with higher magnitude flows (Iwasaki et al. 2012; McGarvey 2014). Although this criteria does not give much information about the seasonality of flow regime (the survival of many aquatic organisms is tightly linked to temporal variation in flow (Bunn and Arthington 2002), most experts agreed that the flow variability was explained by the different ecorregions delineated for Chile. In this regard, the ecoregions implicitly considers climatic characteristics such as temperature and precipitation variability. Others potential controlling factor such as Q90/Q50, maximum proportion of no-flooding period, coefficients of variation in the frequency of low flow, etc. are not included in the WFD guidelines (European Parliament 2000) and the information to make categories within each factor with biological and ecological meaning is poorly reported at national scale.

The criteria that were selected to create a typology system to classify the rivers in Chile and their respective ranges are shown in Table 2.

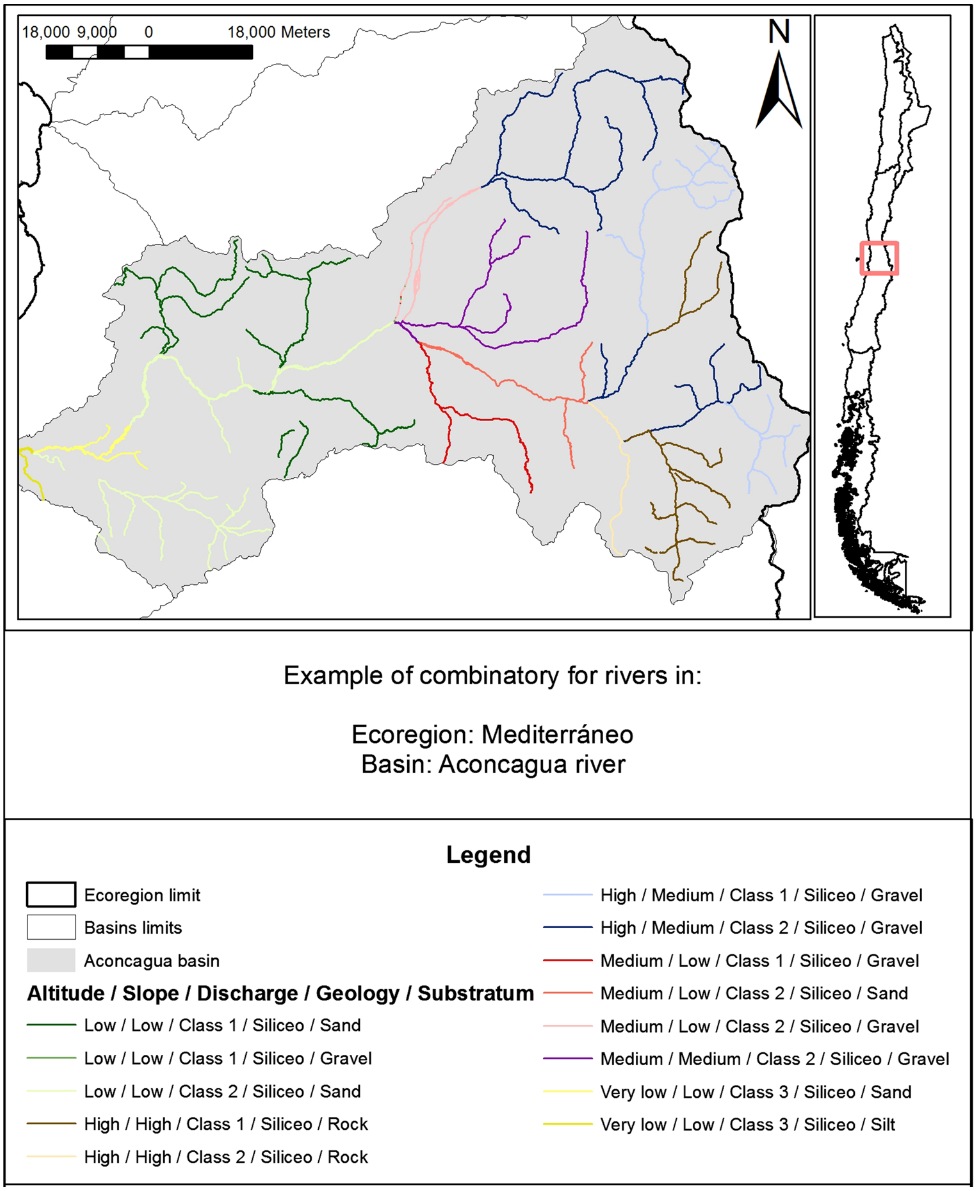

Fig. 4 Example of a criteria combinatory of rivers (Aconcagua river), according to the system of typology for Mediterranean ecoregion

Typology system for rivers in Chile

The application of the abovementioned criteria resulted in 161 possible combinations of rivers. Figures 3, 4, 5 and 6 show examples of these combinations for selected basins in each ecoregion.

Expert confirmation and validation

Expert workshops Each workshop included participants from different government institutions, public and private research centres, and national and international universities. The number of experts was 26 and 22 in the first and second workshop, respectively.

Interviews A total of 12 experts in freshwater ecosystems were interviewed, including at least three experts per ecoregion (Table 3). An agreement was reached regarding the ecoregions and their established limits. The opinion of these experts was coherent and in agreement in terms of the criteria that should be included in the system and the ranges that must be used. Therefore, it can be said that the proposed system typology is based on valid and robust knowledge.

Discussion

Ecoregions

The five ecoregions that were proposed are coherent with the earlier classification processes of Vila et al. (2006) and CEA (2009) mainly because these processes

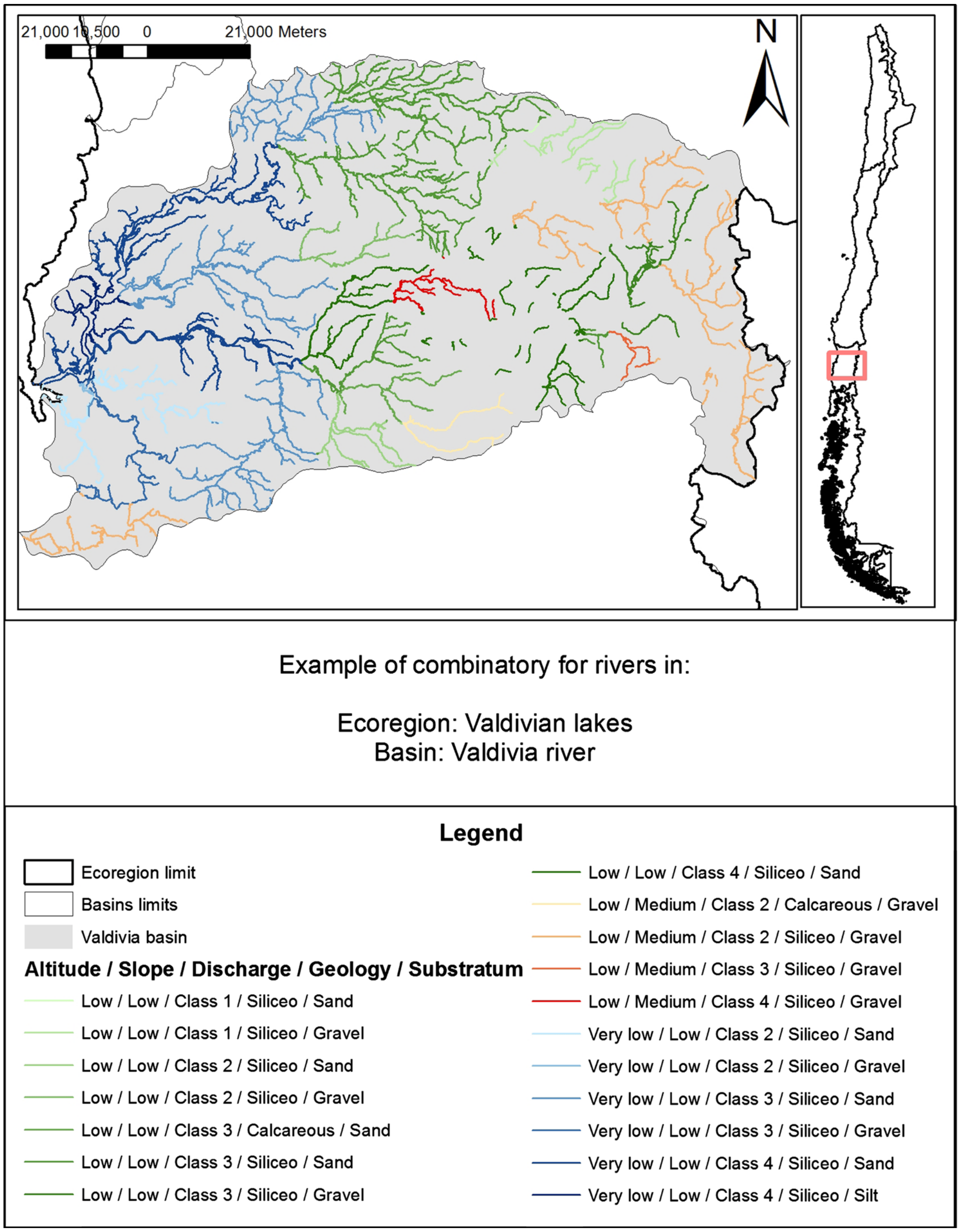

Fig. 5 Example of a criteria combinatory of rivers (Valdivia river), according to the system of typology for Valdivian lakes ecoregion

satisfactorily explain the climatic and hydrological variability of the country (Niemeyer and Cereceda 1984; Santibáñez et al. 2008), which primarily are the main factors influencing the richness and distribution of the ictic species in Chile (Vila et al. 2006). However, due to practical reasons, the ecoregions that were defined by Abell et al. (2008) and Dyer (2000); and, therefore, those that were defined in this study do not consider the distribution of invertebrates and macrophytes. The lack of information about these taxa in the country (Jara et al. 2006; Hauenstein 2006; Rivera 2006; Ortiz and Díaz-Páez 2006; Villalobos 2006) would not permit their use in the short-term to delimit the ecological macrozones at a national level. This limitation becomes important because the biogeographic patterns of other freshwater taxa can differ from those of fish in some places (Higgins et al. 2005; Pérez-Losada et al. 2009), such as the case of the plecoptera, which is distributed between the Mediterranean and the Patagonia ecoregions and is almost absent from the Atacama and Altiplano ecoregions (Palma et al. 2009). However, considering that the ecoregions, by definition, are not strictly homogenous units at a major scale (Wikramanayake et al. 2002), it is expected that these macrozones represent the different hydrological and climatic conditions of the country, determining the existence of characteristic ecosystem units in each case. Therefore, the fact that these ecoregions were validated by experts indicates the precise adjustment of their limits.

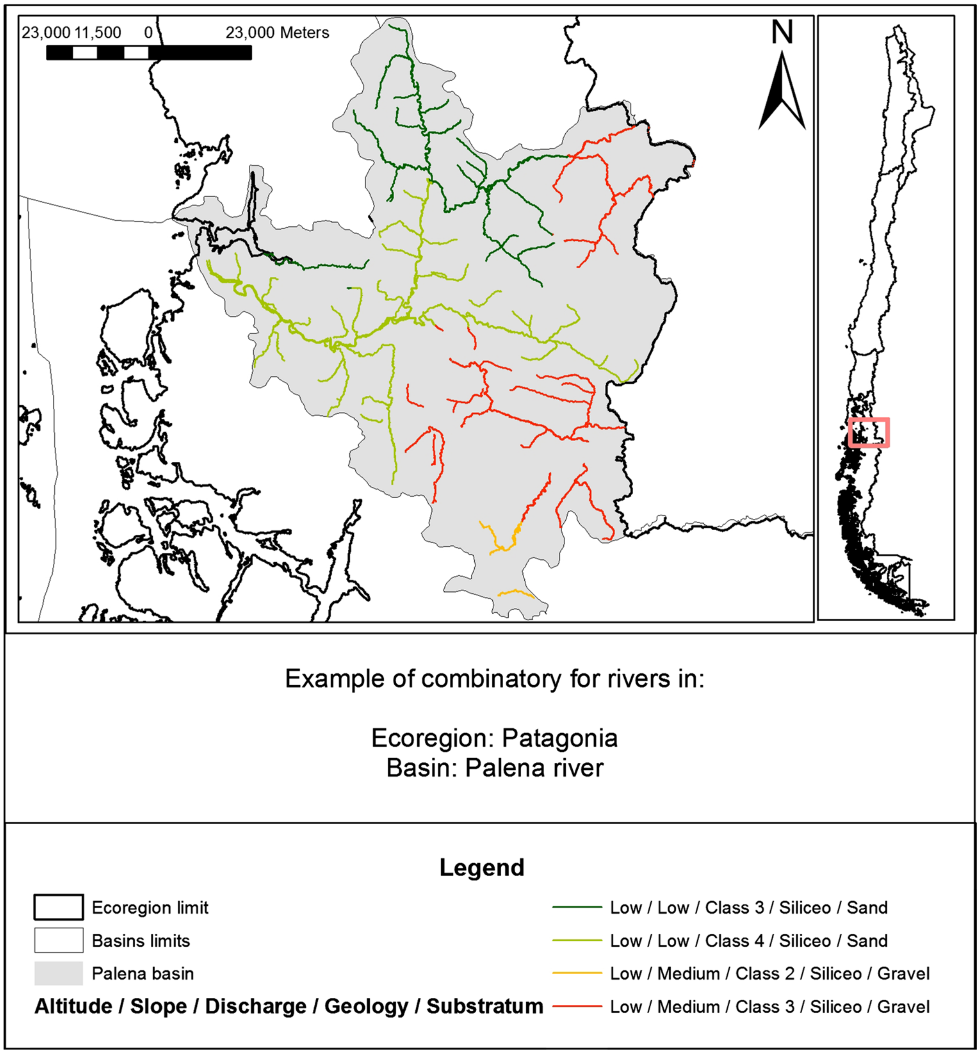

Fig. 6 Example of a criteria combinatory of rivers (Palena river), according to the system of typology for Patagonia ecoregion

Classification of rivers

The typology system was built as a tool to allow us to differentiate the types of water bodies from the point of view of the biocenosis, which should possible to determine under natural conditions at a national scale. The use of a group of abiotic descriptors of water bodies, which can discriminate between the different types of ecosystems, was based on the fact that there is no detailed information about the aquatic communities of rivers throughout the country no are there are historic studies of these communities that allow for the construction of the typology according to the biotic variables. This limited information prompted the use of a methodological framework based on a top–down approach, which has been applied in different countries of the European Union in response to the WFD demands (Wimmer et al. 2000; Rippey et al. 2001; Wasson et al. 2004; Orr et al. 2008; Pottgiesser and Sommerhauser 2008). In agreement with van den Bund and Solimini (2007), it may be said that this typology system is robust because it is based on expert knowledge of the biology of the Chilean river ecosystems; however, it is important to indicate that it is possible that this system will not be very meaningful in regions where knowledge of the aquatic ecosystems is poor (e.g. the Patagonian ecoregion and some basins of the Mediterranean ecoregion).

Combining the criteria of the typology system produced very high numbers of different water bodies, which makes the system difficult to manage at a national level. These combinations should be used referentially in the elaboration of a final typology, in which the group of combinations that are included in a particular river type should be identified due to their similar specific biocenosis characteristics. Therefore, the current lack of knowledge and lack of data at a national level (at a biological level as well as at a cartographic level) necessitate that the potential total number of river types that are obtained from these criteria combinations must be adjusted and validated through a

Table 3 Ecoregion of expertise of the 12 experts interviewed to validate the system of typology. Source: Based on Fuster et al. (2012)

Interviewees (chronologically ordered)	Ecoregion		
	Altiplano and atacama[a]	Mediterránea	Lagos Valdivianos and Patagonia[a]
I. 1	×		
I. 2			×
I. 3			×
I. 4		×	×
I. 5			×
I. 6	×		
I. 7	×		
I. 8	×	×	
I. 9	×	×	
I. 10		×	
I. 11		×	×
I. 12		×	×
Total interviewees	5	6	6
Interviewees (%)[b]	41.6	50.0	50.0

[a] Ecoregions were grouped because an expert with knowledge in one of them has expertise in the other as well (geographic proximity)

[b] Indicates the percentage of interviewees (from the total interviewed in the country) that have expertise in each ecoregion or group of ecoregions

bottom–up methodology, a process that will be necessary in future stages. The biodiversity quantification of each water body should be made using empirical information about the biological features of the most representative taxa. These taxa could be considered potential bio indicators in future management strategies. It is important to mention that in countries such as Chile, with a high diversity of biomes, uniform taxonomically based assessment methods (at a national level) cannot account for all of the differences between ecoregions (Hering et al. 2010). In other words, because water bodies differ in terms of their species pools, the use of a unique formula in which only one particular set of taxa is used to validate a typology system that was created by a top–down methodology will have a low level of applicability at a national level. To put into practice efficient management plans, the resulting numbers of river types should be as large as necessary and as small as possible. Thus, the proposed continental water classification provides a base that can be used to include the biological component in order to group similar water bodies (or divide those that are not analogous) and to establish a group of definitive water body types that can be used by the environmental institutions of this country.

Finally, Chilean institutions should consider that the main objective of a river typology is to establish the natural baseline conditions of each river type. This process is the only way to detect the effects of human disturbance on each water body (Bernadet et al. 2013). Additionally, the correct application of management plans must consider that different water bodies are not isolated units but rather belong to a continual hydrological system where the effects of certain forcing factors upstream (whether natural or anthropic) will be perceived, in part, downstream. Therefore, the use of a river typology as a management tool should consider the real application of an integrated water management strategy.

Expert participation

Although the main objective of this research was the achievement of the first Typology System for rivers for Chile, the successful dialogue between the academic sphere, represented by scientists, and the public sector, represented by decision-makers, became one of the most relevant results of this process. This dialogue, which was favoured by the Ministry of Environment, was brought about by recognizing the participation of scientists as a key element that improves environmental decision-making process. Even though scientists and decision-makers often lack an understanding of the other's knowledge systems (McNie 2007), the positive attitude of the participants favoured a good working environment during the whole process, which enabled to achieve consensual and validated outcomes.

One of the main discrepancies among the actors emerged during the discussion of the classification criteria. Whereas for decision-makers the criteria and classes should be homogeneous for the whole country, for experts the importance of each criteria as key controlling factor of freshwater ecosystems will depend upon the ecoregion. This general opinion rejects, in part, the assumption from WFD about having homogeneous criteria and classes with the aim of having a simple, standard and economically applicable system. For some experts, the dramatic variation in climatic conditions, which lead to a vast variety of natural environments, was the main reason that explains why it is not adequate to represent the variability of freshwater biocenosis with a unique set of criteria and classes for the whole country. Therefore, doubts about the applicability of this tool always remained. This type of circumstance is common in the processes in which the active participation of different performers (i.e. decision-makers and scientists) is involved, which inevitably triggers the emergence of conflicts that are explained mainly by limited visions to tackle and solve a problem (Huitema and Turnhout 2009; McNie 2007). In general, each expert evidenced their methodological differences, which are subject to the amount of knowledge that they have on the ecological systems and the geographic area in which they work. So, it was not surprising that experts tackled the typology from a bottom–up perspective, which contravenes the top–down perspective supported in this proposal of Typology.

Alternatively, whenever this Typology System was presented, it was expressed the need for clarifying the objectives that the institutions wanted to achieve with it, since the level of accuracy and adjustment that it should have depended on the objectives aforementioned. Considering the type of management in which it will be applied, it is absolutely necessary to make this point clear. From the phase of validation and socialization that was characterized by the high level of interaction among scientists specialized in freshwater biological systems, public administration professionals, and the researcher team, it was obtained a Typology System pertinent to the national current situation was obtained.

The validity of the Typology System strengthens the idea that this tool can become the reference frame for the conservation of water resources if it's properly developed. However, it is worth mentioning that the practical validation of this tool is subject to a new stage in which there are two key elements to consider: first, the will to summon the biology experts as active members in the implementation and validation of the Typology in the field; and second, the objective of developing maps using criteria that still do not have spatial expression.

Conclusions

The five ecoregions that are proposed here reflect the general diversity variation of the country without excessive detail that could hinder the management goal for which the typology system for water bodies was designed.

The classification of the continental waters for Chile that is presented in this study agrees with the state-of-the-art of the knowledge about the biocenosis distribution in aquatic ecosystems and, at the same time, reveals the necessity to include an operative base to monitor the water quality based on biological indicators.

The lack of information at a national level (at a biological level as well as at a cartographic level) necessitate that the potential total number of river types that are obtained must be adjusted and validated using empirical information, a process that will be necessary in future stages.

In the elaboration of this work, a significant amount of scientific information and expert knowledge were gathered and systematised. All of this information, along with the decisions that were made in the design of this system, constitutes a valuable base for general consulting and future research on this topic.

The methodology of this work establishes a fruitful dialogue between the scientific and political criteria and management needs. Internationally, this is not only beneficial for the final product of this work but also for future acceptance and implementation because it gathers visions and interests from the different involved sectors.

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