

I Specialized Conference on Ecology, Management and River Restoration: Practices and Experiences. 2015

Lisbon University/FLUVIO Programme – Federal University of Bahia/MAASA

Salvador, Brazil, 27-28 July 2015

Typology of lotic environments of the catchments upstream of Cajuru, Peti and Rio de Pedras dams, Minas Gerais, Brazil

Melo, M.C.¹, Castro, P.T.A.², Freitas, M.D.F.P.P.³, Cordeiro, P.F.⁴, Ferreira, H.L.M.⁵

¹Instituto SENAI de Tecnologia em Meio Ambiente - SENAI FIEMG, *email*:marcia.melo@fiemg.com.br

²Universidade Federal de Ouro Preto, Escola de Minas, *email*:ptacastro@ig.com.br

³Instituto SENAI de Tecnologia em Meio Ambiente - SENAI FIEMG, *email*:mdfreitas@fiemg.com.br

⁴Instituto SENAI de Tecnologia em Meio Ambiente - SENAI FIEMG, *email*:pcordeiro@fiemg.com.br

⁵Instituto SENAI de Tecnologia em Meio Ambiente - SENAI FIEMG, *email*:hlmenezes@fiemg.com.br

Abstract

This paper presents the typology of lotic environments of the watershed of Para, Santa Bárbara and das Velhas rivers, upstream of electricity production reservoirs Cajuru, Peti and Rio de Pedras, respectively. In Minas Gerais State, Brazil, the watershed of rivers Para and Velhas inserted in São Francisco aquatic ecoregion and the river Santa Bárbara in Mata Atlântica Sudeste. The typology, in mesoscale, was based on variables geology, altitude, slope, channel pattern and valley shape.

Keywords: aquatic ecoregion, typology of river, river environment, ecological integrity

Introduction, scope and main objectives

The production of hydropower together with environmental preservation requires complementary strategies to usually adopted in water management. The current legislation, CONAMA 357/05 Act 9433, 08/01/1997, focuses on quality control of water resources physic-chemical and microbiological indicators. However, this guideline does not indicate the need for a general assessment of the state of preservation of water bodies using ecological indicators.

The concept of ecological integrity aims to fill this gap by adding a set of abiotic and biotic attributes that act as indicators of environmental changes. These environmental changes reflect anthropogenic interference and may cause ecological impoverishment when compared to the conditions that is closest as possible to the original conditions - the reference sites (Hughes and Larsen 1986). The concept of ecological integrity may indicate that the water body, although in good condition in terms of physic-chemical and microbiological quality of water, can be highly stressful due to loss of biodiversity and habitat diversity

The state of Minas Gerais enacted the rule COPAM / CERH-MG nº001 / 2008, which start to promote integrated water management. In a similar way to other countries such as that from European Union (DQA 2000), United States (USEPA 2013) and Australia (Parsons, Thoms and Norris 2001) this rule intend that the evaluation of the water expands to evaluate and monitor the aquatic environment as a whole and not only the quality of water. These actions are based on the classification of the ecological quality of water bodies based on typology models that use

interdisciplinary technological procedures (Ferreira and Castro 2005a, 2005b; Castro *et al.*, 2005). In large-scale studies, these classification of water bodies start from the definition of aquatic ecoregions following by classification of water bodies in places of similar altitude and geological characteristics. These classification is validated in detail scale for research abiotic and biotic components such as habitat ecohydromorphology, the physic-chemical quality of water and sediments and the composition and structure of biological communities (AQEM 2002, Castro *et al.* 2005, Silva *et al.* 2005, Junqueira *et al.* 2007 INAG 2008, Castro *et al.* 2011a, 2011b).

In Minas Gerais, such studies are being developed in larger scale, to statewide, and in mesoscale encompasses the pilot areas of the watershed of Para, Santa Bárbara e das Velhas rivers upstream of electricity production reservoirs - Cajuru, Peti and Rio de Pedras, respectively. This project aims to contribute to the improvement of methodologies that support the management of aquatic ecosystems and advances in compliance with the DN COPAM / CERH-MG nº001 / 2008.

Methodology/approach

The typology of bodies of lotic waters in the pilot areas of contribution basins of Cajuru, Peti and Rio de Pedras reservoirs encompasses studies in different scales of analysis. They go from the large to detailed scale. In detailed scale the typology of water bodies has the purpose of validation types by searching abiotic and biotic components, such as ecohydromorphology from habitats, chemical characteristics of water and sediments and community structure (Fig. 1).

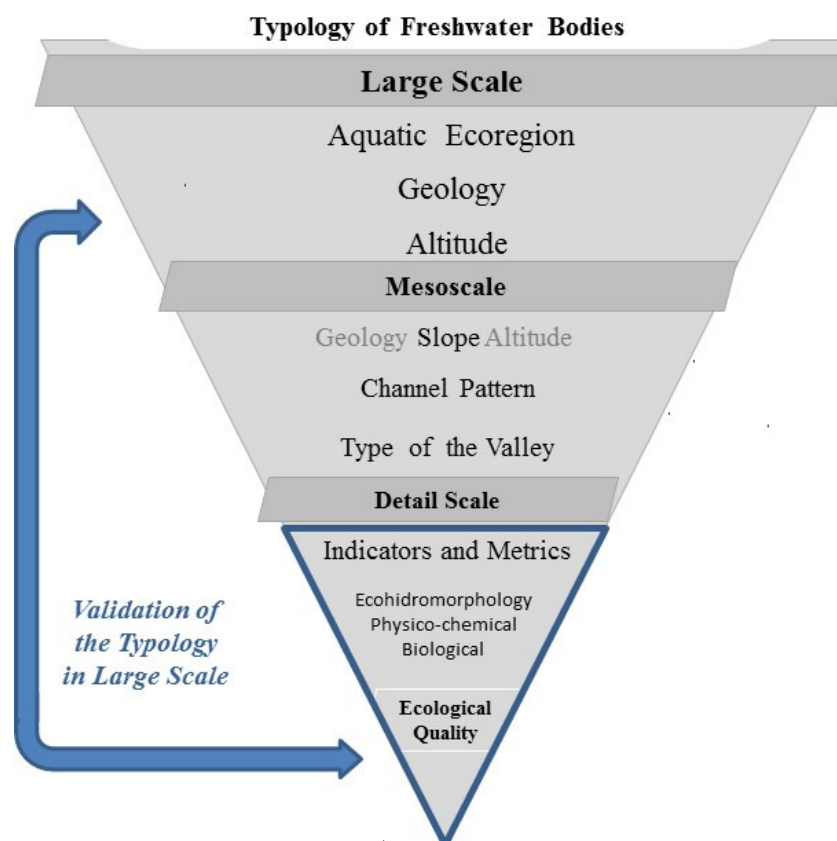


Fig. 1: Scales of analysis for classification of inland water bodies.

For the pilot areas Cajuru, Peti and Rio de Pedras, studies included the following steps:

Step 1: recognition of aquatic ecoregion as System A from DQA (2000) and delimitation of contribution basins of these areas on a scale of 1: 50,000;

Step 2: identifying the types of rivers according to the classification developed on a large scale for the state of Minas Gerais (Castro *et al.*, 2014a);

Step 3: detailing of geological data in mesoscale by using the geological map of the detail scale (Castro *et al.*, 2014b);

Step 4: cartographic representation of the hydrography superimposed on the refinement of geological data on the scale of 1:50,000;

Step 5: partitioning of rivers into segments based on the following hydrogeomorphologic variables: (i) slope: thalweg slope; (ii) channel pattern: sinuos, meandering, straight, braided and anastomosed; (iii) type of the valley: the "v" or normal, open, shallow and embedded. This compartmentalization relied on satellite imagery analysis (Google Pro between 2009 and 2015), the shading map of the MDT relief derived obtained by using the ArcGIS™ 10.3 and topographic profiles (longitudinal) from the hypsometric maps scale of 1: 50,000. This step is in accordance with System B DQA (2000).

Results

The pilot areas covered in this study are part of two of the five aquatic ecoregions defined in the State of Minas Gerais. The contribution basin of Cajuru reservoirs and Stones River located in the ecoregion San Francisco and the Peti in the ecoregion Atlantic Forest Southeast. Among the 21 types of water bodies identified in the mining territory, based on geology and altitude, six occur in the pilot areas, four in Peti five in Cajuru and three in Stones River

The aggregation of the hydrogeomorphologic variables as the slope, channel pattern and type of the valley resulted in 24 types of lotic segments, predominantly those that drain on siliceous rocks above 800m altitude, with low slope, in meandering channel and open valley - S3DBCSVA type (Fig.2).

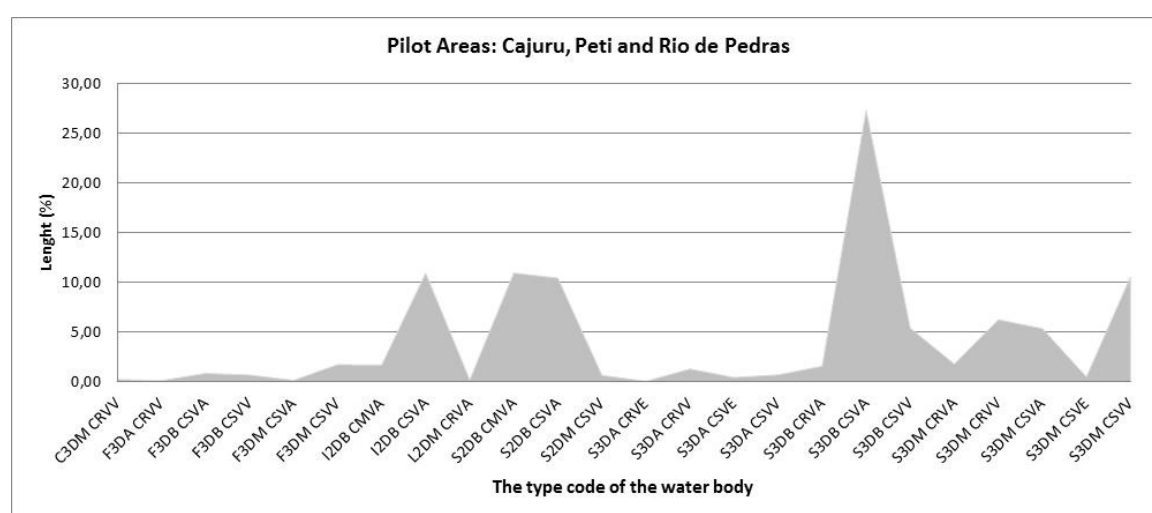


Fig. 2: Ocorrence (%) of the types of water bodies in pilot areas Minas Gerais, Brazil, based on lithologic group, class altimetric and hydrogeomorphologic variables.

Lotic segments S3DBCSVA kind totaling 181.0km, equivalent to 27.3% of 662.2km of river system the pilot areas. In extension also highlight I2DBCSVA types, S2DBCSVA, S3DBCSVV, S3DMCSVV and S2DBCMVA. These drain from 72.6km to 41.4km of unconsolidated sediment (I) and siliceous rocks (S) with low slope (DB) and medium (DM); winding channel (CS) and meandering (CM); open valley (VA) and "V" (VV). The remaining 18 types have 35.8km to 0.4km in length of water network of pilot areas (Fig. 3).

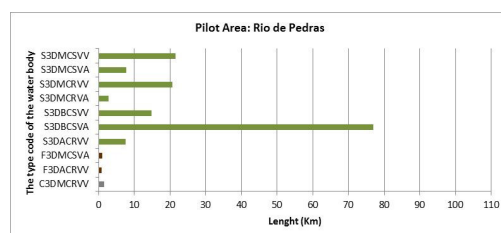
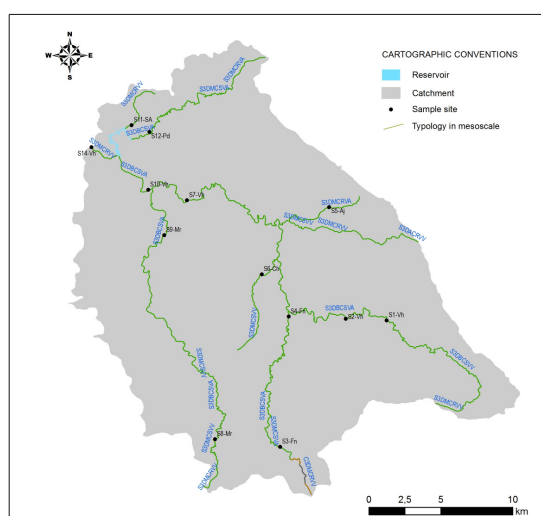
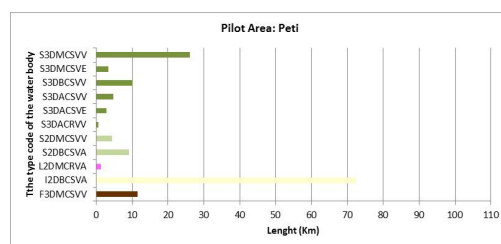
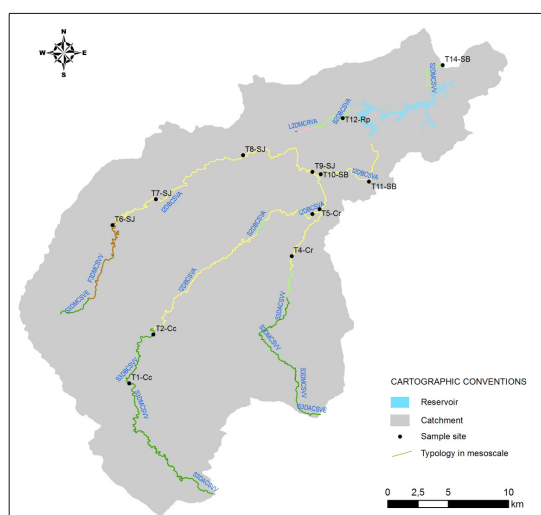
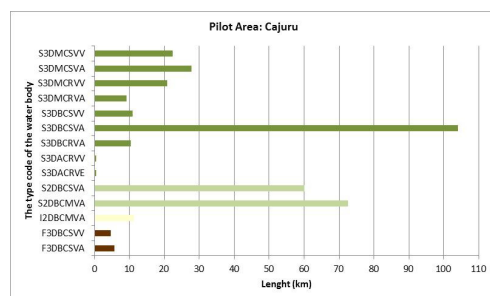
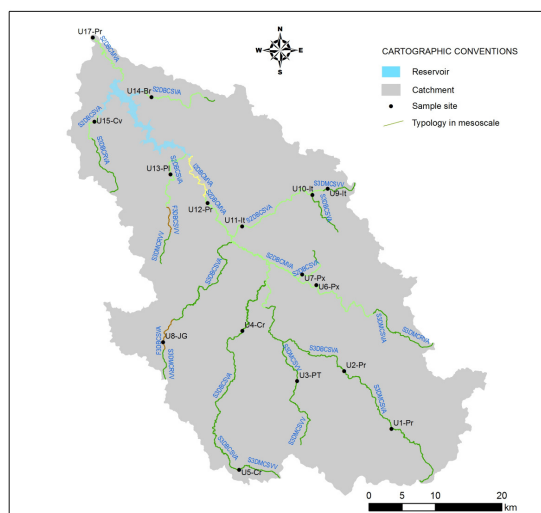


Fig. 3: Length (in kilometers) of types of water bodies identified in the pilot areas. Minas Gerais, Brazil, based on lithologic group, class altimetric and hydrogeomorphologic variables.

Of the 42 sites marked for validation of classification on a large scale and mesoscale 21:43% are located in lotic segment S3DBCSVA type, 19.5% type I2DBCSVA and 14:29% of S2DBCSVA type (Qd. 1).

Qd. 1: Ocorrence of the types of water bodies identified in the pilot areas. Minas Gerais, Brazil, based on lithologic group, class altimetric and hydrogeomorphologic variables.

Typology of freshwater bodies		Type occurrence (n° of sample sites)		
Code	Description	Cajuru	Peti	Rio de Pedras
C3DMCRVV	Lotic segment on carbonates rocks > 800m of altitude, with moderate slope, straight channel and “V” valley			
F3DACRVV	Lotic segment on basic filiation rocks > 800m of altitude, with high slope, straight channel and “V” valley			
F3DBCSVA	Lotic segment on basic filiation rocks > 800m of altitude, with low slope, sinuous channel and open valley	(1)		
F3DBCSVV	Lotic segment on basic filiation rocks > 800m of altitude, with low slope, sinuous channel and “V” valley			
F3DMCSVA	Lotic segment on basic filiation rocks > 800m of altitude, with moderate slope, sinuous channel and open valley			
F3DMCSVV	Lotic segment on basic filiation rocks > 800m of altitude, with moderate slope, sinuous channel and “V” valley		(1)	
I2DBCMVA	Lotic segment on unconsolidated sediments with altitude of 500 to 800m, with low slope, meandering channel and open valley			
I2DBCSVA	Lotic segment on unconsolidated sediments with altitude of 500 to 800m, with low slope, sinuous channel and open valley		(8)	
L2DMCRVA	Lotic segment on lateritic sediments with altitude of 500 to 800m, with moderate slope, straight channel and open valley			
S2DBCMVA	Lotic segment on siliceous rocks with altitude of 500 to 800m, with low slope, meandering channel and open valley	(3)		
S2DBCSVA	Lotic segment on siliceous rocks with altitude of 500 to 800m, with low slope, sinuous channel and open valley	(5)	(1)	
S2DMCSVV	Lotic segment on siliceous rocks with altitude of 500 to 800m, with moderate slope, sinuous channel and “V” valley		(1)	
S3DACRVE	Lotic segment on siliceous rocks > 800m of altitude, with high slope, straight channel and embedded valley			
S3DACRVV	Lotic segment on siliceous rocks > 800m of altitude, with high slope, straight channel and “V” valley			(1)
S3DACSVE	Lotic segment on siliceous rocks > 800m of altitude, with high slope, sinuous channel and embedded valley			
S3DACSVV	Lotic segment on siliceous rocks > 800m of altitude, with high slope, sinuous channel and “V” valley			
S3DBCRVA	Lotic segment on siliceous rocks > 800m of altitude, with low slope, straight channel and open valley			
S3DBCSVA	Lotic segment on siliceous rocks > 800m of altitude, with low slope, sinuous channel and open valley	(3)		(6)
S3DBCSVV	Lotic segment on siliceous rocks > 800m of altitude, with low slope, sinuous channel and “V” valley	(1)	(2)	(1)
S3DMCRVA	Lotic segment on siliceous rocks > 800m of altitude, with moderate slope, straight channel and open valley			
S3DMCRVV	Lotic segment on siliceous rocks > 800m of altitude, with moderate slope, straight channel and “V” valley			(2)
S3DMCSVA	Lotic segment on siliceous rocks > 800m of altitude, with moderate slope, sinuous channel and open valley	(1)		(1)
S3DMCSVE	Lotic segment on siliceous rocks > 800m of altitude, with moderate slope, sinuous channel and embedded valley			
S3DMCSVV	Lotic segment on siliceous rocks > 800m of altitude, with moderate slope, sinuous channel and “V” valley	(2)		(2)
Total of types (n° of demarcated sample sites)		14 (16)	11 (13)	10 (13)
		24 types (42 sample sites)		

Discussion

Despite the adjustments necessary due to availability and limitations of the database and cartography, as well as morphoclimatic characteristics of the state of Minas Gerais, the methodology in development showed application of classification models of aquatic environments to the group of relatively homogeneous bodies of water.

The three pilot areas selected for suitability of the studies together equal to 0.6% of the Minas Gerais area. They have been shown to be representative of the types identified to the state, once covering 28.6% of the 21 combinations of geology and altitude and 13 (27.1%) of the possible combinations of the variables slope, channel pattern and type of valley.

As in German (AQEM 2002), Portuguese (INAG 2008) and Chilean (CONAMA 2010) studies the aggregation hydromorphological variables to typify the water bodies, as contained in System B of the WFD (2000), cause best discrimination among lotic segments in the pilot areas of Cajuru, Peti and Rio de Pedras. The plot of collection sites and the incorporation of the detailed scale studies are used to validate this classification.

Conclusions/outlook

The use of both System A and System B approaches enabled the differentiation of the bodies of water in the pilot areas. The System A provides a common starting point to identify the stream types based on general landscape conditions and serves as a first basis for comparisons. It enables to differentiate the aquatic ecoregions in accordance with the geographical areas and, within each of them, differentiate the water bodies according to geology and altitude. For each type further differentiations are possible using hydromorphologic descriptors which will be validated in detail scale, by studies in the sample sites.

This study, in development, intends to expand the understanding of the processes that affect and influence the structure and functional dynamics of freshwater ecosystems. It intends, also, to contribute to the improvement of ecotechnologies applicable to the monitoring, management and restoration of these environments. Another goal of this project is to broaden the skills and abilities of research groups to work in an interdisciplinary way.

Acknowledgements

To Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), to Cemig - Generation and Transmission (Cemig GT) and the National Agency of Electrical Energy (R & D ANEEL), for project financing " Utilização de Índice de Integridade Ecológica para Classificar a Qualidade de Ambientes Aquáticos de Minas Gerais", which is part of the project work in development

References

AQEM - Assessment system for the ecological quality of streams and rivers throughout Europe using benthic macroinvertebrate. 2002. Manual for the Application of the AQEM System: a comprehensive method to assess european streams using benthic macroinvertebrates, developed for the purpose of the water framework directive, version 1.0, february Version 1.0. www.aqem.de

Castro *et al.* 2011a. *Avaliação do estado de conservação das veredas da região do reservatório de Três Marias, centro de Minas Gerais, com base em características ecofísicas*. Ouro Preto, DEGEO - UFOP / CETEC / FAPEMIG. 40p., apêndices. Relatório técnico final.

Castro *et al.* 2011b. *Avaliação dos impactos da mineração do ferro sobre as características de ambientes fluviais e sua qualidade ecológica*. Ouro Preto, DEGEO - UFOP / CETEC / FAPEMIG. 21p., apêndices. Relatório técnico final.

Castro PTA; Lana CE, Ferreira HLM, Leite MGPL, Sobreira FG, Bacellar LAP. 2005. *A avaliação do estado de preservação do Alto Rio das Velhas, MG, com Base em Características Físicas do Ambiente Fluvial*. Ouro Preto, DEGEO - UFOP / FAPEMIG. 239p. Relatório técnico final.

Castro, PTA, Melo, MC, Ferreira, HLM, Freitas MDFPP, Cordeiro PF. 2014a. Tipificação dos corpos de água em Minas Gerais – ênfase em ambientes lóticos. *Geonorte*, Edição Especial 4, V.10, N.1, p.676-680.

Castro, PTA, Melo, MC, Ferreira, HLM, Freitas MDFPP, Cordeiro PF. 2014b. Tipificação de ambientes lóticos nas ecorregiões aquáticas São Francisco e Mata Atlântica em Minas Gerais. *Geonorte*, Edição Especial 4, V.10, N.1, p.481-484.

CONAMA - Comision Nacional del Medio Ambiente. 2010. *Clasificación de cuerpos de agua*. Chile, Departamento de Ciencias Ambientales y Recursos Naturales Renovables, Facultad de Ciencias Agronómicas, Universidad de Chile. 115p. Informe final. Available at: http://www.sinia.cl/1292/articles-48828_recurso_1.pdf. [accessed 07.04.2015].

CONAMA - Conselho Nacional do Meio Ambiente. 2005. Resolução número 357, 17 de março de 2005. *Diário Oficial da União*, Brasil, n.53, de 18 de março de 2005.

Deliberação Normativa Conjunta COPAM / CERH-MG nº 01, de 05 de maio de 2008. Publicada no *Diário do Executivo* “Minas Gerais”, 05 / 2008.

DQA - Directiva da Agua. 2000. Directiva 2000.60.CE do Parlamento Europeu e do Conselho, de 23.10.2000. *Jornal Oficial* no L 327, p. 001-073, Dez. 2000.

Ferreira HLM, Castro PTA. 2005a. Avaliação ecomorfológica de segmentos e trechos fluviais – aplicação da abordagem rápida no alto curso da bacia do rio das Velhas/MG, Brasil. In: *Anais do*

XII Congresso Latinoamericano de Geologia. Área técnica: Geologia Ambiental. Quito, Equador. 5p. v. cd.

Ferreira HLM, Castro PTA. 2005b. Ecomorphological analysis of fluvial habitats of the upstream part of rio das Velhas/MG, Brazil. In: *Proceeding International Symposium on Land Degradation and Desertification*. Session: S2 – Rivers, Fluvial Systems and Land Degradation. Uberlândia/MG, Brazil. 8p. v. cd.

Hughes RM, Larsen DJ. 1986. Regional references sites: a method for assessing stream potentials. *Environmental Management*, v.10, n.5, p.629-635.

INAG I. P. Instituto da Água I.P. 2008. Tipologia de rios em Portugal Continental no âmbito da Implementação da Directiva Quadro da Água. I-Characterização abiótica. Ministério do Ambiente, do ordenamento do Território e do Desenvolvimento Regional. Instituto da Água. 39 p. Available at: www.drapc.min-agricultura.pt/base/documentos/caracterizacao_rios_am53.pdf. [accessed 03.02.2013].

Junqueira MV. et al. 2007. *Padronização e Consolidação Metodológica de um Índice Biótico de Qualidade de Água para Ambientes Lóticos: bacia do rio Paraíba do Sul*; CETEC/FAPEMIG, Belo Horizonte 106p. Anexos. Relatório técnico final.

Parsons M, Thoms M, Norris R. 2001. Australian river assessment system: AusRivAS physical assessment protocol. *Monitoring river health initiative technical Report number 22*. Commonwealth of Australia and University Canberra, Canberra. 116pp. Available at: <http://www.environment.gov.au/system/files/resources/94149200-d4c7-4228-9eea-0520f645d400/files/protocol-1.pdf>. [accessed 05.05.2004].

Silva AG. et al. 2005. *Estudo da Estrutura da Comunidade Ictiofaunística e dos Habitats Fluviais da Bacia do Rio Jequitá/MG, com Interesse para a Conservação*. Belo Horizonte, CETEC / FAPEMIG.. 150p. Relatório técnico final.

USEPA - U.S. Environmental Protection Agency 2013. *National Rivers and Streams Assessment 2008–2009. A Collaborative Survey. DRAFT*. U.S. Environmental Protection Agency Office of Wetlands, Oceans and Watersheds Office of Research and Development Washington, DC 20460 - EPA/841/D-13/001. Available at: http://water.epa.gov/type/rsl/monitoring/riverssurvey/upload/NRSA0809_Report_Final_508Compliant_130228.pdf. [accessed 07.04.2015].