www.ugb.org.br
ISSN 2236-5664

Revista Brasileira de Geomorfologia

v. 20, nº 4 (2019)

http://dx.doi.org/10.20502/rbg.v20i4.1560

LEARNING, DOING AND PROFESSIONAL DEVELOPMENT – THE RIVER STYLES FRAMEWORK AS A TOOL TO SUPPORT THE DEVELOPMENT OF COHERENT AND STRATEGIC APPROACHES FOR LAND AND WATER MANAGEMENT IN BRAZIL

APRENDIZADO, PRÁTICA E DESENVOLVIMENTO PROFISSIONAL – A METODOLOGIA DOS ESTILOS FLUVIAIS COMO FERRAMENTA PARA APOIAR O DESENVOLVIMENTO DE ABORDAGENS CONSISTENTE E ESTRATÉGICAS PARA O MANEJO DA TERRA E DA ÁGUA NO BRASIL

Kirstie Fryirs
Department of Environmental Sciences, Macquarie University
64G7+F3 Macquarie Park, North Ryde, NSW, Australia
ORCID: 0000-0003-0541-3384
E-mail: kirstie.fryirs@mq.edu.au

Gary Brierley
School of Environment, The University of Auckland
29 Symonds Street, Auckland City 1142. New Zealand
ORCID: 0000-0002-1310-1105
E-mail: g.brierley@auckland.ac.nz

Mônica Marçal
Departamento de Geografia, Universidade Federal do Rio de Janeiro
Athos da Silveira Ramos 274, Rio de Janeiro, Rio de Janeiro. CEP: 21941-909, Brasil
ORCID: 0000-0002-2674-5380
E-mail: monicamarcal@gmail.com

Maria Naíse Peixoto
Departamento de Geografia, Universidade Federal do Rio de Janeiro
Athos da Silveira Ramos 274, Rio de Janeiro, Rio de Janeiro. CEP: 21941-909, Brasil
ORCID: 0000-0002-5518-1588
E-mail: marianaisepeixoto@gmail.com

Raphael Lima
Departamento de Geografia, Universidade Federal do Rio de Janeiro
Athos da Silveira Ramos 274, Rio de Janeiro, Rio de Janeiro. CEP: 21941-909, Brasil
ORCID: 0000-0002-3877-3944
E-mail: raphaelgeo85@gmail.com

Informações sobre o Artigo

Recebido (Received):
04/01/2019
Aceito (Accepted):
30/05/2019

Keywords:
Fluvial Geomorphology; River Restoration, Learning and Teaching.

Palavras-chave:
Geomorfologia Fluvial; Restauração de Rios; Aprendizagem e Ensino.

Abstract:

Ongoing development, training and adaptive learning are fundamental to professional practice in river science and management. River Styles Framework provides a coherent, carefully structured (scaffolded) approach that synthesises geomorphic understandings of rivers as a baseline to support river management applications. As the approach is generic, principles and procedures can applied in any setting. The Framework and its applications build on fundamental research into river forms and processes. Importantly, the Framework was developed in collaboration with river management agencies in New South Wales, Australia and has been used in collaboration with practitioners elsewhere in the world. This paper documents the process used to teach the five-day River Styles professional short course in Brazil, September 2017. We report upon some pedagogical foundations of the Framework to explain the approach to teaching. We present an overview of the types of exercises taught in Brazil, showing how local fieldwork and case studies support the uptake of this geomorphic information to inform river management. We emphasise the importance of careful planning in delivering a coherent product that integrates remotely-sensed work, field interpretation skills and lecture/practical class exercises. These exercises build upon foundation research in fluvial geomorphology in the Macaé Catchment in Rio de Janeiro State.

Resumo:

Formação continuada, treinamento e aprendizagem adaptativa são processos fundamentais para a prática profissional científica e a gestão de rios. A metodologia dos Estilos Fluviais fornece abordagem estruturada que sintetiza compreensões geomorfológicas sobre os rios para prover organização de dados que embasam tais aplicações. Como a abordagem é genérica, os princípios e procedimentos são aplicados a qualquer situação e ambiente. Os Estilos Fluviais produzem pesquisas sobre formas e processos fluviais. A metodologia foi desenvolvida em colaboração com agências de gestão de rios em New South Wales, Austrália e foi utilizada com profissionais em outras partes do mundo. O artigo documenta o processo de ensino durante os 5 dias de curso no Brasil em setembro de 2017. Relatam-se os fundamentos pedagógicos da metodologia visando auxiliar a explicação da abordagem de ensino dos princípios e aplicações da geomorfologia. É apresentada visão geral dos exercícios que foram ensinados, mostrando como o trabalho de campo e os estudos de caso auxiliam na informação geomorfológica para a gestão dos rios. Fundamental planejar a entrega de um produto que integre o trabalho com o sensoriamento remoto, as habilidades de interpretação em campo e aulas expositivas/práticas. Estes exercícios foram desenvolvidos a partir de pesquisas já consolidadas em geomorfologia fluvial na Bacia de Macaé, Estado do Rio de Janeiro.

Introduction

Professional development is an integral part of proactive, cost-effective approaches to land and water management. In fast-changing, increasingly unpredictable and uncertain times, it is vital to make effective use of what we know, adopting a learning approach that engages productively and constructively with new information bases. Solid foundational knowledge is required so that we can meaningfully build upon what we know. Continuing with the construction terminology, we need a carefully scaffolded approach to learning, reporting and information development to underpin the use of these insights. At the same time, we want to ensure that we ask the right questions, don't over-react to the next technological development or measurement technique, and ensure that we sensibly use what has come before (if it's useful). As it is easy to be overwhelmed by too much information, more than ever we need coherent information bases to inform and update management practices, providing a clear rationale and evidence base for the decisions we make and the approaches we apply.

Coherent science is a key component of integrative approaches to land and water management – after all, fragmented science can only support fragmented management and you cannot manage a resource you do not understand. Proactive and precautionary practices build upon a sophisticated understanding of each river system. Incorporation of this information in planning and policy helps to prioritise management actions, at local, catchment, regional and national scales. These actions can span the spectrum from 'do nothing and allow the system to look after itself' because the system is in good condition, to knowing when to 'opt-out' because the system is self-healing, to minimalist intervention to 'kick-start' the process of recovery, to heavy intervention in fully degraded rivers. The further along this spectrum an agency chooses to focus its efforts the more costly the interventions and solutions, with an increasingly reduced prospect for success. So, how does a practitioner or agency generate sufficient understanding of river systems to make well-informed and proactive decisions on management activities? As the scientific study of landforms, processes and landscapes, geomorphology provides a fundamental basis for these initiatives (see BRIERLEY *et al.*, 2019).

Each landscape is a dynamic, evolving template that reflects the cumulative imprint of geologic, climatic and anthropogenic impacts (FRYIRS; BRIERLEY, 2013). A landscape provides a platform to develop 'common ground' among practitioners in professional fields such as agronomy, engineering, hydrology, ecology, geography and water management. This template sets the baseline to develop coherent and proactive river management practices, providing an evidence base to support decision-making. Unless we work together to develop and apply coherent approaches to land and water management, unsustainable outcomes result. This results in greater expense into the future – burdening future generations with problems that can be avoided (or minimised) through sensible and strategic actions taken today.

In Brazil, there is an urgent need to address many land and water management issues. However, current approaches to land and water management are largely reactive, framed around concerns for disaster management, whether this be natural, political or institutional. Coherent and consistent databases on river forms, processes, condition and recovery are not available, and suitably qualified professionals who can undertake such assessments are rare. When asked to reflect upon contemporary river management issues in Brazil, participants at the workshops and short courses documented in this paper identified the following concerns:

- Links between the community, managers, decision-makers and researchers.
- Fragmented scientific information, much of which is unreliable.
- Science links to management.
- Availability of expertise.
- Lack of effective community engagement and participation.
- Implementation of environmental laws.
- Concerns for urban rivers, pollution and sanitation, living on floodplains, deforestation and agricultural/water management programs.

When asked, "What can we do about it?", the following responses were received:

- Engender collective (societal) engagement.
- Work together: Improve partnerships and education activities that link research and management in a more effective way, enhancing communication between researchers, managers and decision makers.
- Improve training.
- Respect the river: Work with nature.
- Ensure management applications are designed and applied at the catchment scale.
- Improve water quality and sanitation facilities.
- Apply existing legislation more effectively.

This feedback indicates that a coherent, carefully crafted and co-ordinated approach to environmental management and professional development/training is required. Therefore, a transition towards more sustainable river futures in Brazil requires:

1) The development of the geomorphic template using a consistently applied framework.

2) The development of good quality, coherent databases with which to make strategic river management decisions.

3) Better professional development of practitioners.

4) Better co-ordination and communication across engineering, hydrology, geomorphology, ecology, social sciences, and policy and planning.

The River Styles Framework provides a coherent basis and integrating platform for such activities (BRIERLEY; FRYIRS, 2005; BRIERLEY *et al.*, 2019; www.riverstyles.com).

To demonstrate the potential use of a geomorphic approach to landscape analysis as a basis for land and water management applications in Brazil, the Post-Graduate Program of Geography (PPGG/

UFRJ) invited Professor Gary Brierley (University of Auckland, New Zealand) and Professor Kirstie Fryirs (Macquarie University, Australia) to run two one-day workshops that provided an "Introduction to Fluvial Geomorphology" and a four day professional short course to provide a practically-based overview of the River Styles Framework in Rio de Janeiro and Recife in September 2017. This professional training for practitioners was an opportunity to train some of the next generation of river managers. This work was co-ordinated by Professor Monica Marçal and her research group at the Federal University of Rio de Janeiro (UFRJ), building directly upon research undertaken during her study leave visit to New Zealand in 2016 and a related publication on River Styles of the Macaé Catchment, 250 km east of Rio de Janeiro (MARÇAL *et al.*, 2017). The four day River Styles professional short course included site visits to the Macaé Catchment. These activities were proceeded by a postgraduate research workshop at UFRJ. The workshops were attended by around 120 people and the River Styles Short Course was attended by 34 people.

This paper outlines the rationale for, and reflects upon, teaching the River Styles Framework as a professional short course in Brazil. In particular it aims to:

- Document and report on the experiences of running the River Styles Short Course.
- Outline the approach to learning (pedagogy) of the River Styles Short Course using examples from the Short Course.
- Highlight the implications of professional development, training and use of the River Styles Framework.
- Provide guidance on how to 'take the next step' to develop a coherent geomorphic template for river management in Brazil.

What is the River Styles Framework and Short Course?

Few frameworks for geomorphic analysis of rivers separate ***classification procedures*** which group like-with-like forms, from ***condition assessments*** which compare reaches of the same river type with expected condition for that river type, and ***recovery assessments*** that situate each reach in a catchment context and use connectivity principles to forecast future trajectories of adjustment. Very few frameworks then use such a carefully scaffolded set of information to set ***catchment-scale visions, prioritise actions and set target conditions*** for conservation and rehabilitation. The River Styles Framework provides a coherent, open-ended approach to the geomorphic analysis of rivers. It achieves this through four Stages (Figure 1).

The River Styles Framework has supported river management practices and decision-making for a wide range of applications in many parts of the world, including Australia, USA, Europe (through the Water Framework Directive), India and China. It has been used specifically as part of programs that address concerns for sediment and water management, fish habitat assessment and protection of endangered species (i.e. conservation), rehabilitation design (particularly using vegetation and wood), to undertake forecasting of river futures and to prioritise river management activities and funding by government agencies and industry (see www.riverstyles.com).

The River Styles Short Course taught at UFRJ focussed on training in Stage One of the River Styles Framework, along with an overview of Stages 2, 3 and 4. The Short Course is a hands-on, activities-based learning experience with an attached accreditation framework. The structure and pedagogic approach of the course followed procedures that have been running successfully in Australia since 2000. On Days 1 and 2, the River Styles Framework was introduced, outlining the method for identifying and naming River Styles. A hands-on exercise identified and mapped the pattern of River Styles in the Macaé Catchment, relating this to analysis of controls along the longitudinal profile. Day 3 was spent in the field in the Macaé Catchment, identifying geomorphic units to interpret formative processes and the range of river behaviour. Four different River Styles were visited, covering confined, partly confined, laterally unconfined with continuous channels and laterally unconfined with discontinuous channels styles. River Styles proformas were completed and handed in for assessment. At the start of Day 4 groups undertook analysis of river evolution and forecasting for the field examples. These analyses and interpretations were presented to the class. This was followed by an introduction to Stages 2 and 3 of the River Styles Framework, covering analysis of river condition and recovery potential. Stage 4 on applications of the River Styles Framework in river management was introduced using examples from around the world. The course ended with a discussion session on how the Framework could be used to enhance approaches to water, land and river management in Brazil

STAGE ONE: Catchment-wide baseline survey of river character, behaviour and pattern

⇓

STAGE TWO: Catchment-framed assessment of river evolution and geomorphic river condition

⇓

STAGE THREE: Assessment of the future trajectory of change and geomorphic river recovery potential

⇓

STAGE FOUR: River management applications and implications: Catchment based vision building, identification of target conditions and prioritisation of management efforts

Figure 1 - The four stages of the River Styles Framework (from BRIERLEY; FRYIRS, 2005).

All River Styles Short Course participants undertook assessment as part of the course and have received Provisional River Styler status. As a consequence, they are now trained in the use of Stage 1 of the Framework. These are the first practitioners to receive such training in Brazil, providing an important opportunity for the use and development of River Styles work elsewhere in the country.

Key Lessons Taught on the River Styles Short Course

Set the course up well and in advance to suit the local conditions and examples

Significant background work and development of teaching resources by the organisers was undertaken to support participant learning on the River Styles Short Course. Each course is tailored to the place in which it is delivered. As fieldwork is a significant component of the course (BRIERLEY; FRYIRS, 2014), it takes many weeks of work to set up and deliver each course. A local 'champion' is needed to set up the fieldwork sites and gain permissions, and provide all the resources (air photographs, remotely-sensed DEMs, longitudinal profiles, textbooks etc.) that are needed to run the activities. Background readings from both the textbook and the scientific literature are carefully selected. Those participants who engage with these readings prior to the course gain the most from the course itself. The mix of resources used on the course itself includes lecture materials, practical exercises, mapping exercises, fieldwork, use of remotely-sensed information, discussions and group and individual work. This mix of activities provides the optimum teaching and learning environment – an approach to ***learning by doing*** that provides an empowering and embedding didactic lens that carefully structures learning through an appropriate balance of theory, practice and critical thinking (see MCPHEE; PRZEDPELSKA, 2018; WINCH, 2013; YOUNG; CHAPMAN, 2010).

Respect river diversity

Geomorphic river diversity reflects a continuum of environmental conditions, such as slope and energy, along which variants of river morphology and behaviour extend from bedrock to fully alluvial types. There is no magic number of river types or river styles. An open-ended approach to river characterisation allows for identification, description and interpretation of common types of river, alongside infrequent or unique types, and even differentiation of new types (if pertinent). Respecting the inherent diversity of the types and patterns of rivers in a given catchment is a key part of a process-based approach to river management and rehabilitation. Appropriate intervention strategies to address river condition issues can be meaningfully differentiated for differing types of river.

On the River Styles Short Course, local examples are framed in relation to the spectrum of river diversity using the rules-based River Styles procedural tree (Figure 2). First the valley setting is identified by placing the valley bottom margin on air photographs or Google Earth images to quantify the extent of valley bottom confinement (FRYIRS *et al.*, 2016; O'BRIEN *et al.*, 2019). Then, river planform, the assemblage of geomorphic units and bed material texture (where visible) are assessed to identify the River Style. Figure 3 shows eight examples of river types found in various parts of Brazil. While laterally unconfined meandering rivers and partly confined bedrock-controlled rivers are quite common, others such as partly confined braided, laterally unconfined chain-of-ponds and laterally unconfined anabranching rivers are relatively rare or unusual.

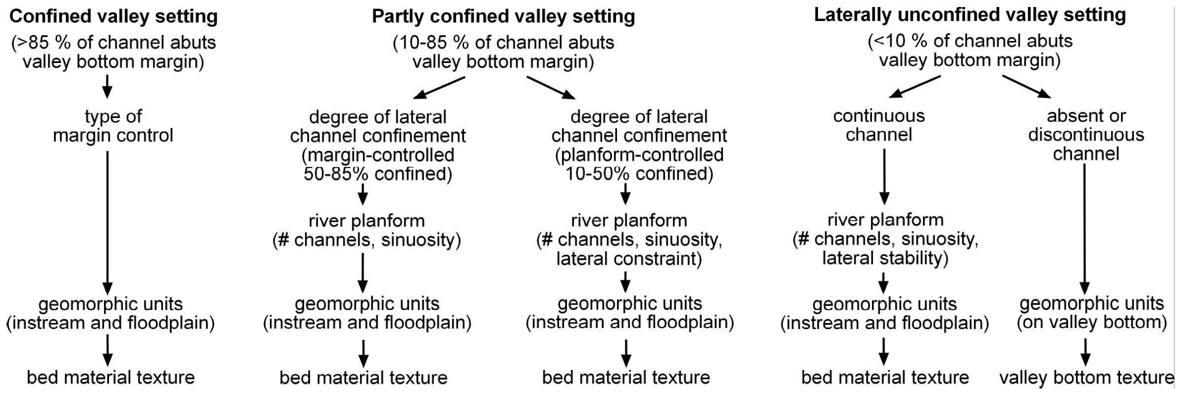


Figure 2 - The River Styles procedural tree. From FRYIRS, BRIERLEY (2018).

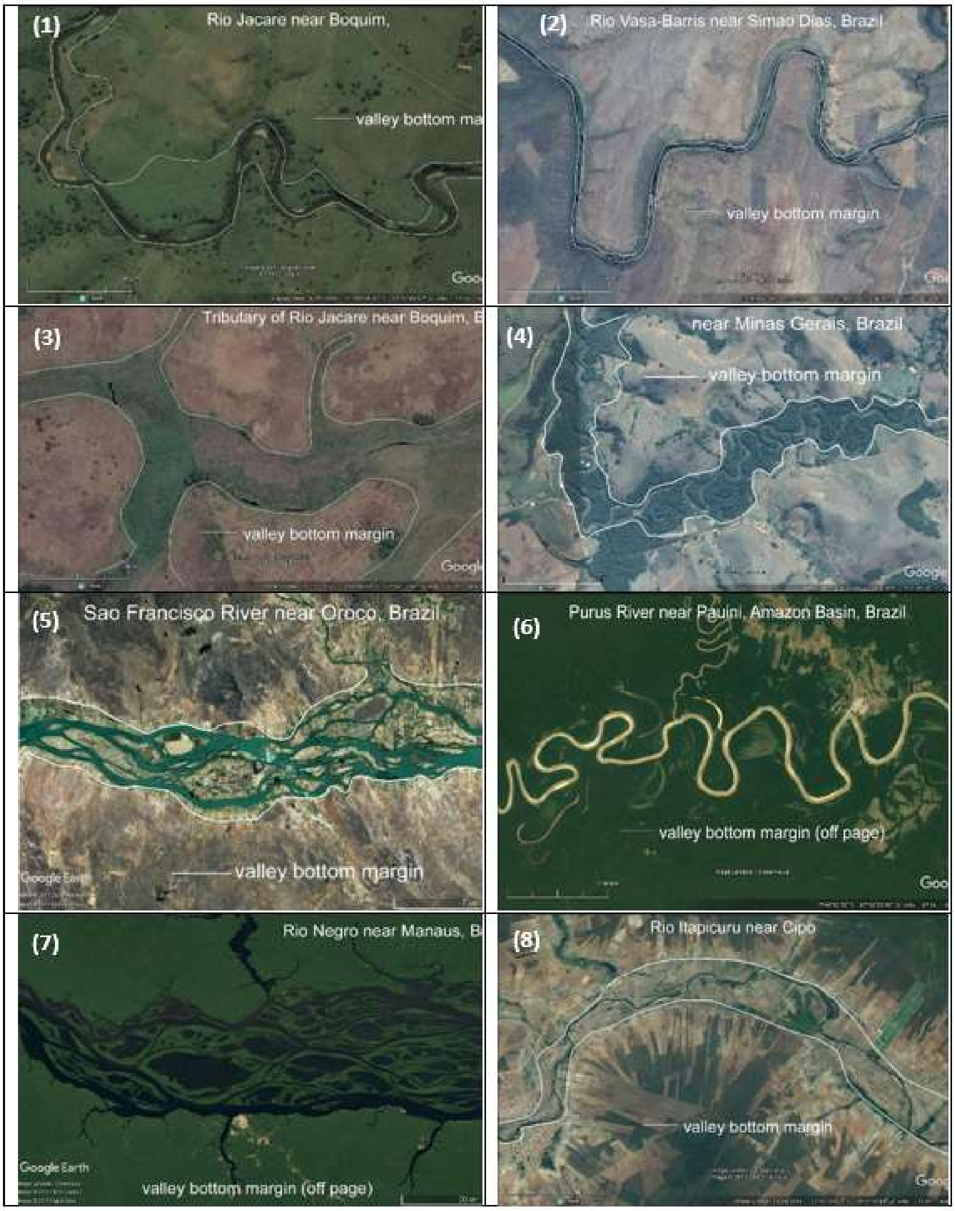


Figure 3 - Examples of the diversity of River Styles in Brazil. (1) is a confined river, (2-5) are partly confined rivers, (6-7) are laterally unconfined rivers with continuous channels and (8) is a laterally unconfined river with discontinuous channel. See Table 1 for full River Styles names. Source of images: Google Earth 2017.

Compare like-with-like

River Styles are identified using a consistent set of measures outlined in the River Styles procedural tree (Figure 2). Each River Style has a distinct assemblage of geomorphic units (erosional and depositional landforms in the channel or on the floodplain) and range of behaviour. Efforts to compare 'like with like' as a basis for informed management decision-making build upon careful and accurate identification of River Style, and appropriate naming of that type of river (see FRYIRS; BRIERLEY, 2018). Using the correct name ensures that practitioners communicate and transfer understanding from one situation to another in a consistent manner.

Giving River Styles a name that reflects their geomorphic characteristics provides a reliable reference system that can be used by a range of audiences and practitioners. Examples of names are given in Table 1. If these types of river are identified for reaches in other river systems, they can be given the same name, facilitating comparison of like-with-like. As part of the scaffolding of River Styles information, getting the identification right at Stage 1 is critical as layers of information on condition and recovery potential are based on, and build on, this layer. In Stages 2 and 3 measures used to assess the condition and recovery potential of different types of river are tailored to the River Styles (see examples below). Participants on the River Styles Short Course in Brazil were able to carefully follow the guidelines for naming River Styles outlined in Fryirs and Brierley (2018) and arrive at a sensible outcome.

Table 1: River Styles identification and naming convention assessment work sheet.

Example	**Full River Style name**	**Abbreviated River Style name**
Example 1	Confined, bedrock margin-controlled, canyon, bedrock bed	C_BrMC_Cyn_Brbed
Example 2	Partly confined, bedrock margin-controlled, discontinuous floodplain, gravel bed	PC_BrMC_DcFp_Gbed
Example 3	Partly confined, planform-controlled, low sinuosity, discontinuous floodplain, gravel bed	PC_PC_LSin_DcFp_Gbed
Example 4	Partly confined, planform-controlled, meandering, terrace constrained, discontinuous floodplain, sand bed	PC_PC_Meand_TrCS_DcFp_Sbed
Example 5	Partly confined, planform-controlled, wandering, discontinuous floodplain, gravel bed	PC_PC_Wan_DcFp_Gbed
Example 6	Laterally unconfined, continuous channel, meandering, sand bed	LU_C_Meand_Sbed
Example 7	Laterally unconfined, continuous channel, anabranching, sand bed	LU_C_Anbr_Sbed
Example 8	Laterally unconfined, discontinuous channel, chain of ponds, fine grained	LU_D_Swp_F

Work with variability in form and process (character and behaviour)

Different River Styles adjust in different ways and at different rates (i.e. they have variable capacity for geomorphic adjustment, or sensitivity; see FRYIRS, 2017). When working within an effective, process-based approach to river management, actions are set in relation to the expected behavioural regime for any given type of river, rather than imposing a particular character and behaviour (i.e. making rivers the same).

In the River Styles Framework, river behaviour is differentiated from river change. Brierley and Fryirs (2005, p. 143) define river behaviour as "adjustments to river morphology induced by a range of erosional and depositional mechanisms by which water moulds, reworks and reshapes fluvial landforms, producing characteristic assemblages of landforms at the reach scale". The range of river behaviour is expressed by the "capacity for adjustment" which is defined by Brierley and Fryirs (2005, p. 144) as "morphological adjustments of a river (…) that do not bring about a change in wholesale river type, such that the system maintains a characteristic state (i.e. morphology remains relatively uniform in a reach-averaged sense)". Different forms of adjustment occur along different river types. These adjustments can occur to the channel bed in the vertical dimension, to the channel banks or as alterations to channel–floodplain relationships in the lateral dimension, or as shifts in channel position on the valley bottom in the wholesale dimension. Appraisal of reach-scale morphodynamics, framed in their catchment context, provides a platform for process-based approaches to river management.

River change is defined as a wholesale shift in the capacity for adjustment of a river such that a new set of form–process relationships occurs (BRIERLEY; FRYIRS, 2005). Realistic river rehabilitation plans builds on an understanding of the (ir)reversibility of river change. Irreversible change occurs when there has been a wholesale change from one river type to another with associated shift in behavioural regime. Reversible adjustments occur when there has been no change in river type and the river still behaves and adjusts today as it did in the past (i.e., adjustments lies within the expected behavioural regime for that type of river).

Correct identification and mapping of geomorphic units is key to interpreting river behaviour using the River Styles Framework. This entails analysis of the ways in which geomorphic units are formed and reworked under differing flow conditions, analysing and interpreting process-form interactions of within-channel and floodplain geomorphic units at low flow, bankfull and overbank flow stages. Findings are recorded on geomorphic maps (Figure 4) and in a River Styles proforma that fully documents the river character, behaviour and controls on that river type (Table 2).

Mapping and proforma exercises are part of the assessment for accreditation on the River Styles Short Course. To do well in this task requires that the practitioner is able to make a cognitive transition from simply mapping and identifying geomorphic units, to analysing the assemblage of those units, interpreting the processes that form and rework those units. Significant guidance is provided in the textbook. In addition, discussion sessions in the office and in the field helped to identify and interpret the range of geomorphic units in rivers, their position and assemblages in the landscape, and assessments of how features are formed and reworked at different flow stages. Collectively, these insights underpin analyses of river behaviour. Field interpretative skills are critical to the Reading the Landscape approach (see BRIERLEY; FRYIRS, 2014; BRIERLEY *et al.*, 2013; FRYIRS; BRIERLEY, 2013).

Know your catchment

Piecemeal, reactive strategies do not provide cost--effective, efficient, low maintenance approaches to river management. Rather, rehabilitation planning is a catchment-specific exercise that requires understanding of the pattern of River Styles in a catchment, and process connectivity between reaches (see BRIERLEY; FRYIRS, 2009; BRIERLEY *et al.*, 2019). The position of any given reach relative to others is critical for analysis of how adjustments taking place in one part of a catchment may have consequences elsewhere. Understanding the downstream patterns of rivers and why that pattern occurs (i.e. analysis of controls), coupled with analysis of sediment (dis) connectivity (see below), determines the degree to which disturbance in one part of a catchment will be manifest or absorbed elsewhere, and the timeframe (lag time) over which this will occur (see FRYIRS *et al.*, 2009).

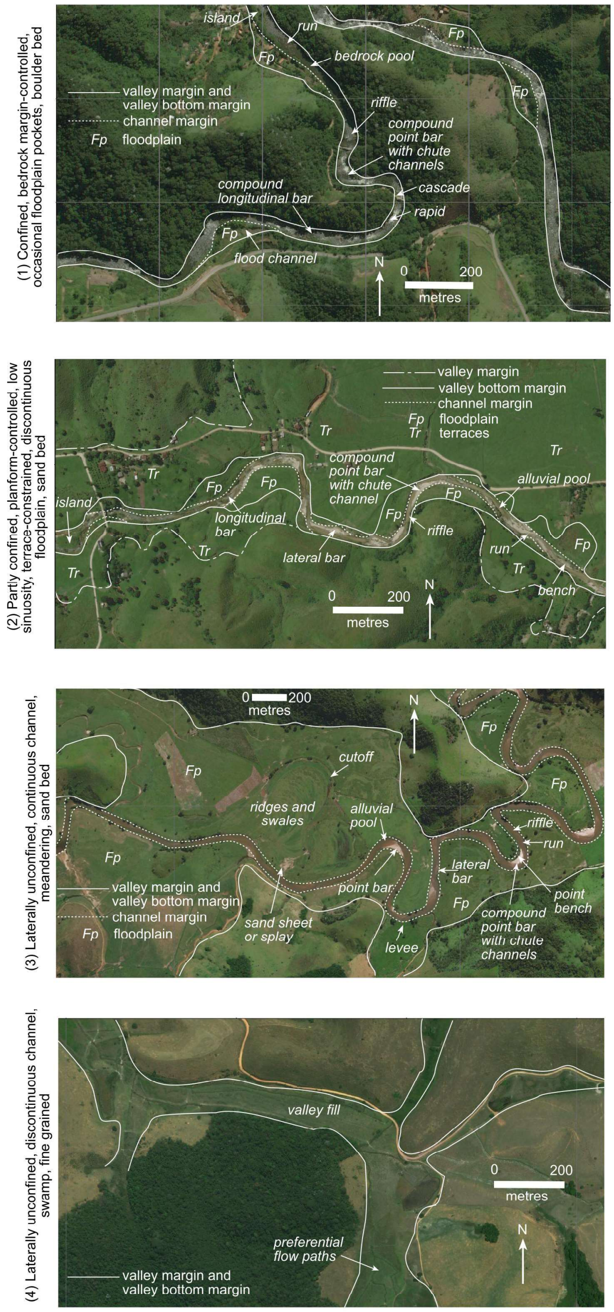


Figure 4 - Geomorphic maps for the four River Styles in the Macaé catchment used as field sites on the River Styles Short Course.

Appreciation of 'context' is the key learning component related to this part of the River Styles Short Course. This is achieved by placing each reach in its catchment context and positioning the reach on longitudinal profiles. All too often, river management practitioners fail to 'get their heads out of the channel', overlooking where they are in a catchment. As such, they fail to consider what is occurring upstream and downstream and how this may impact on activities in a given reach. A hands-on exercise on the River Styles Short Course analyses downstream patterns of River Styles and controls on that pattern (as part of Stage 1 of the River Styles Framework). This supports analysis of river recovery (Stage 3 of the River Styles Framework). When conducting fieldwork at a sequence of River Styles, recurrent reference is made back to the longitudinal profile and the controls analysis that was completed in the office.

On the Brazil short course, analysis of downstream patterns of rivers was performed along the longitudinal profile of the Macaé River trunk stream. The question is then asked: What controls this pattern? A mix of imposed conditions (e.g. valley confinement, slope, landscape unit) and flux conditions (e.g. stream power, process zone and sediment regime) is considered.

The Macaé River has a concave up longitudinal profile and drains a catchment area of 1800km^2. It flows from steep hill country through rounded foothills to the lowland terrain. Six River Styles were identified along the trunk stream. In addition, other River Styles are evident in some of the tributary systems that were visited and analysed on the Short Course (Figure 5). Analysis of controls on the pattern of River Styles is conducted and recorded under the longitudinal profile (Figure 6).

Table 2: Example of a completed River Styles proforma for the Laterally unconfined, continuous channel, meandering, sand bed River Style on the Macaé River. This River Style is noted in pink on Figure 6 and the geomorphic map of this reach is in Figure 4.

River Style name: Laterally unconfined, continuous channel, meandering, sand bed

Defining attributes of River Style (sequence from River Styles tree):

Laterally-unconfined valley setting -> continuous channel -> single channel, high sinuosity, laterally unstable -> point bars, pools, riffles, cutoffs, ridges and swales -> sand bed

Subcatchments in which River Style is observed: Macaé River trunk stream

DETAILS OF ANALYSIS

Map sheet(s) air photographs used:Google Earth 2016
Analysts: Kirstie Fryirs, Raphael Lima
Date: 14/9/17

RIVER CHARACTER

Valley-setting	Laterally unconfined
Channel planform • Sinuosity • # of channels • lateral stability	High sinuosity>1.3, making it a meandering planform Single channel Low lateral stability – evidence of cutoffs, ridges and swales on the floodplain and concave bank erosion along the channel.
Bed material texture	Sand – coarse sand with granules up to 3mm b-axis
Channel geometry (size and shape)	Channel is 25-30m wide and 2.5-3m deep. Channel shape is asymmetrical at the apex of the meander bends with undercutting and vertical concave banks and arcuate, gently sloped point bars on the convex bank. At the inflection points of bends, and in straighter sections the channel is symmetrical with near-vertical banks on both sides.

RIVER CHARACTER	
Geomorphic units (geometry, sedimentology)	***Instream geomorphic units*** **Compound point bar with cute channels and scroll bars** – arcuate shaped feature located on the convex bank of bends, inclined towards the channel, may have several scroll bars and chute channels that short circuiting the point bar, 5m wide and 20m long, comprised dominantly of coarse sand. **Unit point bar** – arcuate shaped feature located on the convex bank of bends, planar surface inclined towards the channel, 5m wide and 20m long, comprised dominantly of coarse sand. **Lateral bar** – elongate shaped feature located on either bank at the inflection points of bends and locally straighter sections of the channel, planar surface, 2m wide and 10m long, comprised dominantly of coarse sand. **Point bench** – stepped feature located behind the point bar on the convex bank of bends, sits just lower than the top of the channel bank, 2m wide and 20m long, comprised dominantly of fine sand. **Alluvial pools** – oval shaped feature located along the concave bank of meander bends, 2 m deep and around 20m long, comprised dominantly of coarse sand substrate. **Riffle** – planar feature that covers the full width of the channel at the inflection points of bends, can be up to 30-40m long and 25-30 m wide, may contain ripples, comprised dominantly of coarse sand substrate. **Run** - planar feature that covers the full width of the channel at the inflection points of bends, can be up to 30-40m long and 25-30 m wide, comprised dominantly of coarse sand substrate. ***Floodplain geomorphic units*** **Floodplain** – covers the full extent of the valley bottom from the top of the channel bank to the valley bottom margin, contains of a range of different geomorphic surfaces, comprised dominantly of fine sand. **Levee** – slightly raised, asymmetrical ridge that occurs along the top of the concave bank of meander bends, subtly inclined towards the distal floodplain, ridge is around 3 m wide, levee is discontinuous along the reach, comprised dominantly of fine sand. **Cutoff channel** – old meander bends that are preserved on the floodplain, channels are the same size as the current channel at 25-30m wide, some infilling with fine sands has occurred, may contain wetland vegetation and sanding water, comprised dominantly of fine sand. **Ridges and swales** – elongate, arcuate shaped features that preserve the meander migration pathway of the bend, ridges are scroll bars that have been incorporated into the floodplain, ridges are raised up to 1 m above the floodplain, low-lying swales may contain wetland vegetation and standing water, comprised dominantly of fine sand. **Sand sheet or splay** – planar features that cover the floodplain in a thin layer of fine sands, splays may be more fan-like and are only of local occurrence where a levee has been cut, splays may be up to 50m long and 20m wide, sand sheets and splays are comprised dominantly of fine sand.

RIVER CHARACTER	
Vegetation associations	***Instream geomorphic units*** The instream zone contains little in the way of vegetation. Most surfaces are bare. Ground cover in the form of grass occurs on some of the more distal sections of point bars. There is no wood in the channel.
	Floodplain geomorphic units The floodplain is dominated by pasture grass. Occasional riparian trees occur, but these are rare. The cutoffs contain an array of aquatic vegetation including tussock grasses where standing water occurs.

RIVER BEHAVIOUR

Low flow stage

At low flow stage the thalweg is positioned along the concave bank on meander bends, and more centrally over riffles and runs along the inflection points of bends. Under low flow conditions, flow occurs over riffles and runs and infills pools. The sand bedload may be moving downstream along the low flow channel bed in the form of ripples. Because the thalweg is positioned against the concave bank, bank undercutting is possible as less cohesive sediment layers are eroded. This can lead to mass bank failure along these bends if the overtopping bank collapses. Flow is not positioned over point bars or floodplains, so these surfaces are exposed and geomorphically inactive at low flow stage.

Bankfull stage

At bankfull stage flow is confined to the channel. This is often the highest velocity flow. The thalweg is positioned along the concave banks of bends and mass bank failure will occur if the banks are undercut. Alternatively fluvial entrainment may be occurring along the banks. Because the thalweg is position against the concave bank, helical flow occurs and pools are scoured and deepened at this flow stage. Broken water flow occurs over riffles. Bedload materials are moving as ripples and dunes on the channel bed. As flow recedes this sediment may be deposited in riffles and runs. On the concave bank of bends, positioned away from the thalweg, secondary circulation and lower flow velocities move sediment onto point bars where it is deposited. This can occur obliquely on the point bar face, or at the head of the bar. Scroll bars may form on the point bars as a result of flow separation. In some cases, point benches located at the back of the point bar may be deposited via vertical accretion. With concave bank erosion and convex bank deposition the meander bend will migrate laterally during bankfull conditions. When flow is aligned over the point bars, chute channels may be scoured as flow short circuits the point bar.

Overbank stage

At overbank stage flow is spread over the floodplain. As a result, stream power is reduced. The thalweg will take a low sinuosity path down the valley, potentially producing cutoffs if the neck of a meander bend is cut. This feature is left abandoned on the floodplain. At overbank stage the processes occurring at bankfull stage may be accentuated with lateral migration of the channel enhanced. Eventually with multiple bankfull and overbank flows, point bars, scroll bars and point benches will become incorporated into the floodplain, producing ridge and swale topography. These features preserve the migration pathway of the meander bend. During overbank flows the swales between ridges may become the focal point for scour (and cutoffs), but during the waning stages will infill with sediment and water, producing non-permanent wetlands. During the rising stages of overbank flows any sediment that is being carried may be deposited, mainly by vertical accretion. If larger loads of sediment are deposited on the top of the channel bank and less deposited more distally on the floodplain, then a levee may form. At the site visited however, this levee was a low-lying, subtle feature suggesting that sediment is deposited more widely and as sand sheets over the floodplain. Locally, if a levee is breached during a rising stage overbank flow a local sand splay is formed where sediments are deposited on the floodplain.

CONTROLS	
Upstream catchment area	Approximately 700 km^2
Landscape unit and within-catchment position	Lowland plain. Reach is located in the middle reaches of the catchment.
Process zone	Sediment accumulation
Valley Morphology (size and shape)	Wide (500-600 m wide valley), steep hillslope outcrops, deep alluvial valley.
Valley slope	Low (0.2%)
Stream power	Low gross stream power (<250W for 1:2 year recurrence interval flow)

Schematic valley-scale cross-section

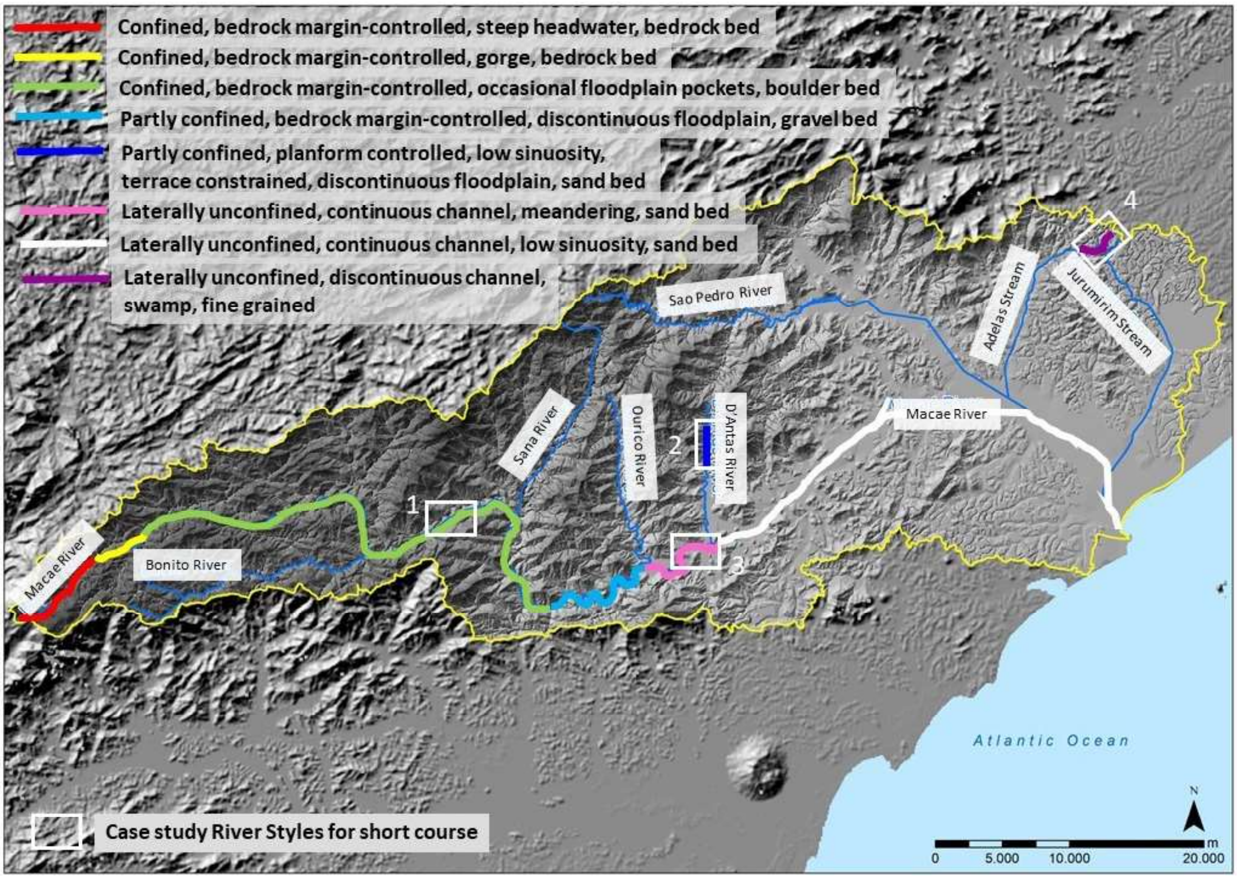
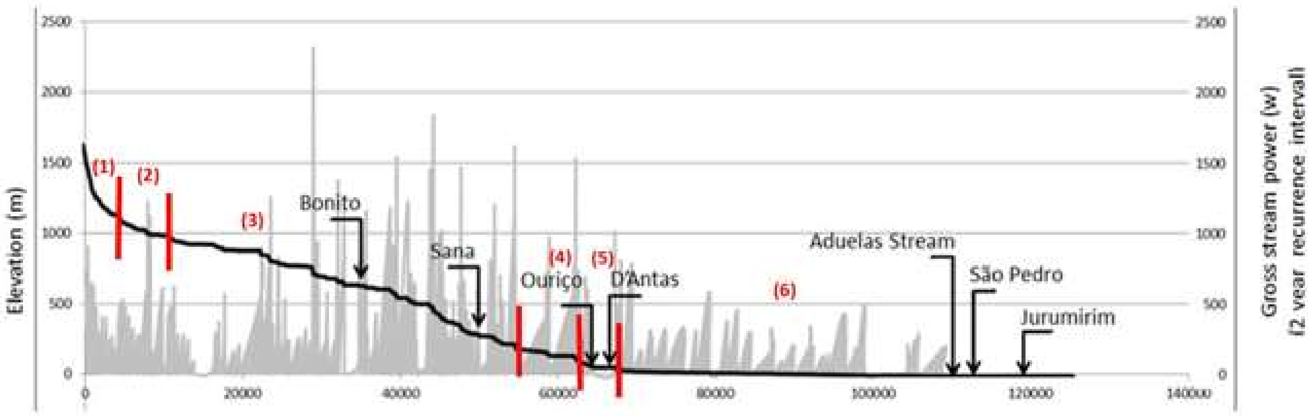


Figure 5 - Pattern of River Styles along the Macaé River trunk stream and at case study field sites used on the Short Course on top of a Digital Elevation Model (DEM) of the catchment.

Use tailored geoindicators to assess geomorphic condition

Geomorphic condition is defined as the state of the river as we see it today (BRIERLEY *et al.*, 2010; FRYIRS, 2015). When conducted effectively, analyses of geomorphic condition allow meaningful comparison of like-with-like. Therefore, in the River Styles Framework the measures used to assess geomorphic river condition are tailored to the River Style under investigation, so that they give a reliable and relevant signal about the condition of the reach as part of a diagnostic approach to analysis of condition (Table 3). These measured are called geoindicators. For example, there is no point comparing the geomorphic condition of a gorge with the geomorphic condition of a meandering river, as they have different assemblages of geomorphic units and associated processes and behaviour. Rather, analyses of geomorphic river condition must be tailored to the type of river and its expected range of character and behaviour. As such, appropriate indicators to analyse river condition should vary from one type of river to another (see BLUE; BRIERLEY, 2016). Using the example above, it is not meaningful (or possible) to use the extent of bank erosion as a geoindicator of geomorphic condition of a gorge. However, it is important to analyse the extent and location of bank erosion for a meandering river as this provides an indication of geomorphic condition for that type of river. If bank erosion is occurring where it is expected (i.e. on the concave banks) and at the expected rate, then the river is adjusting as expected and is in good condition. However, if bank erosion is occurring at an accelerated rate or is occurring in the wrong locations along the reach (e.g. at inflection points of bends) then the geomorphic condition of that reach has deviated away from a good condition.



	(1)	(2)	(3)	(4)	(5)	(6)
Landscape unit	Steep hill country	Steep hill country	Rounded foothills	Rounded foothills	Lowland plain	Lowland plain
Valley setting	Confined	Confined	Confined	Partly confined	Laterally unconfined	Laterally unconfined
River Style	Confined, bedrock margin-controlled, steep headwater, bedrock bed	Confined, bedrock margin-controlled, gorge, bedrock bed	Confined, bedrock margin-controlled, occasional floodplain pockets, boulder bed	Partly confined, bedrock margin-controlled, discontinuous floodplain, gravel bed	Laterally unconfined, continuous channel, meandering, sand bed	Laterally unconfined, continuous channel, low sinuosity, sand bed
Slope	High	High	High-moderate	Moderate	Low	Low
Stream power	High	High	Very high	Moderate	Low	Low
Process zone	Source	Transfer	Transfer	Transfer	Accumulation	Accumulation
Sediment transport regime	Bedload	Bedload	Bedload	Bedload	Mixed load	Mixed load

Figure 6 - Analysis of the downstream pattern and controls on River Styles along the Macaé River trunk stream. Note the use of longitudinal profiles and stream power as primary controls. Boundaries between River Styles noted in red.

On the River Styles Short Course a short exercise gives practitioners an idea of how to select useful geoindicators for assessing geomorphic condition for different River Styles. The geoindicators are chosen from a suite of measures used to assess channel attributes, planform attributes and channel bed characteristics (Table 3). In selecting geoindicators the following open-ended question is asked: "Will measuring this geoindicator tell me anything about the geomorphic condition of this reach? – yes or no". Once selected, a set of desirability criteria is established for each River Style to analyse geomorphic condition. Essentially, this analysis asks questions about the appropriateness of the geomorphic structure of a reach and whether the river has a character and behaviour that is expected for that River Style. Appropriate geoindicators provide significant insight into the causes of geomorphic condition, thereby guiding appropriate river management treatments. This moves practice towards treating causes, not just symptoms of geomorphic condition. Fully worked examples of this type of analysis are in Fryirs (2015) and Brierley and Fryirs (2005) and at www.riverstyles.com.

Table 3: Relevant geoindicators that could be used to assess the geomorphic condition of four case study River Styles in the Macaé catchment. Based on procedures in FRYIRS (2015).

Geoindicator/ River Style	Confined, bedrock margin-controlled, occasional floodplain pockets, boulder bed	Partly confined, planform-controlled, low sinuosity, terrace-constrained, discontinuous floodplain, sand bed	Laterally unconfined, continuous channel, meandering, sand bed	Laterally unconfined, discontinuous channel, swamp, fine grained
Channel attributes				
Size	No	Yes	Yes	No
Shape	Yes	Yes	Yes	No
Bank morphology	Yes	Yes	Yes	No
Instream vegetation structure	Yes	Yes	Yes	No
Wood loading	Yes	Yes	Yes	No
Channel planform				
Number of channels	No	No	Yes	Yes (of preferential flow paths)
Sinuosity of channels	No	No	Yes	No
Lateral stability	No	Yes	Yes	No
Geomorphic unit assemblage	Yes	Yes	Yes	Yes
Riparian vegetation	Yes	Yes	Yes	Yes (on surface of valley fill)
Bed character				
Grain size and sorting	Yes	Yes	Yes	Yes (on surface of valley fill)
Bed stability	No	Yes	Yes	No
Hydraulic diversity	Yes	Yes	Yes	No
Sediment regime	Yes	Yes	Yes	No

Understand evolutionary trajectory

The trajectory by which a reach has attained its present geomorphic condition has a significant impact on its future trajectory of adjustment. Therefore, understanding river evolution provides a situated context with which to explain why the river is in the state (condition) it currently is. Looking into the past can also be used to determine the causes, timing, rate, and magnitude of adjustments that have occurred. These analyses provide foundation insights (the starting point) with which to forecast likely future scenarios (and trajectories). Evolutionary analyses, tied to concepts of landscape (dis) connectivity, are required to interpret the potential for geomorphic river recovery (see FRYIRS; BRIERLEY, 2001; FRYIRS *et al.*, 2007a, b; FRYIRS, 2013). Outputs from such analyses provide a platform with which to consider what is physically achievable in rehabilitation, and how to prioritise those activities (see next section; BRIERLEY *et al.*, 2019).

On the River Styles Short Course, an evolutionary analysis (how the system has adjusted in the past) and a forecasting exercise were conducted for each of the four River Styles visited in the field (BRIERLEY; FRYIRS, 2016). The evolutionary exercise asks participants to use their geomorphic insight, the process of ergodic reasoning (space for time substitution; see FRYIRS *et al.*, 2012), and evidence from the field visits to assess what the river may have been like prior to European settlement, around 1800, and around 1950. The forecasting exercise asks participants to think about how each reach might adjust in the future (around 2050 and 2080) (Figure 7). In full assessments of geomorphic river recovery potential these scenarios would be based on evidence for past adjustment based on historical records or field evidence and future scenarios would be framed in context of analysis of hydrological and sediment (dis)connectivity analysis and consideration of a range of likely pressures and limiting factors operating in a catchment, alongside modelling applications (see FRYIRS; BRIERLEY, 2016).

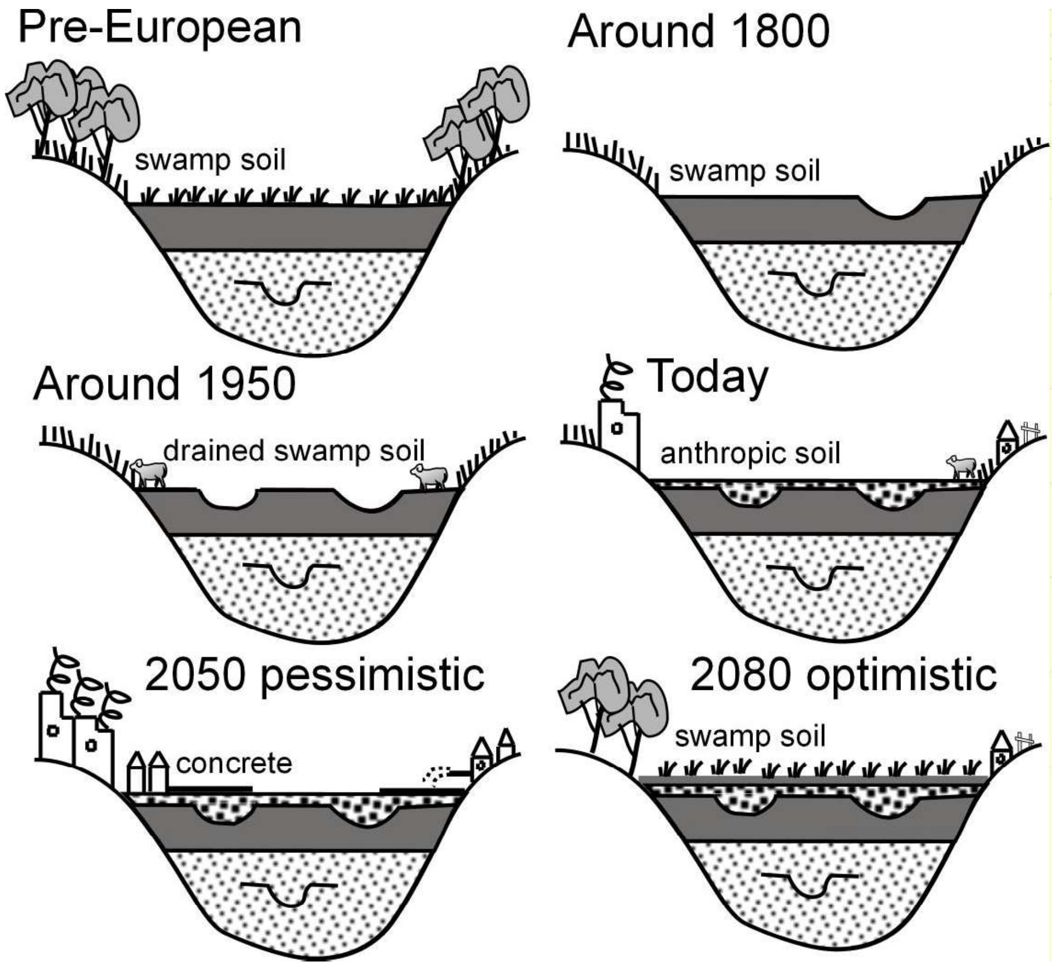


Figure 7 - An example of evolutionary analysis and forecasting undertaken as a teaching exercise on the River Styles Short Course. This is for the Laterally unconfined, discontinuous channel, swamp, fine grained River Style.

Prioritise activities using a conservation-first and recovery-enhancement decision making approach

Proactive rehabilitation plans strategically prioritise actions. The River Styles Framework uses a conservation-first, recovery-enhancement approach to prioritisation in Stage 4 (Figure 8). The most serious threatening processes are tackled first. Notable success for low expenditure can be achieved when rehabilitation target sreaches with a high recovery potential and "Don't fight the site" (BRIERLEY, FRYIRS, 2009; FRYIRS, BRIERLEY, 2009; FRYIRS *et al.*, 2018). Those reaches that are largely intact or in good condition are considered for conservation, essentially looking after these rivers. Next, threatening processes such as incision, headcut retreat, channel expansion or sediment slugs are treated along what are referred to as strategic reaches. Then reaches in good condition with high recovery potential are considered. These reaches may only require minimalist intervention or no intervention to improve their condition and enhance recovery (e.g. vegetation management). If these reaches are connected to other reaches in good condition or are isolated in a catchment, then these reaches are used as locations from which to build out from. Only then are reaches in moderate and poor condition treated. These reaches often require higher levels of intervention (and are more costly to repair) to trigger river recovery and therefore improve condition.

On the River Styles Short Course these principles are taught using the river recovery diagram and the prioritisation decision tree (Figure 8). Fully worked examples of this type of analysis are presented in Fryirs and Brierley (2016) and Brierley and Fryirs (2005) and at www.riverstyles.com.

Discussion and Conclusions

Unlike in the medical or veterinary sciences where there is a requirement for continual professional development and training, this is not yet the case in the environmental sciences. Yet, river managers in particular are much like doctors, nurses and vets in that they are treating a living system and must have appropriate skills and information to adequately prevent poor health (preventative medicine) or identify causes of deterioration or a 'disease' (diagnostic medicine) (see ELOSEGI *et al.*, 2017). This is a complex task as it requires an understanding of the medical history of the patient (contingency) and the conditions under which the response was triggered and manifest (emergence). It is only with this information in-hand that a medical practitioner can recommend a course of action to either ensure no further deterioration in health or to cure the disease (if possible). The treatment and management of the problem is often not simple, and the responses are sometimes unpredictable. The same thinking can be applied to environmental systems, and in particular river systems. Unfortunately, however, managerial simplicity often fails to recognize or appreciate such inherent complexity, and river systems are managed as simple cause-effect systems using cookbooks or manuals (see BRIERLEY *et al.*, 2013). Geomorphologists can be considered as a type of environmental doctor. Appropriate skills and training are required to adequately interpret whether a course of preventative medicine (proactive management) is needed, what the causes of poor river condition may be (strategic management) and how to work with the system to improve condition (process- and recovery-enhancement management). More importantly, the practitioner needs to be able to identify whether a course of treatment is necessary to begin with, is ineffective or inappropriate, or is no longer necessary after a certain period of time. Appropriate interpretative skills are required to determine when the system is able to self-heal or is on the road to recovery. A practitioner is also required to consider the duration of any treatment and the monitoring regime (or check-ups) that need to be in place to track changes in condition. But, where does a practitioner get the professional development opportunities for learning, developing and using such skills for river management?

Short or bespoke courses are becoming an increasingly important part of professional development. Such 'block-mode' teaching can help to up-skill professionals, providing guidance and practical experience with new innovations and approaches to practice. The River Styles Short Course is an example of such developments. It has been taught for nearly 20 years and builds on over 25 years of foundation research on river forms and processes, human-disturbance to rivers, analysis of river condition and recovery and use of this information to design river management programmes. There has been significant uptake of this work in many parts of the world (see www.riverstyles.com). International testing and peer-review processes provide a high level of confidence in the approach and it applications (e.g. BRIERLEY *et al.*, 2011; GRABOWSKI *et al.*, 2014; WHEATON *et al.*, 2015; GURNELL *et al.*, 2016; KASPRAK *et al.*, 2016; BELLETTI *et al.*, 2017; O'BRIEN *et al.*, 2017). Pedagogical aspects of teaching support scientific attributes of the framework (Figure 9).

The overall intent of 'training the users' and embedding assessment in the course ensures that users understand the framework and its structure, are proficient in its use, are making correct interpretations and apply the Framework appropriately. The approach to analysis and learning is called 'Reading the Landscape' (developed in FRYIRS; BRIERLEY, 2013). ***Mastery learning*** and ***scaffolding*** are central to the pedagogic approach.

Mastery learning involves instructional methods that establish a level of performance that all students must master before moving to the next unit (KRAUSE *et al.*, 2013). This requires giving students time to experience and practice, to go over learning material and providing one-on-one or small group instruction, support, feedback and corrective instruction. This approach moves students progressively towards stronger understanding and ultimately greater independence – in terms of both cognition and application (KRAUSE *et al.*, 2013). On the River Styles Short Course this is undertaken in both office-based and field-based settings. Mastery is achieved by first learning through observation and demonstration by the lecturer, then hands-on practice in the office, then fieldwork analysis, then translation into written, visual and verbal content/ outputs and assessment. Once the practitioner is able to undertake analyses at an appropriate level they have achieved mastery.

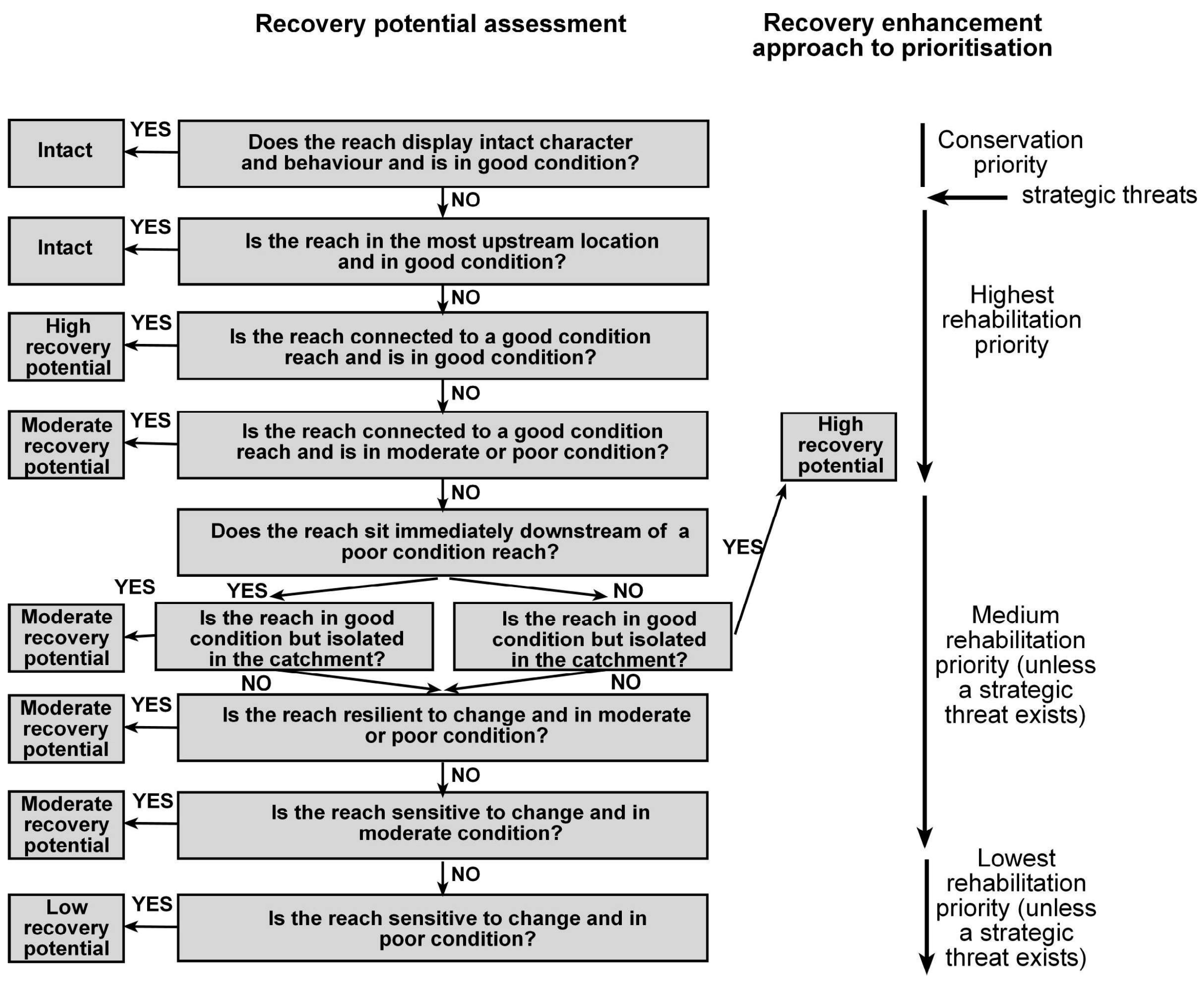


Figure 8 - Decision-making tree for prioritizing river management activity based on analysis of river recovery potential (From FRYIRS; BRIERLEY, 2016).

Introduction to Fluvial Geomorphology workshop, Rio de Janeiro

Mapping River Styles on the short course

Analysis of patterns and controls on River Styles in Macaé catchment

Completing River Styles assessments in the field

Confined, bedrock margin controlled, occasional floodplain pockets, boulder bed River Style – Macaé catchment

Laterally unconfined, continuous channel, meandering, sand bed River Style – Macaé catchment

Identifying geomorphic units and interpreting river behaviour in the field – Macaé catchment

Partly confined, planform controlled, low sinuosity, terrace constrained, gravel bed River Style – Macaé catchment

Laterally unconfined, discontinuous channel, valley fill, fine-grained River Style – Macaé catchment

Presenting river evolution and forecasting of river futures in Macaé catchment

River Styles Short Course participants

Introduction to Fluvial Geomorphology workshop, Recife

Figure 9 - Professional development, training and experiences received in the 5-day River Styles Short Course. All Photographs: Kirstie Fryirs.

Most importantly the River Styles Framework and the way it is taught generates consistent, ***scaffolded*** datasets that can inform a range of applications and purposes. In the River Styles Short Course, the exercises build from basic mapping and identification, to more sophisticated analysis and interpretation that require higher-level cognition, and ultimately contextualisation and use (KRAUSE *et al.*, 2013). Moving from Stage 1 through to Stage 4 of the River Styles Framework works with increasingly sophisticated datasets that require higher and higher levels of geomorphology training. Stage 1 is framed around identification and mapping with interpretation of river behaviour. Stage 2 requires more sophisticated understanding of temporal concepts to produce evolutionary sequences and identify geoindicators for condition assessment. Stage 3 requires forecasting potential and an ability to place reaches in context to undertake trajectory analysis and scenario building. Finally, Stage 4 requires that this work is integrated to create visions, prioritise and use this in decision-making.

At the heart of the framework and the pedagogical approach to teaching it is the adage "you cannot manage a resource you do not understand". Successful use and application of the Framework empowering practitioners to undertake evidence-based decision making as part of a coherent approach to management. In parts of the world where this approach has been adopted, on-ground recovery and environmental benefits (and by extension social and economic benefits) are emerging (see BRIERLEY *et al.*, 2011; FRYIRS *et al.*, 2018). However, this process takes time. It may take many years to generate the baseline information for all four stages of the River Styles Framework. Further time is required to embed the approach and prioritisation in management, and yet more time is needed to see the benefits of implementation on-the-ground. The best documented international exemplar (New South Wales, Australia) took around 20 years to generate the State-wide database (with ongoing and recurrent extension, updating and monitoring), change the philosophy of river management practice and then see the process of river recovery start on-the-ground (see BRIERLEY *et al.*, 2002, 2011; FRYIRS *et al.*, 2018). Having said this, however, the availability of Open Access resources such as Google Earth and the advent of new technology and global topographic data, will support much quicker, more accurate and cheaper River Styles analyses, with prospect to cover much larger areas than previously (FRYIRS *et al.*, 2018, 2019). In the modern era of river management, access to appropriate baseline datasets no longer provides an excuse for not undertaking such assessments. Rather, perhaps the key limitation is the availability of suitably qualified and trained practitioners to do the work. The River Styles Short Course presents an opportunity to address this shortcoming.

The first offering of the River Styles Short Course in Brazil provided some critical feedback on the framework and the pedagogy of the course and how it can be used in river management. Some feedback on the most useful parts of the course were:

- "Actually, the full course is important because all the sections are integrated, but the fieldwork was amazing and unique".
- "The application of fieldwork, we can see the theory in the reality".
- "The overview of fluvial geomorphology principles and their use".
- "The most useful part was the classification procedure of River Styles".
- "The fieldwork combined with exercises in class".
- "The field exercises were fantastic. We can link the theory and reasoning to what we see. We feel more confident in the possibilities for river management".

Practitioners provided the following comments on how they will use the River Styles Framework in the future:

- "To apply the methodology to Brazil rivers and with different characteristics and highlight zones that have different behaviour and need management for specific goals".
- "I will use to integrate important information along with catchment managers".
- "To assess river condition and trajectory of adjustments induced by extreme events and human recovery actions".
- "I will use the River Styles Framework in my academic development and professional activities with river management".
- "We can now, after expanding our vision, develop more networks with researchers and managers".

This feedback, and the comments noted in the Introduction, demonstrate the imperative to instigate a change in river management practice in Brazil. Investment in practitioner training and professional development is integral to these prospects. It is critical that the datasets generated are consistent and contain all fundamental outputs (no stages or analyses are missed), that the datasets are well-coordinated and centrally located, and the datasets undergo assurance-quality control. It is also important that the datasets are 'live' and updated as new knowledge is generated.

Brazil sits at a cross-roads and could make significant inroads on such analyses, learning from the lessons elsewhere through the uptake of readily available technology and resources (FRYIRS *et al.*, 2019). Such a step-change in geomorphologically-informed river management has prospect to produce improved river recovery outcomes on-the-ground. By extension, place-based approaches to land and water management present considerable opportunity to develop cost-effective programs that reduce risk and protect socio-economic, cultural and environmental values. The key is to 'get on with it', ensuring that strategic planning frameworks are in-place so that we are ready to act when called upon to apply such practices. Just as importantly, it is vital for researchers, practitioners and decision-makers to work together to make it happen. This can only happen if there are the professional development opportunities available to skill people in the approaches to analysis and the generation of coherent and consistent databases from which to work. Engaging discussions and conversations during the River Styles Short Course and workshops emphasised the many opportunities for fundamental research and applied contributions that can be generated by the talented resource base of young geomorphologists in Brazil.

Acknowledgements

The workshops and short course would not have been possible without the sponsorship of the following organisations; Federal University of Rio de Janeiro – UFRJ: Postgraduate Program of Geography (PPGG/UFRJ), Postgraduate Program of Energy Planning (PPE-COPPE/UFRJ), Geosciences Institute IGEO/UFRJ and Ecology and Socio-Environmental Development Center of Macaé (NUPEM/UFRJ); the Brazilian Institute of Geography and Statistics (IBGE) and Department of Geographical Sciences of Federal University of Pernambuco (UFPE). Technical and organizational support was provided by various students linked to UFRJ research groups: GEOMORPHOS - Research Group on Fluvial Geomorphology and Hydrographic Basin Dynamics; and NEQUAT - Quaternary & Technogene Studies Center, and by the UFPE GEQUA - Study Group of Brazilian Northeast Quaternary. Kirstie Fryirs also acknowledges the support of the Australian Research Council and Macquarie University. Gary Brierley thanks the University of Auckland for support on study leave. We thank Bárbara Barcelos for instructive guidance upon didactics from a student perspective.

References

BELLETTI, B.; RINALDI, M.; BUSSETTINI, M.; COMITI, F.; GURNELL, A.M.; MAO, L.; NARDI, L.; VEZZA, P. Characterising physical habitats and fluvial hydromorphology: A new system for the survey and classification of river geomorphic units. **Geomorphology**, v. 283, p. 143-157, 2017. DOI: 10.1016/j.geomorph.2017.01.032

BLUE, B.; BRIERLEY, G. J. 'But what do you measure?' Prospects for a constructive critical physical geography. **Area**, v. 48, n. 2, p. 190-197, 2016. DOI: 10.1111/area.12249

BRIERLEY, G. J.; FRYIRS, K. A. **Geomorphology and River Management: Applications of the River Styles Framework**. Oxford, UK: Blackwell Publications, 2005. 398p.

BRIERLEY, G. J.; FRYIRS, K. A. Don't fight the site: Geomorphic considerations in catchment-scale river rehabilitation planning. **Environmental Management**, v. 43, n. 6, p. 1201-1218, 2009. DOI: 10.1007/s00267-008-9266-4

BRIERLEY, G. J.; FRYIRS, K. A. (2014). Reading the Landscape in field-based fluvial geomorphology. In: THORNBUSH, M.; ALLEN, C. D.; FITZPATRICK, F. A. (org.) **Geomorphological Fieldwork**. Elsevier: Amsterdam, p. 231-257.

BRIERLEY, G. J.; FRYIRS, K. A. The use of evolutionary trajectories to guide 'moving targets' in the management of river futures. **River Research and Applications**, v. 32, n. 5, p. 823-835, 2016. DOI: 10.1002/rra.2930

BRIERLEY, G. J.; FRYIRS, K. A; CULLUM, C.; TADAKI, M.; HUANG, H. Q.; BLUE, B. Reading the landscape: Integrating the theory and practice of geomorphology to develop place-based understandings of river systems. **Progress in Physical Geography**, v. 37, n. 5, p. 601-621, 2013. DOI: 10.1177/0309133313490007

BRIERLEY, G. J; FRYIRS, K. A.; COOK, N.; OUTHET, D.; RAINE, A.; PARSONS, L.; HEALEY, M. Geomorphology in Action: Linking policy with on-the-ground actions through applications of the River Styles framework. **Applied Geography**, v. 31, n. 3, p. 1132-1143, 2011. DOI: 10.1016/j.apgeog.2011.03.002

BRIERLEY, G. J; FRYIRS, K. A.; MARÇAL, M.; LIMA, R. The use of the River Styles Framework as a tool to 'work with nature' in managing rivers in Brazil: Examples from the Macaé Catchment. **Revista Brasileira de Geomorfologia**, This volume, 2019.

BRIERLEY, G. J.; FRYIRS, K. A.; OUTHET, D.; MASSEY, C. Application of the River Styles framework to river management programs in New South Wales, Australia. **Applied Geography**, v. 21, n. 1, p. 91-122, 2002. DOI: 10.1016/S0143-6228(01)00016-9

BRIERLEY, G. J.; REID, H.; FRYIRS, K. A.; TRAHAN, N. What are we monitoring and why? Using geomorphic principles to frame eco-hydrological assessments of river condition. **Science of the Total Environment**, v. 408, n. 9, p. 2025-2033, 2010. DOI: 10.1016/j.scitotenv.2010.01.038

ELOSEGI, A.; GESSNER, M. O.; YOUNG, R. G. River doctors: Learning from medicine to improve ecosystem management. **Science of the Total Environment**, v. 595, p. 294-302, 2017. DOI: 10.1016/j.scitotenv.2017.03.188

FRYIRS, K. A. (Dis)connectivity in catchment sediment cascades: A fresh look at the sediment delivery problem. **Earth Surface Processes and Landforms, State of Science Series**, v. 38, n. 1, p. 30-46, 2013. DOI: 10.1002/esp.3242

FRYIRS, K. A. Developing and using geomorphic condition assessments for river rehabilitation planning, implementation and monitoring. **WIREsWater**, v. 2, n. 6, p. 649-667, 2015. DOI: 10.1002/wat2.1100

FRYIRS, K. A. River sensitivity: A lost foundation concept in fluvial geomorphology. **Earth Surface Processes and Landforms, State of Science Series**, v. 42, n. 1, p. 55-70, 2017. DOI: 10.1002/esp.3940

FRYIRS, K.; BRIERLEY, G. J. Naturalness and place in river rehabilitation. **Ecology and Society**, v. 14, n. 1, 2009. DOI: 10.5751/ES-02789-140120

FRYIRS, K.; BRIERLEY, G. J. Variability in sediment delivery and storage along river courses in Bega catchment, NSW, Australia: Implications for geomorphic river recovery. **Geomorphology**, v. 38, n. 3-4, p. 237-265, 2001. DOI: 10.1016/S0169-555X(00)00093-3

FRYIRS, K. A.; BRIERLEY, G. J. **Geomorphic Analysis of River Systems: An approach to Reading the Landscape**. Chichester: John Wiley and Sons, 2013. 345p.

FRYIRS, K.; BRIERLEY G. J. Assessing the geomorphic recovery potential of rivers: Forecasting future trajectories of adjustment for use in river management. **WIREsWater**, v. 3, n. 5, p. 727-748, 2016. DOI: 10.1002/wat2.1158

FRYIRS, K. A.; BRIERLEY, G. J. What's in a name? A naming convention for geomorphic river types using the River Styles Framework. **PLoSONE**, v. 13, n. 9, 2018. DOI: 10.1371/journal.pone.0201909

FRYIRS, K. A.; BRIERLEY, G. J.; ERSKINE, W. Use of ergodic reasoning to reconstruct the historical range of variability and evolutionary trajectory of rivers. **Earth Surface Processes and Landforms**, v. 37, n. 7, p. 763-773, 2012. DOI: 10.1002/esp.3210

FRYIRS, K. A.; BRIERLEY, G. J.; HANCOCK, F.; COHEN, T. J.; BROOKS, A. P.; REINFELDS, I.; COOK, N.; RAINE, A. Tracking geomorphic river recovery in process-based river management. **Land Degradation and Development**, v. 29, n. 9, p. 3221-3244, 2018. DOI: 10.1002/ldr.2984

FRYIRS, K.; BRIERLEY, G. J.; PRESTON, N. J.; KASAI, M. Buffers, barriers and blankets: The (dis)connectivity of catchment-scale sediment cascades. **Catena**, v. 70, n. 1, p. 49-67, 2007a. DOI: 10.1016/j.catena.2006.07.007

FRYIRS, K. A.; BRIERLEY, G. J.; PRESTON, N. J.; SPENCER, J. Catchment-scale (dis)connectivity in sediment flux in the upper Hunter catchment, New South Wales, Australia. **Geomorphology**, v. 84, n. 3-4, p. 297-316, 2007b. DOI: 10.1016/j.geomorph.2006.01.044

FRYIRS, K.A.; RALPH, T.J.; LARKIN, Z.T.; TOOTH, S.; HUMPHRIES, M.; MCCARTHY, T.; HESSE, P.P.; MOSIMANYANA, E. A nested hierarchical perspective to enhance interpretations and communication in fluvial geomorphology for use in water resources management: Lessons from the Okavango Delta, Botswana. **The Geographical Journal**, v. 184, p. 192–207, 2018. DOI: 0.1111/geoj.12250

FRYIRS, K. A.; SPINK, A.; BRIERLEY, G. J. Post-European settlement response gradients of river sensitivity and recovery across the upper Hunter catchment, Australia. **Earth Surface Processes and Landforms**, v. 34, n. 7, p. 897-918, 2009. DOI: 10.1002/esp.1771

FRYIRS, K. A.; WHEATON, J. M.; BRIERLEY, G. J. An approach for measuring confinement and assessing the influence of valley setting on river forms and processes. **Earth Surface Processes and Landforms**, v. 41, n. 5, p. 701-710, 2016. DOI: 10.1002/esp.3893

FRYIRS, K. A.; WHEATON, J.; BIZZI, S.; WILLIAMS, R.; BRIERLEY, G. J.; To plug-in or not to plug-in? Geomorphic analysis of rivers using the River Styles Framework in an era of big-data acquisition and automation. **WIREsWater**, n. 6, p. e1372, 2019. DOI: 10.1002/wat2.1372

GRABOWSKI, R. C.; SURIAN, N.; GURNELL, A. M. Characterizing geomorphological change to support sustainable river restoration and management. **WIREsWater**, v. 1, n. 5, p. 483–512, 2014. DOI: 10.1002/wat2.1037

GURNELL, A. M.; RINALDI, M.; BELLETTI, B.; BIZZI, S.; BLAMAUER, B.; BRACA, G.; BUIJSE, A. D.; BUSSETTINI, M.; CAMENEN, B.; COMITI, F.; DEMARCHI, L. A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. **Aquatic Sciences**, v. 78, n. 1, p. 1-16, 2016. DOI: 10.1007/s00027-015-0424-5

KASPRAK, A.; HOUGH-SNEE, N.; BEECHIE, T.; BOUWES, N.; BRIERLEY, G.; CAMP, R.; FRYIRS, K.; IMAKI, H.; JENSEN, M.; O'BRIEN, G.; ROSGEN, D. L.; WHEATON, J. M. The blurred Line between form and process: A comparison of stream channel classification frameworks. **PLoSONE**, v. 11, n. 3, 2016. DOI: 10.1371/journal.pone.0150293

KRAUSE, K. L.; BOCHNER, S.; DUCHESNE, S. **Educational Psychology for Learning and Teaching**. Victoria, Australia: Thomson, 2013. 656p.

MARÇAL, M.; BRIERLEY, G.; LIMA, R. Using geomorphic understanding of catchment-scale process relationships to support the management of river futures: Macaé Basin, Brazil. **Applied Geography**, v. 84, p. 23-41, 2017. DOI: 10.1016/j.apgeog.2017.04.008

MCPHEE, S.; PRZEDPELSKA, S. Experiential learning, community engagement, and student experience: Undergraduate field school course in rural British Columbia. **The Canadian Geographer/Le Géographe canadien**, v. 62, n. 3, p. 372-383, 2018. DOI: 10.1111/cag.12436

O'BRIEN, G.; WHEATON, J. M.; FRYIRS, K.; MACFARLANE, W.; BRIERLEY, G.; WHITEHEAD, K; GILBERT, J.; VOLK, C. Mapping valley confinement at the network scale. **Earth Surface Processes and Landforms**, v. 44, p. 1828-1845, 2019. DOI: 10.1002/esp.4615

O'BRIEN, G. R.; WHEATON, J.; FRYIRS, K.; MCHUGH, P.; BOUWES, N.; BRIERLEY, G.; JORDAN, C. A geomorphic assessment to inform strategic stream restoration planning in the Middle Fork John Day Watershed, Oregon, USA. **Journal of Maps**, v. 13, n. 2, p. 369-381, 2017. DOI:0.1080/17445647.2017.1313787

WINCH, C. Curriculum design and epistemic ascent. **Journal of Philosophy of Education**, v. 47, n. 1, p. 128-146, 2013. DOI: 10.1111/1467-9752.12006

WHEATON, J. M.; FRYIRS, K. A.; BRIERLEY, G.; BANGAN, S. G.; BOUWES, N.; O'BRIEN, G. Geomorphic mapping and taxonomy of fluvial landforms. **Geomorphology**, v. 248, p. 273-295, 2015. DOI: 10.1016/j.geomorph.2015.07.010

YOUNG, J.; CHAPMAN, E. Generic competency frameworks: A brief historical overview. **Education Research and Perspectives**, v. 37, n. 1, p. 1-24, 2010.