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Original Research Article

River Culture: an eco-social approach to mitigate the biological and cultural diversity crisis in riverscapes

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ABSTRACT

We introduce here the term "River Culture" to delineate an eco-social approach to mitigate the biological and cultural diversity crisis in riverscapes. It is based on the insight that current environmental change endangers both, biological and cultural diversities in rivers and their basins, and those activities to improve ecosystem functions, biodiversity and capacity of the biological species to evolve will have a similarly positive effect on human cultural diversity. "River Culture" has two dimensions, including (a) the influence of the biophysical setting of rivers (specifically, their pulsating flow regimes and their biological features) on the expression of elements of human culture in general and (b) the aspect of "learning from the river" for the development of technologies and management options that are targeted to maintain and improve ecosystem functions and diversity in a more sustainable way. The River Culture approach, as given in this concept and discussion paper, is preliminarily based on five tenets: (1) Reset values and priorities in riverscape management in favor of human wellbeing and a harmonious coexistence of man and riverscape; (2) Live in the rhythm of the waters, i.e. adapt management options in accordance with the hydrological dynamics rather than fighting against them; (3) Transform traditional use of rivers into modern cultural activities and management options; (4) 'Ecosystem bionics': by copying survival strategies of flood-pulse adapted

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organisms novel forms of human use can be developed; (5) Make the catchment (river basin) the geographical base unit for all kinds of political decisions in landscape management.

1. Introduction: interactions between cultural use and ecological state of the global riverscape

Riverscapes can be regarded as an interface of aquatic and terrestrial conditions, strongly controlled by complex interactions of many factors: hydrology, sediment transfer, soil-vegetation dynamics, bio-geochemical processes, and other biotic interactions, and finally by land use and pollution. The natural ecosystem functions are today described as "ecosystem services" that are useful for human beings. In the case of river-floodplain-systems, they include water, means of transport, shelter from enemies, wood, fish and other food resources, open, easily colonized space and fertile plains that can be used for agriculture and livestock and their functions for transboundary trade. Moreover, they provide cultural services such as esthetic inspiration for art and design, spiritual experience and sense of place associated with the identity of an individual, a community, or a society (Daniel et al., 2012).

River valleys (Riverscapes, Allan, 2004) have been used by human beings since the earliest day of humanity. Fluvial-palustrine corridors across the Sahara can explain the migration of early modern humans to the north and out of Africa 120,000 years ago (Osborne et al., 2008). There is strong evidence that pulsing ecosystems were the first sites where agriculture took place, as shown, e.g. in the wetlands of the Sahara and the Sahel, where early farmers domesticated pearl millet between 4500 and 2800 years BP (Manning et al., 2011; Ozainne et al., 2014). The cradles of most known historical empires were in floodplains, being in Mesopotamia or in Egypt, and the spread of Roman and Viking empires benefited from river courses.

The early development of cultures has always been linked to specific technologies to use natural resources. It requires learning from the nature, how to exploit a resource the best way, and to know the best moment to use them. The rhythm of the waters, of floods and droughts, has become an impulse generator for the organization of the annually changing cultural activities, specifically the biological "hot spots and hot moments" such as fish migrations into or out of the floodplains (Junk et al., 1996; Wantzen and Junk, 2006; Krause et al., 2015) or the onset of the falling water period as a starting point for drawdown agriculture and farming in floodplains in early societies. In many places of the world, riverine fish have been revered as symbols of divine power by indigenous communities that relied on their environment for survival (Gupta et al., 2015).

The types of used resources also helped to structure social groups, e.g. a separation of genders and generations between fishing and hunting by boat (men), pottery with clay from riverine sediment deposits (women), and angling (children), as it is still found, e.g. at the Cuiabá River, Brazil (Oliveira and Nogueira, 2000; Neuburger and Da Silva, 2011). Thus, evolution of biological species traits and of cultural activities in and around rivers is triggered by the same engine, the flood pulse (Fig. 1, Junk and Wantzen, 2004).

Moreover, rivers and the natural phenomena linked to them have a very strong value in spiritualism and religion. The personalization of water as the source of life, and of floods as sources of fertility in floodplains or as an intimidating, destructive force may be the reason why so many rivers have been and still are considered divinities in many countries. Hinduism in India is a very strong example how rivers may become central elements of religious and social life (Alley, 2012) – and how a purely utilitarian? policy may impair these structures. Losses of significant cultural ecosystem services may exacerbate social conflicts (Daniel et al., 2012).

Rivers and floods are metaphors for constant change, for the unification of constructive and destructive forces that have driven philosophers since Heraklit's "panta rhei"; and the esthetic values of sinuous meanders, rounded pebbles, or mirroring water surfaces imbued painters and sculptors. The rhythm of running water is at the same time monotonous and highly diverse, and has inspired musicians to compose pieces such as Smetana's *Vltava* (The Moldau), or much of J.S. Bach's diverse work. All these technological and the spiritual linkages of human beings to rivers have contributed to diverse forms of culture. As stated by Irene Klaver (2012), *Cultural diversity, as recognized by UNESCO, is a driving force of development, not only in generating economic growth but also as a means of leading a more fulfilling intellectual, emotional, moral and*

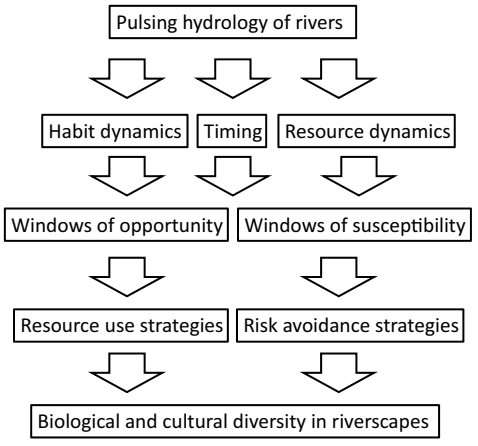

Fig. 1. A pulsing hydrology sets up the stage for both, evolution of biological and cultural diversity.

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spiritual life. Cultural diversity, like biological diversity, is intimately shaped and sustained by the interconnected realms of ecological, genetic and species diversity. As observed by the International Union for the Conservation of Nature (IUCN), it is no coincidence that areas of linguistic and ethnic diversity are also areas rich in biodiversity. . . . Indeed, the biocultural diversity of a given region represents a complex history of human interaction, knowledge, values and stewardship of the environment, and especially of the essential role of water in sustaining life.

Culture is often understood as a learned behavior expressed in patterns that are handed over between generations or social groups (Johnston et al., 2012). Culture also implies the generation of values that are used to balance reasons between different ways of action. Thus, the more the *resource relations* (Donahue and Johnston, 1998) become limited due to ecological deterioration the less nature can serve as a generator of values. Along with alarming loss of biodiversity, we register a loss of cultural diversity linked with rivers and floodplain wetlands (Ricaurte et al., 2014; Wantzen et al., 2008b), as ecological services provided by river systems are not available any more (e.g. fish), or because traditional-cultural use of river-borne resources is "outdated" (i.e. they are not considered to be economically feasible any more) today, or because people have lost the notion of a healthy river (e.g. due to pollution) and prefer to have the river canalized and covered by concrete. However, the economics behind these views are often incomplete, as important financial elements are overlooked, for example, inland fisheries are for many of the world's people the primary source of dietary protein (Dugan et al., 2010) and costs for restoration of deteriorated ecosystems are often manifold those of the benefits. There is an urgent need to re-evaluate and to reprioritize our actions.

The development of human societies goes hand in hand with the development of increasing environmental impacts, specifically so in rivers (Nilsson et al., 2005; Dudgeon et al., 2006; Tockner et al., 2010). While deforestation of the catchments has a very long tradition since the Stone Age, the man-made changes in rivers began with the ancient high cultures such as the channel systems of Angkor Wat, and the irrigation systems and drainage to improve floodplain soil quality in the Maya culture (Lambert et al., 1984). Roman deforestation in the Mediterranean zone had a first large scale impact on European river systems (Sabater et al., 2009). Medieval monks regulated the discharge of tributaries or outflows of lakes in order to gain room for agriculture (Wantzen et al., 2008a). In low-order tributaries of Europe ("Little Industrial Revolution" of the 11th to 14th centuries) and, later, North America, damming for rafting wood or fertilizing riparian meadows, or the construction of mills has considerably changed the upper sections of the river continuum (Brown et al., 2013).

The global environmental impact of these systems was relatively low as long as ecosystem changes were locally or regionally restricted. Only few organisms delivering specific goods, such as the Giant River Pearl Mussel (*Margaritifera auricularia*, Araujo and Ramos, 2000) were overharvested and brought to the brink of extinction in historical times.

In Europe, it was the end of the "Little Ice Age" in perialpine regions (Astrade et al., 2011) and the synchronous Industrial Revolution in the 19th century that prepared the stage for large scale impacts and mass extinctions (Claude Amoros, pers. comm. to KMW), that left their traces in discontinuities in the alluvial records of hydrogeomorphic systems (Brown et al., 2013). Technology now allowed taming the floods of the rivers by diking and damming, and quickly growing populations were responsible for overharvesting and organic water pollution. The chemical and agricultural revolutions in the 20th century finally allowed releasing substances that were toxic even at low concentrations, e.g. in the Rhine (Uehlinger et al., 2008). Moreover, climate change affects the rivers and their riparian systems in spite the fact that these are specifically suited to mitigate climate change effects (Capon et al., 2013). While in Europe and the US these procedures have spanned over centuries, in countries with a more recent history of western colonization they are compressed into a short time span (Kandasamy et al., 2014; Schwartzman et al., 2013), urging solutions of very different problems at the same time. In summary, the increasing loss of ecological interactions is paralleled by an increasing feed-back mechanisms between the different multiple stressors (Fig. 2).

Today, most running water systems are in a deplorable state (Garcia-Moreno et al., 2014). The development of technologies has increased the possibilities of a single human to have a large impact on the nature, which becomes multiplied by the dramatically rising human population. Globalization allows transferring human needs and environmental pressure from one area to another within the time of a mouse-click. Errors in environmental management such as excessive damming that have been performed in Europe and the United States for decades are now being repeated in "developing" countries, in spite the fact that massive efforts are taken to correct these errors in their countries of origin today (Palmer et al., 2007). Indeed, there has been a recent resurgence of dam building that threatens the remaining

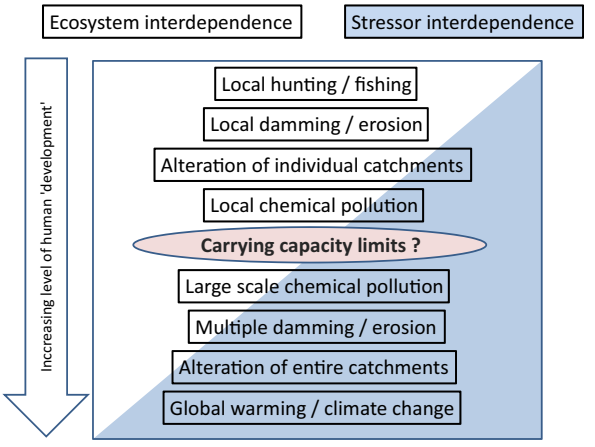

Fig. 2. Increasing number, types and intensity of stressors increase the synergetic effects and interdependences between them. At the same time, interdependences in the ecosystem (e.g., upstream–downstream linkages, river–floodplain interactions, foodweb interactions) become reduced.

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pristine environments (Nilsson et al., 2005; Zarfl et al., 2015) so the current need for management is to mitigate these urgent problems rather than conserve riverine ecosystems.

Freshwater biodiversity is constantly shrinking throughout the Anthropocene (Dudgeon et al., 2006). Due to intensive river engineering and increasing demand of water as a resource, the ecological status of rivers worldwide is decreasing at a much faster pace than that of most terrestrial ecosystems (Garcia-Moreno et al., 2014). There are large incompatibilities between human and ecosystem needs (Richter et al., 2003) that require an improved management of environmental flows (Arthington et al., 2010; Poff et al., 1997, 2010). Agricultural use still produces large amounts of eroded fine particles that threaten biodiversity worldwide (Wantzen and Mol, 2013). Even if treatment of wastewater and habitat restoration measures shows some regional effects, the general trend of decline is far from being halted. Chemical pollution of river waters is still an important issue in spite the Clean Water Act in the USA and the Water Framework Directive in Europe (Malaj et al., 2014). Most riverine landscapes are now modified or highly modified by human activities.

Since Vörösmarty et al.'s (2010) seminal paper it is an undeniable fact that riverine biodiversity and water safety for humans are directly linked. This paper has evidenced that nearly 80% of the world's population is exposed to high levels of threat to water security. Similar or identical stressors that threaten human water security are jeopardizing biodiversity, with habitats associated with 65% of continental discharge classified as moderately to highly threatened. Even if the relative impact of the individual threats may vary for both issues, we can assure that preserving biological diversity by river restoration will directly improve human well-being considering water quality and availability and other critical issues.

The central hypothesis of this paper (and of the UNESCO Chair: *River Culture – Fleuves et Patrimoines*) includes the statement on diversity-human safety relationship described above and it goes one step further by asserting that preservation and restitution of biological diversity in and near rivers will directly improve the material and immaterial cultural diversity, and vice versa, that "learning from the river" allows the development of technologies and management options that are targeted to maintain and improve ecosystem functions and diversity in a more sustainable way. "River Culture" goes therefore beyond the original term ('*une culture du fleuve*') describing an anthropological collection of cultural features linked to a river such as the Rhône (Vincent, 1999); however, it maintains the statement that rivers are 'mirrors of the society' (Béthemont, 1993).

The "River Culture" approach acknowledges that human wellbeing and the maintenance of both, biological and cultural diversity depend on the same factors (natural habitat dynamics, water quality, diverse ecosystem services) and it delivers a framework to re-organize priorities in river management based on these needs. The River Culture approach proposes several tenets to improve the sustainability of human activities in or nearby rivers.

2. Tenets of the River Culture approach

2.1. Reset values and priorities in riverscape management in favor of human wellbeing and a harmonious coexistence of man and natural river dynamics

In spite of a large body of literature on integrated river basin management, which are combining different use forms, flood protection and conservation, the riverine reality is still far from experiencing holistic approaches, especially so in the Global South (Sreeja et al., 2015). This is not astonishing if we consider that by their natural setting, rivers are prime sites for conflicts over different ways how to use their "ecosystem services". Economic and institutional development often focuses on fulfilling needs of the human population at the expense of the river environment (Pahl-Wostl et al., 2012). Many if not most politicians are willing to sacrifice the integrity of rivers and such services as fisheries in favor of a nationwide supply of commodities such as electricity or irrigation water, ignoring the long-term effects that put entire societies at stake by destroying life support systems and by risking wars about essential resources such as water.

The need to reconcile river management and environmental protection for the benefit of mankind (Vörösmarty et al., 2010) has often been ignored. Lack of space (due to intensive land use in the diked part of the floodplain) and lack of natural dynamics (due to damming and subsequent reduction of hydrodynamics and sediment transport) have sewn a straight corset for river restoration. Those rivers are considered as "domesticated ecosystems" (Tockner et al., 2011). Even under large programs such as the Water Framework Directive, most restoration projects are limited to site-specific small-scale measures where fundamental change on much larger scales was needed (Moss, 2008) and restoration targets such as the re-establishment of target assemblages are often not achieved (Hering et al., 2010).

The River Culture approach proposes to re-consider the values so far used and to set new priorities in river management and global land management strategies, beginning from the insight that human wellbeing, cultural and biological diversity are menaced by the same threats. As a consequence, all activities that improve the biological diversity will improve human wellbeing and culture at the same time. The restoration of the Thur River (Switzerland) is a good example for this (Schirmer et al., 2014). Along with the restoration of riparian and riverine habitat dynamics by dike removal, the social valuing of the river improved tremendously (Woolsey et al., 2007). Observations and interviews have shown that visiting restored habitats improves the wellbeing of the visitors (Abraham et al., 2010). However, care has to be taken that the attractiveness of restored riparian habitats (especially in the urban context) does not create additional pressures on the re-establishing biota, therefore, alternative visiting sites should be envisaged (Hamed et al., 2015). Moreover, public perception may also hinder the establishment of near natural structures (Junker and Buchecker, 2008) such as wood in river channels (Piegay et al., 2005). On the other hand, green structures are "sought after" by the human eye in the urban landscape, and the linkages between human

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esthetics and ecological health of restored river systems require further attention (Cottet et al., 2013).

By identifying the optimal habitat dynamics considering biodiversity, cultural diversity and human wellbeing, ecosystem services attributed to river sections, habitat classification and habitat modeling will achieve new qualities. Once the faunal/floral species assemblages, their potential use forms (beginning with zero use for the most sensitive habitat types) and respective carrying capacities for the different use types have been identified, these models can be used to improve a networked habitat management scheme integrating conservation and the different use forms, but they should also include the immaterial elements of human well-being. The positive effects of dynamic rivers on human being are manifold, including stress reduction (Adams et al., 2014), positive effects on the microclimate (Pinto et al., 2014), and reduction of respiratory diseases (Theeuwes et al., 2013). Diverse river flows have a great esthetic value (Pfluger et al., 2010) and restoration of river ecological status and services may lead to a cooperation and peace (Gosnell and Kelly, 2010). While rivers in a bad ecological state provoke negative affects due to olfactory, optical cues (e.g. bad smell or visible litter), rivers in a good ecological state increase the attractiveness of the entire region. It is not surprising that many cities such as Frankfurt at the Main river or Berlin at the Spree "re-discovered" their vicinity to the rivers and developed impressive water front architecture only after overcoming the post-war water pollution. Recognizing these positive values of healthy rivers for human wellbeing and economic development is an important element of River Culture.

The River Culture approach goes far beyond the "good ecological status" defined by the European Water Framework Directive: by accentuating the human wellbeing on a riverscape scale, it includes that we "feel" the environmental quality and that we "care" for the living nature as we would do this for a fellow human being. The affective relationship between man and nature may reveal strong energies for restoring rivers, which we are just beginning to understand (Rivière-Honegger et al., 2014). Empathy, mind-reading, and cooperation were elementary for the survival of the human species over millennia (Burkart et al., 2009). Now that the human race is menaced by the ignorance of the dependence of its survivorship on ecosystem functionality, we need to reinforce the element of empathy with our environment. Empathy is the basis for the ethics of care (Gilligan, 2014), and in analogy to human-human care, we need to develop a human-environmental care. The positive experience of living with the river and living in the rhythm of the river may considerably stimulate this affective relationship.

2.2. Living in the Rhythm of the Waters

The major problem identified with river management according to nature's needs appears to be the lacking acceptance of the pulsating nature of rivers. "Taming the floods", "correcting the river course" and other metaphors show that river management is still considered rather a war against nature than being a harmonious coexistence, using the natural power for human benefit. All natural superficial water bodies, and even the ground water, show a pulse-shaped hydrology (Junk and Wantzen, 2004). These oscillations between higher and lower water levels may have variable frequency, altitude, intensity, amplitude, and may recur in different forms of temporal units (e.g. annual flood and multi-year phases of higher and lower floods in the Pantanal, Fantin-Cruz et al., 2011), however their general physical features remain similar and provoke comparable changes in the respective ecosystem that have been conceptualized in the Flood Pulse Concept (Wantzen et al., 2008a; Tockner et al., 2000; Junk et al., 1989; Junk and Wantzen, 2004; Junk, 1999). The hydrological cycle is responsible for the development and maintenance of biodiversity in floodplains (Junk and Wantzen, 2006) and it has been sustaining many human cultures such as the Egyptian agriculture that used the flood pulse advantage sustainably for 5000 years until the Nile became dammed. The term "Living in the Rhythm of the Waters" was originally used when describing the adaptations of settlers and native tribes to the wet-and-dry cycle of the Pantanal wetland (da Silva and Silva, 1995) and other Latin American floodplains (Ortiz et al., 2008). We use it here in a broader sense, respecting the wider range of riverscape dynamics in their short (days to months), medium (annual), and long-term (decades to centennial) dimensions.

The River Culture approach considers the rhythmic change of environmental conditions in the wet and dry cycle as one of the most important impulse generator for the evolution (and thus for the diversity) of human culture, and claims that this relationship needs to be better valued for decision-taking about river management (Fig. 1). Increasing isolation of human societies from natural cycles, as a result of improved living conditions, high-quality nutrition and 24/7 working practices, provokes a series of negative effects on human health (Foster and Roenneberg, 2008). Re-integrating the "Rhythm of the Waters" into modern society may include a large number of cultural activities, for the benefit of human wellbeing that needs recurrent events as a cultural impulse generator:

- *Seasonal exploitation of natural resources.* Given that restoration activities were successful and that populations have achieved sufficient population size so that their productivity can be sustainably used, the use of seasonally appearing resources may serve as a cultural trigger. For example, the advent of migratory Allis and Thwaite shad (*Alosa alosa, A. fallax*) gave rise to large festivals in Europe in previous time (Degroot, 1990), in a similar way as we can witness this still today with the Jaraquí fish in Amazonia (Junk, 1984) and in other species in near-natural rivers.
- *Seasonal contact with natural habitats.* River beaches are excellent sites for establishing contact with the nature (given that they are respectfully used and that protected bird/fish breeding zones are preserved). The intensive use of artificial sand beaches in cities shows the large demand for this kind of leisure activity. In many countries, winter flooding provide frozen floodplain zones the use of which may be important for leisure

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activities (ice skating). The perception of seasonal or inter-annual changes of the appearance of the riverine nature is an important asset for human wellbeing (Abraham et al., 2010). The benefits of reconnecting the river to its floodplain was demonstrated in California as a flood control measure (Opperman et al., 2009), allowing an improved perception of the flood cycle by the human population. Maintenance of river seasonal rhythms ensures harvesting of the economical benefits of the ecosystem services (Turner and Daily, 2008) and also warrant their cultural, artistic and spiritual values such as, e.g. Indian cultural festivals, religious sanctuaries and rituals (Lokgariwar et al., 2014).

- *Respecting natural constraints.* Apart from "use" strategies, "stress avoidance" strategies are equally important to trigger biological and cultural evolution and diversity. "Living in the Rhythm of the Waters" also means the adaptation to adverse or constraining conditions, such as floods events. An uncritical belief in water retention structures such as dams and dikes has resulted in billion-Euro damages in i.a. Germany, Poland, Austria, Czech Republic, Hungary, Switzerland during the last two 'centennial' floods 2002 and 2013 (Zurich-Group, 2013). Respect for the inundation cycle, therefore, also includes the avoidance of settling sites in the lower part of the landscape gradient, where inundation risk is too high and hydraulic forces may become too strong (e.g. European Floods Directive 2007/60/EC).

Finding back the "Rhythm of the Waters" appears to be one of the major problems in modern river management, which can be broken down into two main questions: (a) How to find space for rivers in diked and colonized floodplains, and (b) how to re-establish appropriate environmental flows to maintain historic patterns of flooding? Solutions often come at a cost to the new primary users of the floodplains who are reluctant to lose electricity or irrigation water in the interests of activities such as fisheries or conservation. Thus, social and political energy is needed to overcome this problem. The values for decision taking need to be reconsidered (see above). Re-calculating economic budgets including costs for environmental restoration and public healthcare resulting from short-term use of riverine resources may be one way out of the dilemma. Technological solutions such as a flood-adapted architecture, adequate use of riverine ecosystem services may be another (see Section 2.4 below).

2.3. Transform traditional and cultural use of rivers into modern management options

Many cultural activities such as festivals strengthen the affective link between man and nature. In spite of very large population density, India and other South Asian countries still have preserved forests and wetlands which supply a variety of feed, plants or animals. The fact that many plants and animals are revered as gods or god companions and their use in religious festivals probably explain to some extent the conservation of their natural habitats (Anthwal et al., 2010). In India, millions of devotees converge at Haridwar or Allahabad (the confluence of the Ganga and Yamuna) to have a holy dip in the River Ganges during a highly religious period-popularly known as "Ardh Kumbh" (held every 6 years) and "Kumbh" (held every 12 years, Singh and Bisht, 2014). This and other festivals involving dips in the river are so important to sacred rivers, especially the Ganges, that socio-cultural aspects are incorporated into a methodology for determining the environmental flows in India (O'Keeffe, 2013).

Many traditional use forms have become abandoned as they are not any longer economically feasible. Others have been maintained for leisure or folkloristic activities but they were rather statically conserved than being object of a cultural evolution. Finally, riverine species that have become too rare or too polluted to be traditionally used (the Atlantic Eel is an example for both phenomena) lose their cultural connotation.

All these trends result in exclusion of activities from the everyday life of people living next to the river and in exclusion of their resulting products from the value chain. Especially, in fast-developing countries, the cut-off of traditional resource usages from the fast evolving markets is a severe problem. As soon as the previously used resources are not considered as "valuable" any more, the territories on which they have been growing may easily be transformed into intensive use forms that are often not sustainable. This phenomenon has been described i.a. from floodplain wetlands in the Pantanal of Mato Grosso (traditional cattle breeding, traditional use of pharmaceutic plants, Wantzen et al., 2008b) and the Andean Piedmonts of Colombia (multiple use of the palm *Mauritia flexuosa*, Ricaurte et al., 2014).

In analogy to the current decisions of habitat restoration managers who have to decide over which faunal/floral assemblages they prefer to reinforce by the selected restoration activity and which of them will be allowed to perish (i.e. "playing God"), landscape managers and regional decision takers have to select, which traditional cultural activities they allow to be saved from oblivion. Of course, not all cultural features must be maintained, however, it is clear that the unrivaled extent of the current biological and cultural mass extinction in river systems must be halted. The choice, which species and cultural forms to preserve, is often supported by conservationist lobby groups and NGOs who have studied their history and their importance for ecosystems and societies.

Different strategies can be envisaged:

- In an ideal case the traditional use form can be directly preserved because it is possible to add an economic value to it. This is for example the case with the traditional boat and ship construction on the Loire River, which has ceased to be a means of transport but which has become an important element of the local tourism (Fig. 3).
- Labeling. Protection of the cultural activity in form of the European "appellation d'origine protégée" (AOP) or "green seals" for certain regional products may help to protect these against falsification/copying and to maintain an elevated price. It may also open the opportunity for demanding subventions from the regional government.
- Lastly, there is the possibility to "re-invent" cultural activities that are based on elements of traditional use forms that do only exist in form of memories (historical

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Fig. 3. Bridging traditional and modern use in riverscapes. Classical boat architecture and shipping culture at the Loire has been transferred from a means of transport to a leisure activity.

documentation, etc.) in the context of ecological restoration measures, such as basket-weaving from replanted willows. The conservation principle here is the integration of these activities into environmental education, if economic valuing is not possible.

All these use forms can be employed to strengthen the liaison between man and river. Eco tourism plays an important role in this context (Gutierrez and Alonso, 2013), as it allows to maintain local products as well as cultural and natural features by attributing high economic values that are above the market prices. However, it replaces the driving forces of biological and cultural evolution by the interests of the eco tourists, and special care has to be taken to keep the cultural development going on.

2.4. Ecosystem bionics

Bionics is a scientific approach to mimic individual natural structures or mechanisms for human use, e.g. to copy the "lotus effect" of plant leaves in order to develop specific material surfaces that do not stain quickly (Vincent et al., 2006). We introduce the new term "ecosystem bionics" here in order to express the approach to mimic a set of interactive structures and mechanisms of entire ecosystems. In the context of the River Culture approach, "learning from nature" is here specifically meant as "learning from the river". We propose to use the adaptive mechanisms of biota to the flood pulse (see "windows of susceptibility" and "windows of opportunity" defined in the updated FPC (Junk and Wantzen, 2004) in order to find sustainable use options for rivers and their floodplains.

Some examples:

- *Use of the flood pulse advantage.* The *flood pulse advantage* describes the increased productivity of floodplain organisms as compared with organisms living in non-pulsing habitats (Bayley, 1991). The time when these resources are available is limited, but then they are very abundant (biotic hot moments, Wantzen and Junk, 2006), resulting in a bad usability of these resources in the context of markets that need to supply the same good all year round. A more seasonal life style (see point 1) and adapted use forms would help to improve this situation. Many "flood-borne resources" may be named here, i.a. increased productivity of plants and animals during the early flood, or availability of highly fertile soils during drawdown. Other than annual organisms, floodplain trees and long-lived fish may accumulate this advantage over years. A novel concept for the sustainable use of Amazonian trees has been based on the variable growth rates of different tree species and their position in the flood gradient (Schöngart, 2008).
- *Survival strategies to flood and drought conditions.* Terrestrial organisms have developed a wide range of adaptive strategies to survive during flood, including migratory strategies, physiological adaptations, and the development of morphological structures (Adis, 1997; Wantzen et al., 2015). Some of these strategies may be used to make human settlings along riversides smarter. For example, ants construct their nests above the water line, or they float (Adis et al., 2001). A mimesis to this strategy is the house construction on stilts or on floats in order to minimize flood damages strategies. These technologies exist from neolithic times on, they are still used today (Fig. 4), and undergo a current renaissance (Flood Adaptive Architecture – Aquatecture) in the context of increasing urban flood resilience (Balsells et al., 2015).
- *Use the capacity of floodplains to act as filters and bioreactors.* The use of ecosystem functions of floodplains is one important element of Ecohydrology (Kiedrzynska et al., 2015; Zalewski, 2002, 2011, 2000). By their nature, floodplains act like a filter for sediments and dissolved substances and make them available to other organisms. They absorb flood and pollutant peaks and may minimize the danger of flooding (Kiedrzynska et al., 2015, 2008). The pulsing hydrology does not only act as a pump, it also causes steep gradients of environmental conditions (e.g. oxygenation of the sediments) allowing a highly efficient use of the retained substances by a large diversity of organisms applying different resource uptake and use strategies. Biogeochemical services by riverine biota are still far from being acknowledged by river basin managers and by economic models (Arthington et al., 2010).
- *Use the power of floods.* Flood events mobilize huge amounts of kinetic energy, which is hardly used yet. However, this energy may be used for river restoration projects (rejuvenation of habitats), rather than using cost-intensive caterpillars, and for electric energy production, using floating devices equipped with water current turbines.

2.5. Make the catchment the geographical base unit for all kinds of political decisions on landscape management

Large rivers have often been considered as limits of political units, as they could be overcome only at high expenses (bridge construction), for example the German-French border along the Rhine or the Polish-German

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Fig. 4. Traditional architecture adapted to the rhythm of the waters. Above: floating house in Leticia, Amazonia Colombia; below: reconstruction of a neolithic stilt house, Unteruhldingen, Lake Constance, Germany.

border along the Oder and Neisse rivers. The different environmental policies in both countries resulted in strongly differing landscape management, which is only now beginning to be overcome by joint activities.

Biogeochemistry and hydrology teach us the contrary. Since Sioli's classical metaphor as "Rivers as the kidneys of the landscape" (1955, published in English in 1975) and Likens et al. (1970) legendary Hubbard Brooks experiments, we know that all kinds of human activity such as agriculture, land use change, urban growth, etc. have an impact on the environmental integrity of the rivers via the catchment.

From the perspective of resource use, rivers are the most important element of the hydrological cycle, because they provide renewable resources and because of the interdependency of their ecosystem elements. On the other hand, human activities in the catchment reducing groundwater infiltration, accelerating surface runoff, and favoring the leakage of soil carbon and natural and artificial nutrients into the stream network have caused diffuse pollution and increased hydrological stochasticity that go beyond climate change effects and local point source pollution. Thus, the important questions are: '*What have we done to the hydrological cycle on the catchment scale?*' and '*What can we do to re-establish the natural functions of rivers in the hydrological cycle in the catchment scale?*'.

Moreover, rivers have an important function as biological and cultural vectors. The current of the water transports propagules of biological species but also natural "rafts" (driftwood) or allows long-distance migration, making rivers "biodiversity hotlines" for fish (Decamps, 2011) but also for benthic assemblages (Wantzen et al., 2014). In a similar way, culture was transported on the river corridors over long periods, e.g. the expansion of the wine culture along the European River systems in the Roman period (Bouby et al., 2013).

It is therefore mandatory to put the river in the center and not at the margins of land management (thus: geopolitical) units, as requested by the Integrated River Basin Management concept (Brethaut and Pflieger, 2015). There are many positive examples citing attempts to do so, e.g. the European Water Framework Directive claims to establish authorities for the European River Systems, however only for the management of water resources. This goal has only been partly achieved.

Transboundary rivers (Armitage et al., 2015), such as the Mekong (Smajgl et al., 2015) or the Okavango (Green et al., 2013) systems present specific problems, especially in water scarce regions (Falkenmark et al., 2014). The global problem of ever-increasing water demand bears a strong risk for armed conflicts (Akbas, 2015; Aggestam, 2015; Chakraborty, 2004; Shuval, 2000) but also the chance for cooperation (Wolf, 2007).

3. Conclusions

There is consent in the society that rivers worldwide are in peril and that action is urgently needed to mitigate this situation. There is scientific evidence that the man-made impacts in rivers menace biodiversity and mankind in the same way (Vörösmarty et al., 2010), and that the diversity of water-borne cultural elements is equally endangered by this trend (Johnston et al., 2012). This insight is not new. Already the Large Rivers Symposium as of 1985 (Dodge, 1989) or the Second International Symposium on the Management of Large Rivers for Fisheries 2003 (FAO, 2004) laid out clear recommendations for future actions. Yet the observed action is still far from being satisfactory. Several reasons for this have been identified.

(A) The ideal of a holistic approach to river basin management would suggest that the system could be managed to maximize the benefits accrued from all activities in the basin at some cost to any one activity not maximizing its yield. This has never been achieved as all sectors seek to maximize their yield irrespective of the damage caused to other users. No mechanism exists for the sort of mediation needed to reconcile basically hostile interests, be they commercial or administrative.

(B) Generally, the sites/cities and social groups that profit by the benefits resulting from the misuse of riverine assets and those that have to pay for the environmental impacts are geographically separated (for example, the

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people that become displaced when dam basins are filled are not the main users of the energy produced by the dam).

(C) Splitting up the governance about river catchments into different political units within a country, and the establishment of political borders along or across the river continuum reduce the success of holistic approaches, moreover, they cause risks for political conflicts about water use.

(D) Due to water pollution, control of water-level fluctuations and transformation of floodplains, human everyday life and cultural activities have become decoupled from riverine phenomena, river-borne resources (other than water) have lost their values, the flood cycle has lost its function as cultural pulse generator. Affections to rivers, acknowledgment of their positive effects on human spiritual and physical wellbeing are increasingly lost. The "western", mechanistic view of nature and the position of man as "maître et possesseur de la nature" (Master and owner of nature, in Descartes "Discours de la Méthode", 1637) has largely eliminated the option to respect nature for values that go beyond their quantifiable services. Rivers are today seen as a sum of megawatts of hydraulic energy, cubic meters of water for cooling, irrigation or drinking supply, and some kilograms of fish.

The River Culture approach may help to mitigate these problems. Its central tenet is to harmonize man and nature in river corridors and beyond, in river catchments.

The list of five tenets stated above has to be seen as preliminary, as this paper has been conceived to stimulate discussions in order to improve and complete this concept. We can summarize the main targets of the River Culture approach as follows:

(1) Culture – rational and emotional appreciation of healthy rivers. The categorical imperative that follows from Vörösmarty et al.'s (2010) paper is a clear order to re-assess economic and political priorities in river management. However, political decisions are often driven by emotionally motivated people. Thus, the affective link to rivers and the appreciation of their value for the spiritual and physical wellbeing is evenly important.

(2) Technologies – from and for rivers. Ecosystem bionics may teach us in future how we can develop technologies by learning from entire ecosystems, e.g. how to improve use efficiency of resources and how to make use strategies more sustainable. At the same time, improved and transferrable ecohydrological technologies will help us to use riverine resources more sustainably (Zalewski, 2015).

(3) Economy – re-calculating environmental and global budgets. Spatially explicit modeling tools, such as the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST, Nelson et al., 2009), may help to predict changes in ecosystem services, biodiversity conservation, and commodity production levels. Riverine ecosystem services are not yet sufficiently budgeted (Brauman et al., 2007). By bringing together the budgets of the parts of the population who pay for environmental costs with those who profit by the use of the natural resources (see point 4), budgeting will become more equitable.

(4) Governance – centered on rivers. Putting the rivers in the center of geopolitical planning, profiting by their natural functions of rivers as cultural vectors, will help to use, share and sustain resources on a more equitable basis and reduce political conflicts.

The River Culture approach has an universal character, applicable in different continents with highly variable climatic – geomorphological and use forms, under the auspices of UNESCO's mission and the UN Millennium Development Goals, specifically Goal 7: Ensure environmental sustainability. It is our hope that this paper and the following discussions may bring back the reference of rivers to the cultural heritage of societies and to provide the scientific background for promoting the culture of sustainable use of riverine resources and the conservation of their biological and cultural diversities.

Conflict of interest

None declared.

Ethical statement

None.

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