**Rivers as Social-Ecological-Technological Systems**

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***Why Think of Rivers as Social-Ecological-Technological Systems?***

Flowing surface waters continue to capture the human imagination, and in turn, are harnessed by many interdependent human activities. Existing theories for understanding rivers as cohesive ecological systems, such as the river continuum concept, have struggled to integrate human activities into an ecological framework.

For almost 50 years, ecological science has offered a promise of an integrative approach for understanding the complex forces shaping ecological systems (Odum 1977). For over 30 years, theories of landscapes as socio-ecological systems (Folke et al. 2007, Liu et al. 2007), have brought our attention to how social processes are fundamentally intertwined with ecological processes in most landscapes. Socio-ecological approaches however have struggled with incorporating infrastructure into investigations of landscape change, often treating it as a particular land cover (e.g. impervious cover) or disturbance (e.g. large dams). And yet it is s obvious that infrastructure shapes environment flows of nutrients and energy, and mediates the human relationship with the environment by enabling certain interactions (e.g. driving, flying, using a computer) and precluding others (e.g. highways preventing pedestrian movement). It is also obvious that technology shapes the human relationship with nature through enabling certain forms of management and material transformation (e.g. large agricultural, mining, and logging equipment), as well as how nature is known (e.g. satellite imaging, distributed sensor networks, automated weather models, etc…).

Social-Ecological-Technological Systems (SETS) frameworks offer a way to study and understand how complex systems are materially and conceptually produced by interactions between social, ecological, and technological processes. SETS also seeks to spur reflexivity in constructing and applying conceptual models of ‘how the world works,’ which builds off of some approaches in reflexive Socio-ecological sytesm modeling (Manuel-Navarrete 2015). In this sense, SETS serve as a heuristic for examining interdependent processes which manifest as a particular system of interest, as well as encouraging us to periodically ask, does our representation of the world seem to be useful? To what ends? What is it leaving out? What are the effects in the world of applying this type of understanding?

***Applying SETS to Rivers***

Rivers have long been studied using interdisciplinary methods to understand their ecology, geo-morphology, and hydrology. As you have already learned, the river continuum concept sought to create a unified theory for investigating the inherently spatial biophysical and ecological processes occurring along gradients in river systems. As you have also learned, others, such as Burchsted et al. (2010) have pointed out that rivers, complex drainage networks of heterogenous landscapes, also have many ecologically vital discontinuities (e.g. beaver dams). We therefore need to contextually examine river processes and characteristics using spatially explicit methods that can address the complex factors shaping heterogenous rivers. This understanding of the spatially explicit nature of river properties has shaped an emerging literature using spatially explicit indicators of river-landscape interactions (e.g. Peterson et al. 2011, Giri and Qiu 2016).

However, coarse geographic data are less useful for integrating infrastructure into landscape-riverscape interactions, as many data sets around current and relic hydraulic infrastructures are non-standardized and incomplete. For example, data on dams in the United States is only consistent for federally inventoried dams, with many states having their own definitions of what constitutes a dam (Grabowski et al. 2018). This leaves many, many smaller barriers un-inventoried and unknown, even by local ecological knowledge holders (Grabowski 2011). Similarly storm and sewer drainage networks are not contained in any unified national data base. These data gaps persist despite the massive ecological and hydro-geomorphological simplification of river systems in ‘developed’ countries that occurred through diking, channel straightening, loss of beavers and wetland complexes, damming, floodplain development, piped stormwater conveyance, agricultural drainage, and riverside infrastructures such as road and rail systems.

Despite a lack of consistent data around the infrastructural transformation of river systems,

enviro-technical historians, such as Sara Pritchard (2011), have drawn our attention to how rivers in industrialized countries cannot be seen as ‘pure’ ecological systems (. Rivers have complex technological histories that have fundamentally altered riverine structure and function, and they are often ‘remade’ over time – prior infrastructures do not disappear they accrete and degrade in often subtle ways. Others, such as Richard White (1996) in his work on the Columbia River in the Pacific Northwest, point out that many current rivers are managed as ‘organic machines’ – regulated rivers that feed into many technological systems such as irrigation and power systems, and yet continue to sustain vital ecosystems and fisheries, while meeting other social desires such as recreational and aesthetic values. As the ecosystem services literature has pointed out, many of the desired ecological services provided by landscapes require human and cultural capital in order to be realized (Jones et al. 2016). The SETS framework has likewise been applied to examine how urban ecosystem services result from interactions between S, E, and T domains. Social values, institutions, and behavior are all embedded within river infrastructures. Ashley Carse’s (2012) study of how the construction of the Panama canal created new systems of landscape management requiring new forms of expertise and regulation of social activity such as timber harvest and agriculture, points out that large infrastructure systems both create and require landscape level transformations created by and enforced upon social actors in order to function. Thus, technological transformations of rivers systems are not only environmental and technological transformations, they indicate shifts in social values and create new social realities.

The social goals of managing rivers themselves are often contested. In settler colonial countries, Native scholars and organizations have continued to advocate for treating rivers as living systems worthy of respect on their own terms, and have made significant political and legal headway with the concept of the rights of rivers. As evidenced by constitutional amendments in New Zealand, Columbia, and elsewhere (O’donnell and Talbot-Jones 2018) along with ongoing court actions in the United States (e.g. Lapier 2017), recognizing the rights of rivers, and of nature more broadly is on the rise. As you have learned already, the idea of returning land to Native peoples has also continued to gain momentum. Demand for restored and healthy rivers, along with recognizing the need to protect and enhance water quality and availability in the face of climate change, continues to grow .

How do these new social demands for ecological justice and healthy and resilient river systems intersect with the realities of highly transformed landscapes, thick with infrastructure, politics, and land uses that are deleterious to river health? A SETS framework can be useful for identifying how these landscapes have been coproduced over time, as well as what opportunities exist to restore right human relations by transforming infrastructure and land management affecting river health, as well as understanding the immediate ways in which people interact with river systems. Framing river infrastructures as SETS highlights the social processes for setting the overall goals for river infrastructures, identifying the complex causes of river system quality and characteristics, and engaging in larger processes of designing future and transforming existing infrastructures (Grabowski et al. 2017) As students of rivers, these different SETS dimensions can be useful in shaping how you observe rivers and the various forces shaping them. Some of the major dimensions of SETS are outlined below:

***Social dimensions***

**Governance**: Who has power to shape human-river interactions? These power relations within and outside of social and political structures such as institutions, corporations, formal governance bodies, informal associations, etc... They manifest as formal (e.g., regulations, customs, rituals) and informal (e.g., agreements, attitudes) mechanisms for shaping human-river relations.

**World Views and Identities:** How do individuals and organizations define rivers, how do they value them? How do they emotionally resonate with the river and associated landscapes and features (e.g., dams).

**Consensus/Dissensus:** To what extent do individuals and organizations agree or disagree on goals of river and landscape management and the interpretation of formal mechanisms set in place to achieve those goals(Dis)Agreements, e.g., treaties, contracts, laws, protests, legal disputes, war, etc.…

**Capacities and Affordances:** What are the different capacities (e.g., physical, technical, social, communicative) possessed by different actors and organizations? How are they employed in relationships with ecologies, the river itself, landscapes, and other social actors? How do these capacities influence what ‘niche’ different actors utilize, socially, infrastructurally, ecologically, etc. Capacities and affordances draw our attention to the role of experience and creativity in understanding rivers as nuanced systems (e.g., where is the local swimming hole) and the creation of informal infrastructures or formal engagements with large technical systems.

**Knowledge Systems:** How is knowledge around the river produced? Documented? Disseminated? Utilized? What constitutes ‘river knowledge’ – it can be disciplinary, scientific, situated, spiritual, hybrid, etc… not all knowledges can be integrated or considered compatible (Cartwright 1999).

***Environmental and ecological dimensions***

**Hydro-meteorological processes:** The basic biophysics driving surface water characteristics, e.g. patterns of rainfall, seasonal and diurnal temperature fluctuations, radiative balance, position in relation to large patterns of atmospheric and oceanic circulation.

**Hydro-geomorphological processes**: How climatological factors are translated into drainage network characteristics, can also be profoundly altered by ecological agents (e.g. beavers, riparian vegetation, bank dwelling animals). These often determines where water ends up and how it travels over and through land, as well as why rivers take the form they do in relation to landforms and infrastructures. Can be fundamentally altered by land use, by altering basin level sediment flux and runoff dynamics (e.g. rainfall runoff response of different land uses – also see ‘Urban Stream Syndrome’ – Walsh et al. 2005). Also highly influenced by regulating infrastructures, such as dams, which by curtailing high flows and lowering base flows can dramatically increase channel incision.

**Ecological Structure and Function:** How terrestrial-riverine and wetland ecosystems are related to one another – can also include subsidies from marine systems from birds and migratory fishes. Generally tracking the flow of nutrients and energy through different trophic levels, but also takes into account differences in functional traits of species. Includes the impact of ecological engineers, who can shape trophic structure without directly participating in food web interactions (e.g. by building habitat). Ecological engineering can be conceived as occurring along a gradient of intention (e.g. beaver ponds vs fallen trees creating large woody debris affecting channel morphology).

***Technological dimensions***

**Hydraulic infrastructures:** Human built infrastructures requiring and managing water. These can be thought of as those controlling water flows, like dams, levees, stormwater management structures), those distributing water both for supply and for managing excess, like irrigation canals, water supply pipes, or stormwater and sewer systems, those related to water treatment both on the supply and waste side, and those enabling utilization – like those incorporating water into power generation facilities, food processing, manufacturing etc…. All of these require different forms of human capacity and expertise, often housed in particular institutions like government agencies or special purpose entities (like irrigation districts).

**Technologies of representation:** Include methods of generating, collecting, storing, distributing, and analyzing data, as well as ways of modeling and creating visual or other types of media). Often have a strong connection to the technologies of managing water, and many are specifically built for that purpose (e.g. USGS stream gauges integrated into flood prediction models which in turn influence dam operations). These are often based upon physical sciences, but also include film, photograph, and written narratives or other depictions of rivers used to convey a particular experience or advocate for a particular relationship with rivers.

**Indirect technological interactions**: These include all the diffuse technologies that people use that have an impact on rivers even if they weren’t designed or intended to, like plastic trash, industrial contaminants, lawn chemicals, global atmospheric pollution (e.g. mercury in North American fish from jet stream deposition of Chinese coal combustion), or road runoff. Often there is some attempt to regulate these through other infrastructural means (like treating stormwater flows).

The above dimensions are not completely comprehensive, they are a starting point and a simplification of the complex human relationship with water and rivers. A key element of treating rivers as co-produced and complex SETS is understanding that rivers are formed through relationship – as Indigenous Mohawk Scholar Elizabeth Hoover points out – ‘the river is in us’ (Hoover 2011). Hopefully by now it is obvious that by having a broad framing of how rivers are shaped and represented by humans allows us to think about what forces most actively cause river issues.

***Applying a SETS framework of Rivers in the Field***

The lived experience of being on, around, and in rivers is invaluable for understanding them. Rivers are not abstractions, nor can they be known solely through desk work, lectures, or literature review. Those various avenues of learning all depend on different technologies of representation, in the field, you get to use your senses and your own experience of the river to better understand what those representations are trying to represent. Other field exercises you have been exposed to introduce one or several dimensions of rivers as SETS. The purpose of this module is to get you to collaboratively integrate these different forms of knowledge in a creative problem-solution framing exercise with other students, instructors, and potentially other members of the river community. Overall, the goal of this SETS exercise to is to expand your thinking on how the river came to be the way that it is, which will be focused around the following questions (all of which will be expanded upon in the lesson content and procedure).

***Formative Assessment Questions to be completed prior to the field lesson:***

In the field we can use SETS as a heuristic to ask, ‘why is the river the way it is? Using a series of integrative SETS questions (note each one of these has S-E-T domains embedded within it):

What direct human interactions can we see with the river?

What infrastructures are visible from the river that affect its structure and function?

What land uses require the river? (e.g. mills, power plants, irrigation withdrawals, etc…)

What are the values of different river user communities? (e.g. what do people enjoy/find useful about this river? What do you find valuable about it?)

Do uses and values conflict or align with each other?

What land uses affect river conditions? (e.g. agricultural and urban runoff, residential development, industrial uses)

What ‘problems’ or ‘issues’ is the river facing? How are these defined? By whom?

What are causes of those problems? Are they primarily ‘social?’ ‘environmental?’ ‘technological?’ some combination of two or more factors?

Where could we intervene in the SETS to address those root causes? (e.g. policies on land use and infrastructure, public outreach to raise awareness / build relationships between different river communities).

As you look at the river through the SETS lens, see what answers you can come up with to the above questions, and come prepared to discuss with your classmates and instructors in order to formulate creative solutions to river challenges.

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