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Social-ecological feedbacks lead to unsustainable lock-in in an inland fishery

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ABSTRACT

This interdisciplinary paper presents an empirical analysis of techno-institutional lock-in in a regional fishery, in the Logone floodplain in the Far North Region of Cameroon. In the Logone floodplain, one fishing technique is spreading exponentially even though it is changing the social, hydrological and ecological dynamics of the system in ways that are largely considered problematic by local communities. We use a complex systems framework to analyze large hydrological and socio-economic datasets. Results show how social-ecological feedbacks foster the spread of the technique and contribute to the process of lock-in. The lock-in leads to a resistance to change despite awareness of the technique's impact, a situation that may also be described as a social-ecological trap. We identify and explain four kinds of positive feedback loops relating to socio-economic, behavioral, demographic and hydrological processes, respectively. We also identify possible solutions that consider the complexity of the feedback loops across multiple dimensions of the floodplain system.

1. Introduction

1.1. Theoretical framework

Governing common-pool natural resources requires understanding how social and natural processes interact. This research agenda has been pursued across various academic disciplines, and relatively recently in an integrated manner under the research umbrellas of social-ecological systems, and coupled human and natural systems. A community in its environment may be conceptualized as a social-ecological system because it is the interplay of social and ecological processes that drives system dynamics (e.g., Carpenter et al., 2009). A coupled system framework (e.g., Liu et al., 2007) emphasizes the bidirectional nature of these social-ecological interactions: for example, a community may use various practices and technologies to exploit

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natural resources, practices that can in turn change the natural processes that produce the resources they exploit.

Common-pool natural resource systems like fisheries, or global commons like the Earth's atmosphere, are complex social-ecological systems that can exhibit nonlinear transitions leading to abrupt or slow shifts between different regimes of system structure and function (Hughes et al., 2013). They may be studied using tools and concepts from the rapidly developing science of complexity (e.g. Moritz et al., 2013) to identify and analyze feedbacks between social and ecological processes (Liu et al., 2007; Carpenter et al., 2009). Unforeseen nonlinear transitions in social-ecological systems, such as collapse or saturation, and how to maintain or increase system resilience to avoid them, have also been foci of the common-pool resources literature (Ostrom, 1990; Folke et al., 2004; Stern, 2011). This paper draws on the intersection of these lines of research, with the premise that while scale and complexity are important factors when analyzing common-pool resource systems, some lessons can be drawn across them (Stern, 2011).

We are especially concerned with social-ecological systems in which a changing environment is associated with inertia in the social system. By social inertia, we mean a situation where there is awareness in the community to be contributing to environmental change in ways that are damaging overall system resilience (the capacity of the system to maintain its functions in a changing environment), but where this acknowledgement does not lead to individual or collective action to change relevant practices. A mismatch between a fast-changing environment and a social system that is slow to respond characterizes many social-ecological systems, and has been described as the consequence of various feedbacks leading to a state of "lock" (Scheffer and Westley, 2007). When these feedbacks push the social-ecological system towards an undesirable state, the situation has been called "social-ecological trap" (e.g. Cinner, 2011). Social-ecological traps are path-dependent processes (Boonstra and de Boer, 2014) that can lead to system overshoot (Scheffer et al., 2003) and the crossing of thresholds resulting in nonlinear transitions (Steneck et al., 2011; Rockström et al., 2009). A global and current example of such a trap is the apparent paradox of the continued increase of anthropogenic CO_2 in the Earth's atmosphere and the social, political and institutional inertia to shift away from fossil fuel energy production: feedbacks between social and ecological processes have led to a resilient yet undesirable state. The process leading to this trap has been called the "carbon lock-in" in the ecological economics literature, as a case of techno-institutional lock-in (Unruh, 2000).

Techno-institutional lock-in is a specific form of a collective action problem that characterizes the path-dependent co-evolution of social networks of users and institutions around a practice or technology, even as it is considered suboptimal (Arthur, 1989). More specifically, it describes a situation in which a technology remains dominant because institutions have adjusted to it, and the benefits of switching are not perceived to outweigh the costs for individuals even though they would collectively benefit from a switch (Perkins, 2003). In the example of the carbon lock-in, the combustion of fossil fuels has become the dominant form of energy production, while also shaping socio-economic life and habits since the industrial revolution. With time, this co-evolution has led to the dominance of a technology that is today known to be problematic in social-ecological terms, because of global warming. Another example is that of insecticide spraying to limit plant-hopper infestation in rice cultivation, a practice that has been shown to increase the rice crop's vulnerability to pests, leading to more spraying in a feedback loop (Spangenberg et al., 2015). In other words, techno-institutional lock-in is a situation where the social system has become rooted in practices and institutions, in relation to a technology, which are making it slow to adapt to change in its environment – change to which the technology is contributing (Unruh, 2000).

The concept of lock-in has roots in complexity economics. Positive socio-economic feedback loops have been associated with lock-in processes, in particular: social learning, adaptive expectations and network effects (Arthur, 1994). First, the more a technology is ubiquitous, the easier it is to access the knowledge to operate it. This creates a positive learning feedback towards the adoption and use of that technology. Second, confidence in the technology increases with increased adoption, which also fosters early adoption and lock-in. Finally, lock-in has been associated with dynamic complementarities or network effects (Maréchal, 2007): interrelated activities and socio-economic fluxes that reinforce the institutionalization of the technology. In relation to the 'carbon lock-in', one may think for example of the co-development of the road network and the automobile industry (Unruh, 2000).

In this paper, we use the concept of lock-in to analyze the mechanisms leading to a social-ecological trap as it unfolds in a regional social-ecological system: the Logone floodplain fishery, in the Far North Region of Cameroon. We start by introducing the case study of the Logone floodplain fishery. Second, we describe the methods used for the analysis underpinning this paper, including field surveys, satellite imagery, household surveys and ethnographic research. We then present an analysis of four feedbacks contributing to lock-in in the fishery: demographic, environmental, socio-economic and behavioral feedbacks, and their consequences. Finally, we discuss the theoretical and practical implications of our findings, for our case study and for social-ecological systems in general.

1.2. Research context

The Logone floodplain is located in the Lake Chad basin where hydrology, ecology and human livelihoods are tightly interdependent (Béné et al., 2003a; Scholte 2005). The floodplain on the Cameroonian side is populated by about 200,000 people, with large seasonal variations as some people follow fluctuations in resource availability, such as forage for pastoralists and migrating fish for some Musgum and Kotoko fishers (Delclaux et al., 2010). Every year the floodplain is inundated by water from the Logone River. This occurs at the end of the rainy season, with the peak flood in October. The floodwaters then recede between November and January (Fig. 1), leaving first a number of flooded depressions, and then a dry floodplain (Seignobos and Iyebi-Mandjek, 2000). The area and timing of flooding and flood recession vary annually with climatic and river discharge conditions.

The seasonal patterns of flooding and flood recession drive the vegetation and fish productivity, on which mobile pastoralists, small-scale rice farmers and fishers directly depend. Two transitions in flooding regimes were documented in the recent past as combined effects of climatic trends and hydro-engineering interventions. First, a large dam (the Maga Dam, Fig. 1) was built in 1979 on the Logone River, limiting flooding and negatively impacting vegetation and fish biomass in the downstream floodplain (Scholte, 2005). The dam construction coincided with a period of below-average rainfall in the 1970s and 1980s, a long drought that further reduced seasonal flooding of the plain and impacted the whole region (Hulme, 2001). The second shift occurred in the mid-1990s, with the implementation of a re-flooding program via the engineered opening of two waterways into the floodplain to mitigate the effects of the dam (Loth and Acreman, 2004). Around the same period, regional rainfall also recovered to average values (Delclaux et al., 2010). These past transitions in flooding regimes evidence that the system can shift from one dynamic state (large flooded plain) to another (reduced