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Mapping social-ecological systems to understand the challenges underlying wildlife management

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ABSTRACT

A holistic understanding of the complex interactions between humans, wildlife, and habitats is essential for the design of sustainable wildlife policies. This challenging task requires innovative and interdisciplinary research approaches. Using the newly implemented ecosystem-based management of moose (*Alces alces*) in Sweden as a case, we applied Ostrom's social-ecological system (SES) framework to analyse the challenges that wildlife management faces throughout the country. We combined data derived from natural and social science research to operationalize the framework in a quantitative way; an approach that enabled a spatially explicit analysis on the national and regional levels. This study aimed to discover patterns in the social-ecological context of Swedish moose management. Identifying these patterns can provide input for an in-depth evaluation of the institutional fit of the current system and subsequently for national policy development. Our SES maps suggest that there are spatial variations in factors challenging moose management. In some areas, ecological aspects such as the co-occurrence of carnivores and other ungulate species burdens future management, while in other regions challenges are shaped by governance aspects, e.g. diverse property rights. These findings demonstrate that the new management system must apply adaptive learning principles to respond to local context attributes in order to be successful. Our innovative approach provides a valuable tool for the assessment of other natural resource management issues and the avoidance of panacea traps, especially when repeated over time.

1. Introduction

Managing wildlife (i.e. the processes of dealing with or controlling wildlife for different purposes) in a sustainable way is a key challenge around the globe. To balance societal needs and ecological functions, the complex interactions between humans, wildlife, and habitats must be fully understood (Apollonio et al., 2017). Previously, our understanding of these relationships was limited by the disciplinary boundaries that restricted complex analyses (Berkes et al., 2008; Liu et al., 2007; Ostrom, 2009; Schlüter et al., 2014). To bridge the gap between social and ecological sciences research and to foster a holistic understanding of how humans interact with the surrounding ecosystem, a number of frameworks, e.g. social-ecological systems (SES) and human-environment systems (HES), have been developed (Binder et al., 2013). These analytical frameworks aim to avoid the tendency of prescribing certain governance solutions or policy instruments as a panacea for environmental conflicts (Brock and Carpenter, 2007; Ostrom et al., 2007). The use of such one-size-fits-all approaches as a simple solution to complex issues has been highly unsuccessful (Cox, 2011; Ostrom et al., 2007). It includes the obvious risk of falling into panacea traps due to incorrect assumptions; notably that all resource governance problems can be represented by a small set of simple models and that most resource users have the same preferences and perceptions (del Mar Delgado-Serrano and Ramos, 2015; Ostrom, 2007; Ostrom et al., 2007).

Previous research has highlighted that sustainable management of natural resources depends on a thorough diagnostic procedure, which produces a holistic understanding of the system and assists the design of suitable policies (Cox, 2011; Ostrom, 2007; Schlüter et al., 2014; Young, 2011). A misfit between social institutions (i.e. rules and norms) and ecological attributes can lead to conflicts and the unsustainable use of resources (Cumming et al., 2006; Folke et al., 2007; Leslie et al., 2015; Ostrom, 2009). Thus, the unique attributes of SES must be understood and considered in order to find the best policy solutions (Brock and Carpenter, 2007; Folke et al., 2007; Ostrom, 2009). Moreover, the policies that set the objectives and institutions should not be static, but

Abbreviations: SES, social-ecological system; I, interactions; A, actors; GS, governance system; RS, resource system; RU, recourse units; MMA, moose management areas; MMU, moose management units; PCA, principal component analysis

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rather adapt over time and diversify according to different spatial scales when needed (Brock and Carpenter, 2007; Olsson et al., 2007). Regional and local adaptations may be necessary to maximize adaptive capacity and ensure resilience within the framework of national policies (Berkes et al., 2008; Liu et al., 2007).

However, policies are often designed on an overarching and national perspective to enhance uniform solutions that promote predictability and rule of law, which might leave little or no room for local variation or flexibility (Ebbesson, 2010). This poses a dilemma from a sustainability perspective, as these types of policies include a prominent risk of creating a misfit between social institutions and ecological attributes, which will undermine the long-term governability and resilience of the system (Galaz et al., 2008; Young, 2011). This risk of a misfit further increases when the system changes over time. In the case of wildlife management temporal changes can likely happen due to increasing and/or spreading wildlife populations. Thus, any policy or institution that is designed to manage natural resources, such as wildlife, must include the capacity to handle diverse and changing ecological systems (Galaz et al., 2008; Levin et al., 2012; Young, 2011). Still most management strategies focus on a single natural resource and specific groups of users instead of adopting a system perspective. This overlooks the fact that most SES are complex, since the same resource system may contain several resources that compete with each other and are of varying importance to certain stakeholders (Dwyer and Hodge, 2016; Hinkel et al., 2015). One classic example of such a system are forest ecosystems that host valuable timber resources for forestry stakeholders, game species that are cherished by hunters, and a recreational value for the public. Hence, the governance model for forest ecosystems should include policies and a mix of policy instruments that may contribute to the sustainable use of all competing resources and take different objectives into consideration. However, forest governance models rarely do so. For example, the Swedish forestry model has been struggling with the task of balancing the diverse policy objectives due, among other things, to the lack of a system perspective (Lindahl et al., 2015).

Being linked to the forest ecosystem Swedish moose (*Alces alces*) management is an example of a continuous strive to adjust and adapt to changes in the moose population and environment. Sweden has one of the world's densest moose populations, but this was not always the case (Kardell, 2016). Both the population and corresponding management approaches have undergone major changes during the past century (Edenius et al., 2002; Sandström et al., 2013). Rationalization in agricultural practices in combination with the shift in forestry from single tree harvesting to large-scale clear cutting have opened up the forest structure and created large areas of land that provide moose with a suitable diet and habitat (Edenius et al., 2011; Kardell, 2016). This led to a rapid increase in the moose population and heavy browsing on certain tree species, causing not only economic losses for forest owners but also threatening the natural regeneration of these species and thereby biodiversity (Ericsson et al., 2001; Jaren et al., 2003). The previous management attempts were criticized for not being able to handle increasing conflicts, creating a mismatch between ecological and social scales, and disregarding the importance of a system perspective (Sandström et al., 2013).

Thus, as a response to increasing browsing pressure and conflicts among stakeholders (Sandström et al., 2013), Sweden established a local, ecosystem-based management system for moose in 2012 (Prop. 2009/10:239, NFS 2011:7; for more information see Appendix A. Detailed description of the current moose management system). Following the Malawi principles for the ecosystem approach (UNEP/CBD/COP/4/INF/9; Jaren et al., 2003), its central components are decentralization of decision-making to local levels, the involvement of relevant actors to find a balance between different societal interests, as well as adaptive and knowledge-based management. A range of structures and institutions had to be created at various levels before the new system could take effect. For example, so-called moose management areas (MMA) were established, with each area comprising a distinct moose population and requiring that the local landowner and hunter representatives come to an agreement about management plans and population goals (Bjärstig et al., 2014). These changes led to the introduction of a more comprehensive multi-level governance system, which aims to create a better match between social and ecological aspects.

The new ecosystem-based approach is therefore a promising starting point, but to be sustainable in the long run the management system must be carefully adapted to the local ecological and social circumstances. For this reason, the present study aims to analyse the spatial patterns in social and ecological attributes that the newly designed institutions have to accommodate.

We use the SES framework developed by Ostrom and colleagues (McGinnis and Ostrom, 2014; Ostrom, 2007, 2009) for our diagnostic procedure and apply it in a quantitative and spatially explicit way. The framework enables the integration of social and ecological aspects with equal analytical depth, multi-layered diagnostic procedures of a system and flexibility in choosing relevant variables (Binder et al., 2013; del Mar Delgado-Serrano and Ramos, 2015). As it is derived from the Institutional analysis and development (IAD) framework, the SES framework contains action situations in which interactions lead to certain outcomes in terms of sustainability (McGinnis and Ostrom, 2014). Interactions (I) and social-ecological performance (outcomes, O) are directly shaped by involved actors (A), the governance system (GS) in place, the ecological resource system (RS) and attributes of the natural recourse units (RU), with each of these components providing feedback to the others (McGinnis and Ostrom, 2014).

So far, studies focused mainly on the action situation and took the system context less into consideration. Most attempts to operationalize the SES framework in a comparative way have either been rather descriptive in nature, limited in scale (with a primary focus on the local scale), or restricted in the choice and operationalization of variables (del Mar Delgado-Serrano and Ramos, 2015; Hamann et al., 2015; Leslie et al., 2015; Thiel et al., 2015). These restrictions limit the transferability of case study results to different systems. In contrast, we focus on the social-ecological context in which the action situations take place. Furthermore, the system presented in this paper offers the possibility to apply the SES framework across a whole country, based on high-quality quantitative data derived from ecological monitoring, GIS or nationwide surveys on human-nature interactions. The variables within the SES framework have proven to play an important role in predicting outcome in terms of sustainability and therefore provide a clear picture of social and ecological attributes that the governance system has to acknowledge (Hinkel et al., 2015; Ostrom et al., 2007).

Consequently, we apply the SES framework to examine the current social-ecological context for moose management in Sweden to provide input for in-depth evaluations of the institutional fit of the current system as well as further studies on action situations. We use an interdisciplinary approach to map spatial variations in the SES, which has rarely been done before (Hamann et al., 2015). Thus, the objectives of our study were to elucidate spatial variations in relevant context variables, which can provide a tool for national policy development and show a type of SES mapping that can be applied to other systems. In this way we respond to the recent call to use the framework to reach a place-based understanding of SES and contribute to the development of new methodological approaches for applying the framework in practice (Hamann et al., 2015; Karimi et al., 2015; Leslie et al., 2015).

2. Methods

2.1. Variable selection

The starting point for the diagnostic approach was the framework for analysing SES proposed by Ellinor Ostrom and colleagues (McGinnis and Ostrom, 2014; Ostrom, 2007, 2009). We used elements of an adapted version of the framework proposed by Vogt et al. (2015), to