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Using qualitative models to define sustainable management for the commons in data poor conditions

Francesca Mancini[a,*], George M. Coghill[b], David Lusseau[a]

[a] Institute of Biological and Environmental Sciences, University of Aberdeen, Zoology Building, Tillydrone Avenue, Aberdeen AB24 2TZ, UK
[b] Department of Computing Science, University of Aberdeen, Meston Building, Meston Walk, Aberdeen AB24 3UE, UK

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ABSTRACT

Nearly 50 years after Hardin's "tragedy of the commons" we have not yet found predictive tools to guide us towards sustainable management of common-pool resources (CPR). We often have a good understanding of the qualitative relationships between the principal actors in socioecological systems (SESs), but classical quantitative approaches require a tremendous amount of data to understand the drivers of SESs sustainability. Here we show that qualitative modelling approaches can provide important governance insights for SESs that are understood but not quantified.

We used Loop Analysis to test the outcomes of different management regimes on a simple nature-based tourism SES described by economic, social and environmental variables. We tested the sustainability of different management scenarios on this system and we identified the necessary conditions to achieve it.

We found that management regimes where property rights and responsibilities are shared between different stakeholders are more likely to be successful. However, the system is generally highly unstable and it is important to tune each strategy to each particular situation.

The conditions for sustainability found across the different systems tested were: a low reinvestment rate of tourist revenues into new infrastructures and a low growth rate of the environment. Management strategies based on maximum sustainable yield, which keep the environment far from its carrying capacity, have less chance to be sustainable.

Qualitative models of SESs are powerful diagnostic tools; they can help identifying variables that play an important role in determining socioecological sustainability in data-poor circumstances and guide the design of efficient data collection programmes. Our results highlight the importance of careful planning when designing management strategies for nature-based tourism. The application of one-size-fits-all solutions to every situation is likely to lead to the failure of the commons; however tourism-based SESs can be sustainable if management strategies are tuned to each particular case.

1. Introduction

Natural resources are usually considered common-pool resources (CPRs): it is usually impossible or very costly to exclude individuals from using them and their use by one user reduces the quantity or the quality available to other users (Ostrom et al., 1999). There are two main approaches to dealing with the "commons dilemma". The "panacea" approach applies simplified and general models to all situations. Advocates of this approach propose one particular governance structure as the only possible solution to the tragedy of the commons (Hardin, 1968). The other approach consists in deriving from empirical case studies the characteristics that enable sustainable governance (Ostrom, 1990). The first approach does not recognise the importance of the particular circumstances that characterise each different situation (Ostrom et al., 2007), while the second has to deal with all the issues associated with obtaining observations and data from these complex socioecological systems (SESs) (Hilborn and Ludwig, 1993). As a consequence of the limitations of these approaches, attempts to manage CPRs have often failed (Acheson, 2006).

Commons and their users form SESs, which are composed of different, relatively separable, subsystems that interact in a complex and, sometimes, unknown way (Ostrom, 2009). The

* Corresponding author at: Room 418, Zoology Building, Tillydrone Avenue, Aberdeen AB24 2TZ, UK.
E-mail address: r03fm14@abdn.ac.uk (F. Mancini).

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inherent complexity of SESs requires an integrated approach to predict the outcomes of management strategies (Ostrom, 2007). However, we do not yet have analytical tools to accurately predict these outcomes (Agrawal, 2014), especially in data-poor circumstances. These systems are difficult to study empirically, because the scope for experimental work is limited and replication, control and randomisation are difficult to achieve (Hilborn and Ludwig, 1993). Therefore, a simulation approach could offer insights on the outcomes of different management regimes. However, little is known about the relationships between the ecological and socio-economic components of these systems and, often, we cannot quantify important variables in the model. Qualitative approaches have proven advantageous to model complex systems in data-poor circumstances (Metcalf et al., 2014).

Recreation is one of the cultural ecosystem services that the environment provides. Tourism is often a primary income for local communities, it can dominate national economies and play a key role in nations' macroeconomics (O'Connor et al., 2009). While nature-based tourism has been welcomed by conservation and environmental organisations as an eco-friendly alternative to other consumptive activities, such as hunting and fishing (Tisdell and Wilson, 2002), there is growing evidence that nature-based tourism, if not managed properly, can have negative effects on the environment (Meletis and Campbell, 2007; Pirotta and Lusseau, 2015). Therefore, the issue of managing nature-based tourism becomes a CPR issue.

In this study, we tested the sustainability of management regimes on qualitative representations of nature-based tourism SESs using Loop Analysis (Puccia and Levins, 1985). SESs are subjected to press-pulse dynamics (Collins et al., 2011) and in order to understand what drives their sustainability we need to investigate their responses to both press and pulse perturbations. Pulse perturbations are sudden events, such as droughts or fire, which rapidly alter the state of the system, while press perturbations are sustained and slow, such as climate change or economic growth. A pulse event temporarily "shakes" the system, while a press disturbance slowly pushes it away from its current state. We define sustainability in terms of responses of the SES to pulse and press perturbations. For each different management strategy applied to a simple nature-based tourism system we asked three questions: 1) Does the system's equilibrium lose stability after a pulse perturbation? Stability is the ability of a system to return to its previous state after a perturbation. A stable system offers more predictability and reliability of management interventions, because it is less likely to shift to a different state after a sudden event. We assessed this property of the system using qualitative stability criteria. 2) Under which conditions could the system remain stable? A sensitivity analysis of the stability criteria can identify the key drivers of system's stability, in other words, which components of the system could be modified to shift the system from being dysfunctional and unstable to being functional and reliable. 3) How does the system behave after a press perturbation? For example, during the development of a nature-based tourism destination, how will the different components of this system respond to an increase in the number of tourists using the area? If this positive press perturbation does not result in environmental degradation, or a reduction in the number of users or in the tourism capital, then the SES can maintain environmental quality, social justice and economic profitability, in other words, triple bottom line (TBL) sustainability (Elkington, 1998). In this study, social justice is intended as access to the resource by the community of users: if responses to press perturbations predict that some users will be excluded from the resource we considered the system to be unjust. For a system to be sustainable it needs to be stable to pulse perturbations and have potential to keep TBL sustainability in presence of a press disturbance in any of its components.

2. Materials and methods

2.1. Property rights scenarios

In the resource management literature property is mainly considered as owned or affected by private individuals, local communities or governments (Acheson, 2006; Hoffmann, 2013). In this study we consider an open access scenario in which there are no rules governing property rights, and scenarios where property rights are owned by a central authority or the local community of users. In order to represent both marine and terrestrial systems, we do not consider private property, which is often not possible in a marine context where boundaries are difficult to define and wildlife is highly mobile. Some studies have highlighted the importance of nesting and institutional variety in governance structures (Dietz et al., 2003), showing how mixed strategies can determine the success of CPRs (Pirotta and Lusseau, 2015). Following these studies we considered hybrid scenarios, where property rights are shared between the users and a third party. Within these property rights regimes we also considered different management tools.

The scenarios are represented as signed digraphs (Fig. 1). The nodes represent the variables in the system. The links connecting the nodes represent the qualitative relationships between the variables. Positive relationships (an increase in the first variable produces an increase in the abundance of the second variable) are represented by links with an arrow-end, while the links with a circle-end represent negative relationships. Links that start and end on the same variable are called self-effects, and they represent

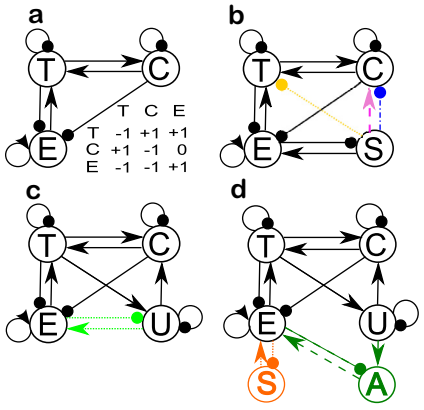

Fig. 1. Signed digraph of all the scenarios tested. The nodes represent the variables in the model. T: tourists; C: capital; E: environment; S: state intervention; U: users; A: external agency. The links connecting the nodes represent the relationships between the variables: arrow-ended links indicate positive relationships, circle-ended links represent negative relationships. The links starting and terminating on the same variable represent self-effects. a) Signed digraph of the open access scenario and its matrix representation. Each entry in the matrix corresponds to a link in the graph. b) State ownership scenarios. The pink (dashed), blue (dash-dotted) and yellow (dotted) links represent the three alternative scenarios, respectively, subsidies, licencing and access fee. c) User group ownership scenarios. The first scenario is represented by the black links, while the second scenario includes the green dotted links representing the adaptive management of the environment. d) Hybrid scenarios. In the first scenario the government intervenes to monitor and manage environmental quality (orange dotted lines), in the second one users invest in an external agency to monitor and manage environmental quality (green dashed lines). For detailed description of the models see text. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)