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Advancing understanding of natural resource governance: a post-Ostrom research agenda

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Abstract

Institutions are vital to the sustainability of social-ecological systems, balancing individual and group interests and coordinating responses to change. Ecological decline and social conflict in many places, however, indicate that our understanding and fostering of effective institutions for natural resource management is still lacking. We assess theoretical and methodological challenges facing positivist institutional analysis, focusing on natural resource governance according to Ostrom's social-ecological systems (SES) framework. Rather than adding more variables, progress requires a clearer, more consistent approach to selecting, defining and measuring institutional elements; stronger links between theory and empirical research; a greater focus on mechanisms and causality; and the development and application of new methods, including quantitative approaches. Strengthening the connections between theory, models, and data suggests several promising avenues for advancing institutional analysis through the study of relationships between institutional structure, process, function, context, and outcomes.

Introduction

In our current context of global environmental change [1], the need for effective institutions (i.e., formal laws, rules, norms and customs [2]) to moderate human impacts, through environmental governance and management, has never been greater. Institutions are essential to coordinate resource use across different jurisdictions, resolve trade-offs between individual and group interests, and allocate benefits and costs among actors [3-5]. While there are many approaches to institutional analysis and design (e.g., [6-9]), and some are incompatible with the perspective we adopt here, the strongest influence on environmental sustainability science has been the 'Bloomington School' [10], and particularly Ostrom's IAD (Institutional Analysis and Design) and Social-Ecological Systems (SES) frameworks [11-14].

Despite its widespread use in environmental science, the application of the IAD/SES framework is limited by a set of theoretical and methodological challenges. Although research into environmental governance has identified many institutional characteristics and arrangements (or subsets thereof) that have proven effective at different scales [15-17], successful models of governance are often difficult to transfer across environmental issues, contexts or scales [18,19], suggesting that we do not fully understand how models of governance must change with context and scale. We first provide a short critique and then focus on challenges and new directions, proposing a post-Ostrom agenda for institutional research on natural resource governance as the study of the relationships between institutional structure, process, function, context, and outcomes (Box 1).

A Critique of Institutional Analysis in Social-Ecological Systems and Environmental Science

Institutional analysis is central to understanding the management and governance of natural resources [3]. Institutional solutions for natural resource governance [20,21] highlight the importance of interactions among a wide range of social, ecological and institutional factors [22], and have contributed to analytical tools for interdisciplinary inquiry and empirical synthesis [11,23]. Theoretical and practical progress in SES analyses of institutions have, however, run into barriers in recent years as scholars have struggled to connect high-level general principles and detailed case studies [24].

The Bloomington School has excelled at identifying salient features of SES governance, resulting in long lists of potentially influential factors; but has struggled to explain why, how, and under which social-ecological conditions specific institutional elements contribute to specific outcomes (as defined in Box 1) for at least three major reasons. First, despite repeated calls for coordination and integration [13,25], inconsistent definitions and measures of the elements in Box 1 continue. The SES framework was designed to address this challenge, but lacks definitions and measures for core concepts [14,26-29]. Further development is also needed in defining and categorising relevant outcomes, the processes and interactions that create them, and trade-offs.

Second, institutional analysis using the IAD and SES frameworks says little about the longer-term processes by which institutions emerge, change, and interact with resource use and management decisions. Ostrom's institutional design principles contribute to sustainable management in certain local contexts [15,30], but the pathways through which they are implemented, the relevance of history and path dependence (Epstein et al., this issue), and the role of embedded agency are poorly understood [31,32]. For example, decentralization programs for community-based management may fail if policymakers, bureaucrats or local elites respond strategically to maintain or enhance their influence over resources [33,34].

Third, institutional analysis using the IAD/SES framework has focused on local communities and resources, often neglecting broader scales (or occasionally, *vice versa*). Institutions at different scales often interact. For example, local depletion of resources can be driven by connections to global markets [35], which can have a range of broader impacts on other ecosystems [36]. Local framings may also ignore cross-scale power dynamics and the relationships between power, efficiency, sustainability, and effectiveness [37]. While the

notion of polycentric governance [38] formally recognizes the existence of multiple interdependent centers of decision-making, it has traditionally suffered from many of the same methodological challenges as institutional analysis [39,40].
Key theoretical and methodological challenges relate to (1) specification (i.e., consistently describing, measuring, and relating the elements of institutional analysis across different studies and disciplines); and (2) causal relations (mechanisms) by which institutional elements of SESs influence outcomes over time.

Theoretical Challenges for Institutional Analysis of Social-Ecological Systems

Specification

Applications of Ostrom's SES framework generally take an *ad hoc* approach to selecting and defining variables, resulting in limited overlap between studies. Differences in measurement, terminology and definitions, and a lack of precision in concepts, measurements, and theory, threaten the validity of attempts to compare, contrast, or synthesize findings between studies [41].

A particularly important challenge is to define and measure environmental governance systems, which are heterarchies that incorporate elements of both networks and hierarchies [42,43]. Although they include a wide range of actors, networks, power relations, and tasks (e.g. rulemaking, monitoring, and maintenance), comparative empirical studies usually rely on binary measures of environmental governance, such as community vs. government-owned forests or presence/absence of local autonomy in making rules [44,45]. This can result in the grouping of vastly different models. For instance, local autonomy in rulemaking might encompass decisions made by a single community or a group of communities in a system of nested governance; communities operating independently of other stakeholders; and communities that receive significant support from external partners.

Although a more precise understanding of relational structure is developing through network analysis [46], systematic coding of the attributes of institutional statements (i.e. formal and informal rules, norms and strategies) using the institutional grammar tool [47] and mapping of power relations [48], important gaps remain.

Second, while many theories of governance exist [49], few are specific enough to permit robust empirical tests or quantitative formalization. Both abstract theories about institutions and context-specific hypotheses derived from local case studies can be difficult to empirically operationalize and falsify [50]. For instance, institutional theory often highlights the importance of institutional fit, or matching institutions to the problems they are meant to address [51-53]. However, few theories explicitly identify the combinations of social and/or ecological conditions and the elements of institutions (Box 1) that give rise to fit.

Causal relations and dynamics

Institutional theory analyzes the outcomes of institutions, but there is a growing demand for an improved theoretical understanding of the processes by which institutions emerge, change, and influence environmental outcomes [54]. The SES literature focuses on explaining system states and resource robustness (with exceptions; [3,55]), while feedback loops, historical influences, and changes in dynamics of power, culture, and beliefs that provide a broader social context often receive limited attention [48,56]. The same is true of the responses of institutional structures to ecological dynamics and uncertainty.

Second, additional challenges are raised by theories that endogenize the development of institutions. Environmental governance can involve many decision-making venues [5,57], tasks (e.g., enforcement, conflict resolution, environmental monitoring [58]), and competing interests [59], that interact with biophysical processes as well as technological expertise [29,60]. Three possible entry points into endogenizing the dynamics of these environmental governance components include (i) the ecology of games, (ii) the network of action situations, and (iii) social-ecological network analysis.

The ecology of games framework [5,61] focuses on the structure, function and process of complex (e.g. polycentric) environmental governance. It has contributed to understanding decision-making, as well as the potential implications of participants, institutions and network structures for coordination and cooperation [62]. Nonetheless, by focusing on collective decision-making in multiple venues, the ecology of games framework typically does not clarify or trace the processes by which collective-choice decisions influence implementation and resource use.

The network of action situations approach [63] has been used to follow institutions from their development to their outcomes [54,64]. It has promise for understanding feedbacks and other dynamic elements of institutional change, but generally neglects the diversity of venues in which decisions are made, venue specialization around particular functions or action situations, and biophysical processes.

Social-ecological network analysis shows promise for understanding the implications of biophysical processes (e.g. fragmentation, dispersal) for environmental governance systems [65,66]; but the ways in which links are conceptualized typically vary across study systems, and ecological and/or social processes are often simplified, resulting in a loss of information about human-biophysical interactions [67]. In addition, although networks provide a context for an institution, the geographic and economic contexts of individual nodes and entire networks (e.g., location on an environmental gradient) are often ignored or hard to integrate. Network studies in SES research often lack a well-developed structure-function theory with associated methodology, making rigorous hypothesis development and testing difficult.

In sum, social-ecological outcomes emerge from the interplay of a wide range of processes [11]. These include (i) social processes by which actors interact (e.g. rulemaking, enforcement and conflict resolution); (ii) biophysical processes involving interactions among the natural and built components of ecosystems (e.g. predation, water flows through canals); and (iii) two-way, social-ecological interactions between actors and the natural and built environment (e.g. appropriation, monitoring, maintenance, recreation; [23]) over multiple spatial and temporal scales. While many of these processes are well-recognized in Ostrom's IAD/SES frameworks and related SES approaches, others (e.g., predation, ecological competition, non-extractive SES interactions) are not; and we lack a contextual understanding of their inter-relationships. Lessons learned in other fields (e.g., epidemiology, physics) suggest that a stronger interaction between empirical data and models may result in faster progress.

Methodological challenges for institutional analysis of Social-Ecological Systems

Specification

Differences in conceptualising and measuring institutions frequently result in incommensurable data, leaving findings open to interpretation and argument. Better coordination between researchers and the adoption of formal approaches, such as ontological databases designed for knowledge sharing and re-use, would facilitate translation and synthesis of case studies from different conceptual settings [68]; but three additional problems arise.

First, system structure is often weakly defined or undefined. Methods are needed to clearly define system boundaries and the relative placement of different actors in *heterarchical* systems of governance, including weak and informal ties that may nonetheless be vital during times of change or reorganisation [69]. Defining and bounding the study system explicitly facilitates definition of ‘context’, and its role in constraining or confounding the relationships between institutional structure, process, function, and outcomes.

Second, institutional analysis often involves both aggregation and selection; the subjectivity of current approaches for aggregating and selecting study elements contributes further to our inability to compare between studies. And third, we lack rigorous approaches for measuring and comparing the roles of formal and informal rules (*de jure* vs. *de facto*). Promising quantitative approaches include multilevel networks, which consist of two or more separate but interconnected networks [70]; and multiplex/multilayer networks, which can incorporate heterogeneous nodes connected through different types of social and ecological relationships [71] or agent-based models [72].

Causality and dynamics

Institutional analysis in SESs faces practical difficulties (e.g., short-term funding, respondent attrition, career incentives and competition between researchers) in collecting long-term panel data. Ecologists have developed a range of long-term, broad-scale system manipulations and controls, as exemplified by fenceline contrasts, exclusion plots, and fragmentation experiments, to test hypotheses about the ecological components of SESs [73]. Corresponding long-term observations and experiments treating institutions as elements of SESs are needed [74,75], although research on these themes must confront and resolve the ethical challenges of working on human subjects as well as methodological issues related to operating in complex adaptive systems [74]. Top priorities include methods and measurement of fast-changing process-related variables, such as perceptions, attitudes and certain kinds of behaviour [76], as well as environmental outcomes through time (and their interactions with social tradeoffs and outcomes) in a greater diversity of cases.

Second, the lack of a clear understanding of causality in SES institutional analysis makes it difficult to relate heterogeneity in institutional elements to outcomes. For example, greater actor diversity in decision-making may lead to more effective problem-solving, via a mechanism similar to that of natural selection; but tests of this hypothesis are easily confounded by the formal and informal institutions that guide decisions. Methods that can deal more effectively with heterogeneity in SESs are needed.

New Directions and Opportunities for Institutional Research in Social-Ecological Systems

We perceive a strong need in SES research to (1) develop clear, fully specified models of the relationships between different institutional elements (Box 1); (2) use these to generate hypotheses about institutional emergence and influences on SESs; and (3) test such hypotheses systematically with data and models (Fig. 1). Several related avenues of enquiry again seem particularly important.

First, reliable generalisations about populations of cases depend on rigorous measurement. In ecology, which experienced similar problems [77], standard approaches to description and measurement (e.g., Linnaeus's taxonomy; areas of quadrats) were developed by deliberately testing and comparing alternative empirical approaches and their feasibility, cost, and associated errors. For institutions, the equivalent is to combine simulation models, case study data, and experiments (Fig. 2) over time and across levels and scales. One possible entry point for measuring governance systems as continuous entities is the concept of heterarchy, which unifies the perspectives of hierarchy (i.e., top-down or bottom-up controls) and network (i.e., peer-to-peer controls) in a single framework [43]. Analysts could use the heterarchical approach, for example, to compare and evaluate different types of polycentric systems, catering for both hierarchies and networks in a single system [40], and thereby moving beyond normative prescription toward practical insight.

Second, system definitions must be consistent, while coping with change and transformation. At the very least, the analyst must know whether they are still working on the same system after a perturbation, intervention, or regime shift. System identity resides in the spatiotemporal continuity of key system elements and interactions [78]. Social-ecological identity can be measured both qualitatively (e.g., observations of customary practices) and quantitatively (e.g., proportion of community engaged in farming; area of forest) in relation to the subjective or normative goals of an analysis, and tracked through time [79].

Third, modelling approaches for understanding causality have been under-exploited in SES research, particularly in relation to understanding inconsistency in the outcomes resulting from individual institutions. In particular, we propose (i) using a diversity of theory-oriented and empirically-based models more deliberately to develop and test hypotheses; and (ii) clarifying the scope of generalizations by defining populations of relevant cases to which they apply. Theory-oriented or stylized models, which focus on key system components and interactions to develop principles of broad general relevance, are tools for both understanding causality and directing empirical research [80] and have additional value in clarifying concepts, framing potential outcomes and counterfactuals, and improving rigour. In SES research they can, for example, connect social and ecological dynamics via feedbacks [81], or be used to assess how theoretical understandings of human behaviour explain observations [82,83]. Models can and should guide theory testing [84]; while empirical research should generate and assess hypotheses that in turn drive new modelling enquiries. Clarifying the scope of generalisations about SESs means acknowledging that not all case studies will yield the same general conclusions; understanding why; and using this knowledge to build partial theories with bounded applicability. Middle-range theories, which are contextualized generalizations of phenomena [85], may provide the missing link [86] once clarity is attained on which theories relate to a particular question or context [49]. Archetype analysis, another form of mid-range theory, identifies recurrent 'building-blocks' and dynamics that explain outcomes in multiple cases [87] and can help to move beyond analysis of single pairs of variables.

Fourth, consistent use of theories and terminology is vital for comparative research. Few institutional studies explain how frameworks should be used to collect and store data (for an example, see [88]). Key 'necessary developments' include (1) improving practices for writing and publishing social-ecological analyses [41], (2) developing incentives to resolve collective action problems in science, and (3) developing public infrastructure to document and curate SES knowledge [26,89-91].

In summary, institutions are a critical interface between people and ecosystems, and they play a vital role in regulating and directing social-ecological dynamics. Here we call for more effectively formalised methods and theory, and a stronger push to connect structure and process. This research direction can help institutional analysis transcend its current case-based, 'list of variables' approach to achieve much greater levels of generality and a more rigorous understanding of how to design or foster effective, resilient institutions for environmental governance and management.

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Figures

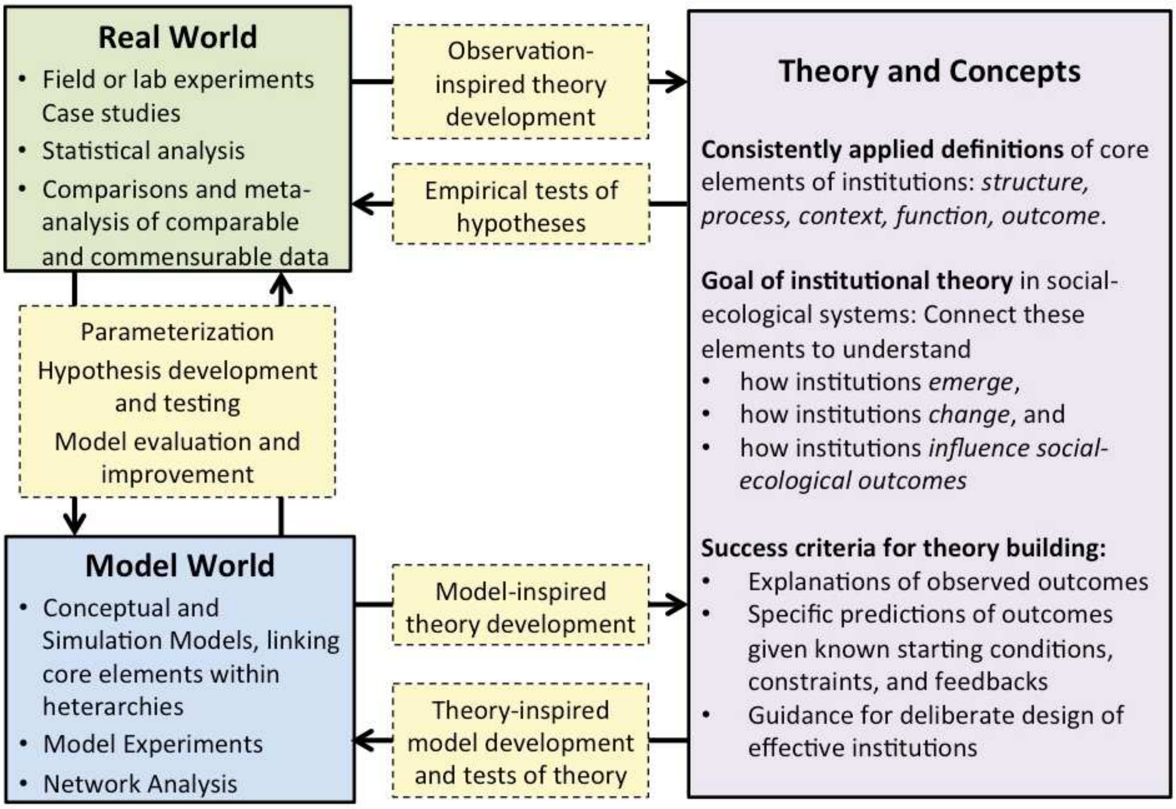

Fig. 1. The interaction between theory, models, and empirical data. We propose that the primary goal of institutional analysis in environmental and sustainability science is to understand how institutions emerge, change, and influence social-ecological outcomes. Theory and concepts (including frameworks) should be both inspired and tested through observations of real-world phenomena. Models have a critical role to play in the process of theory development, acting as a mediator between empirical data and theory as well as an approach for generating hypotheses.

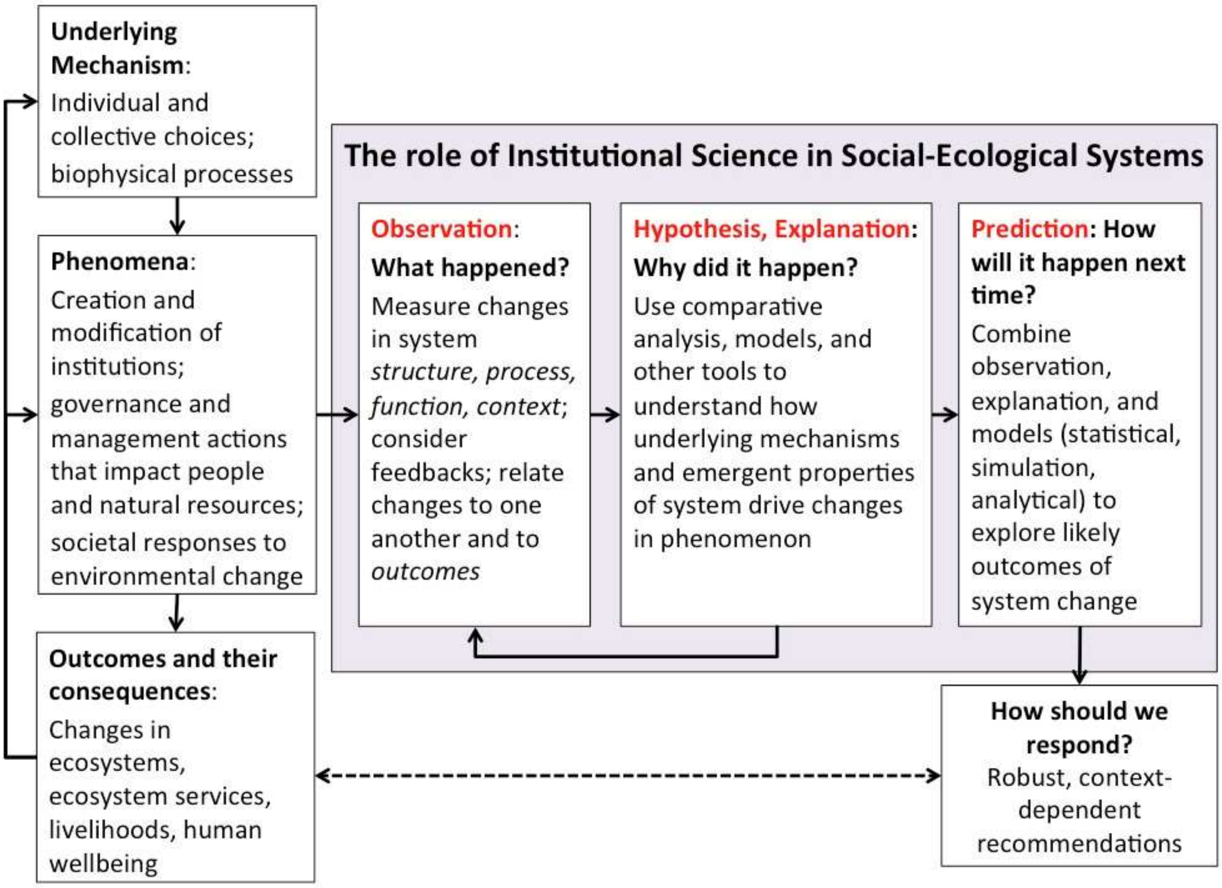

Fig. 2. The role of institutional science in social-ecological systems research. Institutional science seeks to understand how underlying mechanisms, both social and ecological, produce phenomena relating to the different elements of institutions. These in turn have consequences for ecosystems and societies. The scientific process involves observation, explanation, and prediction. Once our scientific understanding of the nature of a problem has been improved, it can inform responses that lead to desirable outcomes in ecological and social systems.

Box 1: Elements of Institutions for Analysis of Social-Ecological Systems

Institutions are the laws, rules, norms and customs governing human behavior and human-environment interactions. They often act as intermediaries between people and resources by structuring incentives and property rights that influence resource management decisions. In the study of institutions, identifying general patterns and trends from case studies requires that we describe different institutions in comparable ways and compare equivalent (commensurable) examples. However, broad understandings of institutions and applications of idiosyncratic theories to diverse case studies often render analysis and comparison difficult. To overcome this impasse, we identify five key elements of institutions:

- **Structure**, or system architecture, defines the composition, spatial pattern, and nature of the connections (e.g., power relations, dependencies, and spatial patterns; nestedness) between different components of the study system. Institutions also have their own relational structure ('the grammar of rules') that defines allowable, prohibited, and required uses of natural resources. Analysts often measure institutional structure using networks (nodes and links, i.e. system components and their relationships), or through hierarchical descriptors such as scale. For example, locally specific applications of environmental law may be hierarchically constrained by a principle, such as the right to use navigable waterways for transportation, which is contained in national legislation.
- **Process** refers to interactions (e.g., cooperation, learning, bargaining) that occur over time between and among actors, institutions, and the components of the natural and built environment, resulting in outcomes. For example, democracies often rely on a voting process where voters choose between candidates for leadership roles. Process is influenced or directed by structure, and *vice-versa* (e.g. links between system components emerge through different processes, and the existence of these links can constrain processes). Where processes lead demonstrably and causally to outcomes, they are often described as **mechanisms**. For example, the institutional structure of a commons governance system can be described using the number of different rules in use and their relationships to one another (e.g., rules about livestock access to water may be subordinate to rules relating explicitly to human drinking water). Structural change can be described as the difference in these rules and relationships between two points in time. Understanding why institutional change has occurred depends on understanding the processes that underlie it, such as the ways in which rules can be changed. Such processes will interact with, and often depend upon, the existing structure.
- **Function** describes the role or objective of an institution in relation to broader system dynamics or societal goals. For example, rules that limit over-grazing and over-fishing function to prevent a tragedy of the commons situation. Functions may be purposive (i.e., the system has been designed to achieve a given function), unintentional, or subverted. Subversion occurs when a rule that has been introduced for one purpose is co-opted to support another purpose. For example, Article VIII of the International Convention for the Regulation of Whaling allows countries to undertake whaling for scientific research. This loophole continues to be exploited by Japan to harvest whales without a genuine scientific justification (Clapham, 2017).
- **Context** describes the dynamic environment that is considered exogenous or fixed within the study system for the purposes of analysis. Context has spatial and temporal dimensions and includes both biophysical and social components, such as geography, land use history, or power relations.
- **Outcomes** describe the impact or difference that institutions and institutional processes make to the social and ecological context. For example, in Madagascar, the radiated tortoise *Astrochelys radiata* was historically abundant because the Mahafaly and the Antandroy people had a taboo against eating it. Movement of people from other groups into the tortoise's range has resulted in the taboo being abolished leading to widespread radiated tortoise consumption and IUCN Red-Listing of the tortoise as critically endangered (Lingard et al., 2003).