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Insight, part of a Special Feature on A Framework for Analyzing, Comparing, and Diagnosing Social-Ecological Systems

Social-ecological system framework: initial changes and continuing challenges

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ABSTRACT. The social-ecological system (SES) framework investigated in this special issue enables researchers from diverse disciplinary backgrounds working on different resource sectors in disparate geographic areas, biophysical conditions, and temporal domains to share a common vocabulary for the construction and testing of alternative theories and models that determine which influences on processes and outcomes are especially critical in specific empirical settings. We summarize changes that have been made to this framework and discuss a few remaining ambiguities in its formulation. Specifically, we offer a tentative rearrangement of the list of relevant attributes of governance systems and discuss other ways to make this framework applicable to policy settings beyond natural resource settings. The SES framework will continue to change as more researchers apply it to additional contexts; the main purpose of this article is to delineate the version that served as the basis for the theoretical innovations and empirical analyses detailed in other contributions to this special issue.

Key Words: *frameworks; governance; institutional analysis; social-ecological systems*

INTRODUCTION[1]

Most of the authors in this special issue have been working together in an informal "SES Club" to build upon and improve the social-ecological system (SES) framework initially proposed by Ostrom (2007). Here, we summarize changes that have been made to the original SES framework as a consequence of interactions among the members of this still-growing network of collaborators. We also discuss some proposed future adjustments, especially related to the characterization of governance systems. In a companion paper, Elinor Ostrom (*unpublished manuscript*) gives a detailed account of the initial meetings of the SES Club. Finally, Hinkel et al. (*unpublished manuscript*) offer a procedure intended to help regularize the process of making further changes to the SES framework in the hope of facilitating collective learning from its applications to diverse empirical settings.

Our analysis builds specifically on two articles by Ostrom (2007, 2009) in which she emphasizes that the SES framework emerged from a long process of collaboration with other scholars. Her interactions with John (Marty) Anderies, Marco Janssen, and other members of the Resilience Alliance were especially important in enabling her to formulate this innovative framework (Anderies et al. 2004, Janssen et al. 2007, Ostrom et al. 2007). The SES framework remains a work in progress, but the contributors to this special issue demonstrate that it is already sufficiently well-developed to inspire and potentially unite compelling lines of research on diverse types of resources in settings throughout the world.

Ostrom sought to begin the process of building a common vocabulary and a logical linguistic structure that would facilitate communication among scholars interested in the sustainability of SESs, all of whom confront the daunting problem of developing a coherent mode of analysis to apply to complex, nested systems operating at multiple scales. To understand how multiple forms of governance influence resource users of various scales and background and how they affect resource systems that have diverse characteristics, scholars need to draw on multiple scientific disciplines, each of which has developed its own technical language. Frequently, the definitions of terms in one discipline's language differ from those of another discipline, e.g., the meaning of community in ecology as contrasted to that in sociology.

Ideally, a framework helps scholars and policymakers to accumulate knowledge from empirical studies and assessments of past efforts at reforms and to organize their analytical, diagnostic, and prescriptive capabilities. Because SESs are inherently complex, theory is needed to guide the selection of an effective analytical focus. However, no one theoretical perspective is sufficient to analyze all feasible situations. This language framework was intended to remain "theory-neutral" so that competing hypotheses from alternative theoretical perspectives could be evaluated on a common basis. Of course, no language can be totally free of cognitive preconceptions and inherent limitations.

Fundamental to the SES framework is the presumption that humans can make conscious choices as individuals or as members of collaborative groups, and that these individual and collective choices can, at least potentially, make a significant difference in outcomes. These choice processes are not required to comport to any specific model of decision making or policymaking, nor are all outcomes observed required to have been intended by participants in that process. Alternative theoretical explanations highlight different components of the framework as being especially important in influencing individual preferences, collective choices, unintended consequences, and ultimate outcomes. However, any approach has its limitations, and the SES framework would not be an appropriate basis for applications of any mode of explanation that denied a meaningful degree of agency to the people living within an SES.

WHY A FRAMEWORK?

Many analysts use the terms "framework," "theory," and "model" almost interchangeably, but we make a more precise distinction among these terms, as articulated by Ostrom (2005). A framework provides the basic vocabulary of concepts and terms that may be used to construct the kinds of causal explanations expected of a theory. Frameworks organize diagnostic, descriptive, and prescriptive inquiry. A theory posits specific causal relationships

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among core variables. In contrast, a model constitutes a more detailed manifestation of a general theoretical explanation in terms of the functional relationships among independent and dependent variables important in a particular setting. Just as different models can be used to represent different aspects of a given theory, different theoretical explanations can be built upon the foundation of a common conceptual framework.

Frameworks provide a metatheoretical language that can be used to compare theories. They attempt to identify the universal elements that any theory relevant to the same kind of phenomena would need to include. The SES framework was designed to identify basic working parts and critical relationships among these elements that are essential to consider when studying SESs. It provides a general list of concepts that can be used to analyze all types of SESs ranging from Wisconsin lakes (Brock and Carpenter 2007) to the planet Earth (Rockström et al. 2009). These concepts combine or interact with one another in diverse ways that tend to be understood differently by scholars operating from different theoretical perspectives. Investment in updating and improving an interdisciplinary framework can provide an essential scientific dictionary for core concepts and their subconcepts so that multidisciplinary teams of researchers can work together more effectively.

Through their development and use of theories, analysts specify which of a framework's basic elements (and their interconnections) are particularly relevant to certain kinds of questions. Theories select for further analysis a subset of variables in a framework and make specific assumptions that are necessary for an analyst to diagnose phenomena, explain processes, and predict outcomes. Several theories are usually compatible with any framework. Diverse ecological and evolutionary theories and multiple social theories (e.g., game theory, transaction cost theory, social choice theory, covenantal theory, and theories of public goods and common-pool resources) are all compatible with the SES framework discussed in this special issue.

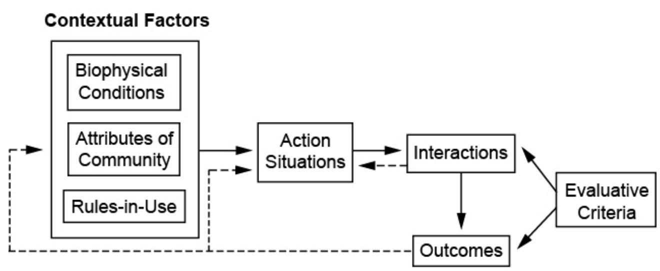
Theories can be further specified by the development and use of models that make precise assumptions about how the general causal logic of that theory might be manifested in particular settings; these restrictions on a limited set of parameters and variables can be investigated systematically using logic and mathematics, as well as simulation and laboratory experiments. For example, in an effort to understand the strategic structure of the games that irrigators play in differently organized irrigation systems, Weissing and Ostrom (1993) developed four families of models that specify the consequences of different institutional and physical combinations relevant to understanding how successful farmer organizations arranged for monitoring and sanctioning activities.

We start at the level of a framework for analysis because of the number of diverse processes occurring in SESs. If one is interested in understanding processes of use, maintenance, regeneration, and destruction of natural resources or humanly constructed infrastructures, then one is necessarily interested in a wide diversity of different processes going on either simultaneously or sequentially. If scholars working independently on theoretical explanations for limited aspects of an SES have no effective means of communication, none will be able to achieve a satisfactory understanding of that system as a whole. For example, markets and hierarchies are frequently presented as fundamentally different "pure types" of organization, each of which requires its own explanatory theory. Scholars who attempt to explain behavior within markets use microeconomic theory, whereas scholars who study hierarchies use political and sociological theory. Such a view precludes a more general explanatory framework that could help analysts make cross-institutional comparisons and evaluations.

Connecting the institutional analysis and development framework and the social-ecological system framework

Over the last few decades, scholars associated with The Vincent and Elinor Ostrom Workshop in Political Theory and Policy Analysis have used the institutional analysis and development (IAD) framework (Fig. 1) to cope with the complexity inherent in policy analysis. The SES framework builds on the foundation of the IAD framework, and the two are very closely related.

Fig. 1. Institutional analysis and development framework. Source: Adapted from Ostrom (2011:10).



In extensive work on such topics as urban governance, groundwater, irrigation systems, forestry resources, and development policy, we and our many colleagues have found the IAD framework especially useful as a foundation for microanalysis of a diverse range of social dilemmas (Blomquist and deLeon 2011, Bushouse 2011, Heikkila et al. 2011, Oakerson and Parks 2011, Ostrom 2011). Since the first initial statement of the IAD framework (Kiser and Ostrom 1982), substantial progress has been made, particularly related to the governance of diverse systems and concepts of strategies, rules, norms, and other key institutional terms (see McGinnis 2000, 2011*a,* Ostrom 2005, 2011, Poteete et al. 2010).

At the heart of the IAD framework is the "action situation," in which individuals (acting on their own or as agents of formal organizations) interact with each other and thereby jointly affect outcomes that are differentially valued by those actors. The actors in any action situation are presumed to be boundedly rational. They seek to achieve goals for themselves and for the communities to which they identify, but do so within the context of ubiquitous social dilemmas and biophysical constraints, as well as cognitive limitations and cultural predispositions.

Within this broad framework, a range of theoretical perspectives (game theory, historical institutionalism, social constructivism, etc.) may be employed to develop and analyze models of specific situations. The IAD framework highlights the social-cultural, institutional, and biophysical context within which all such decisions are made. Specifically, this framework helps organize the task confronting a scholar or policy analyst approaching a policy issue by directing their attention to (1) the rules in use, rather than only written, formal rules; (2) the underlying biological, chemical, and physical nature of the resource under consideration, as well as its characteristics in terms of being a private, public, or toll/club good or a common-pool resource; and (3) the most relevant attributes of the community, especially ambient levels of trust and shared norms of reciprocity.

The IAD framework is based on a dynamic view of policy processes as systems. Social, institutional, and biophysical factors are inputs to the decisions made by individuals (either acting on their own behalf or as agents of larger groups or organizations). Individual decisions are aggregated to constitute patterns of interaction that, when combined with exogenous factors, produce observable outcomes. Evaluations of these outcomes made by these actors (or by other observers) then feed back into all of the previous components of this continuous process.

Systems typically look very different depending on the level of aggregation being used, and this observation certainly applies to action situations. The IAD framework explicitly distinguishes three levels of analysis at which different types of choice processes take place: operational, collective, and constitutional. At the operational level, actors (either as individuals or as representatives of collective entities) make practical choices among their available options. Options are determined by both collective-level choices involving the determination of which strategies, norms, and rules are, should be, or are not available to actors fulfilling the specific roles defined by that group (as well as specifying who is assigned to fill these roles) and constitutional-level choices relating to who is or should be empowered to participate in the making of collective and operational-level decisions. The rules that define and constrain the operational activities of individual citizens and officials are established by previous or concurrent collective-choice processes, and the rules by which these rules themselves are subject to modification are determined through a process of constitutional choice. The critical insight behind this framework is that the outcomes of interactions in different levels of analysis are explicitly connected to each other.

The IAD framework was designed for application to any type of policy situation in which individuals and communities craft new policies as partial solutions for changing policy problems. When applied to resource management issues, the natural tendency within the IAD framework is to treat the dynamics of a resource system as a mostly exogenous force, that is, as a driver of changing circumstances and not something directly under the control of the actors making policy in those settings. This separation between natural processes as drivers and policy processes as the core analytical concern make the IAD framework seem directly relevant to the dynamics of complexly coupled human-natural or social-ecological systems.

INITIAL MODIFICATIONS

In a series of collaborations with different groups of scholars (Anderies et al. 2004, Janssen et al. 2007, Wollenberg et al. 2007, Poteete et al. 2010, Basurto et al. 2013), Ostrom turned her attention to the much broader set of ecological and social variables that are needed for the analysis of an SES. These collaborations, along with the findings of other scholars working over a span of several decades, identified a long list of variables of demonstrated importance in SESs. Ostrom (2007, 2009) offered the SES framework as a potential foundation for integrating this research, and especially for inspiring and organizing the findings of subsequent research on related topics.

The SES framework was originally designed for application to a relatively well-defined domain of common-pool resource management situations in which *resource users* extract *resource units* from a *resource system.* The resource users also provide for the maintenance of the resource system according to rules and procedures determined by an overarching *governance system* and in the context of *related ecological systems* and *broader social-political-economic settings.* The processes of extraction and maintenance were identified as among the most important forms of *interactions and outcomes* that were located in the very center of this framework, as illustrated in slightly different forms in Ostrom's (2007, 2009) initial work.

The italicized terms in the preceding paragraph serve as first-tier categories in the SES framework. Potential explanatory factors that had been highlighted by previous researchers are included in the SES framework as second-tier variables, and allowance is made for the potential relevance of more detailed variables or empirical indicators located at lower tiers in this ontological framework.

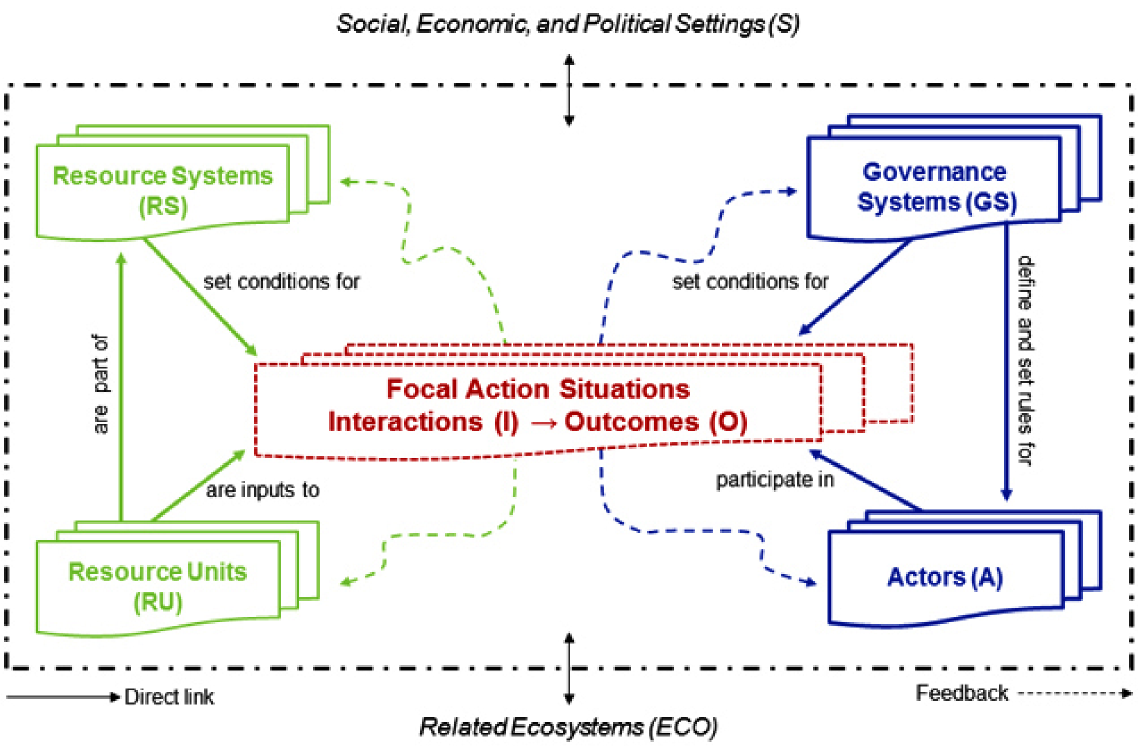
To be clear, we use the term "tier" to denote different logical categories, with lower-level tiers constituting subdivisions within elements of the next higher tier. Thus, for example, Resource Systems denotes a top-tier category with second-tier subdivisions denoting such characteristics as its size, type of resource sector, clarity of resource boundaries, etc. In turn, entries in the second tier have characteristics that can be identified at the third tier. To continue this example, size may be denoted in terms of geographic expanse, number of species interacting within the system, etc.

As detailed by Ostrom (*unpublished manuscript*), many discussions among members of the SES Club focused on whether or not this framework was potentially broader in scope than was originally claimed. Although originally presented as being of particular relevance to common-pool resources, many SESs also generate public goods and services, most notably the ecological or ecosystem services on which many markets depend for their continued operation. Related problems of balancing resource use and systems maintenance occur in social-technical systems, for which outcomes range from private consumption goods to complex infrastructures shared by members of widely dispersed communities. Just how broadly the SES framework can be usefully applied remains an open question.

We next specify a few modifications that emerged from initial meetings of the SES Club. In these discussions, participants were primarily interested in making changes that enabled the framework, as originally described, to be revised in a way that makes it potentially applicable to a broader range of empirical settings without becoming so general as to be vacuous. Each of the changes discussed here generated a wide consensus of support in these discussions.

We illustrate the updated SES framework as it was agreed upon by contributors to this special issue (Fig. 2, Table 1). Resource Systems, Resource Units, Governance Systems, and Actors are

Fig. 2. Revised social-ecological system (SES) framework with multiple first-tier components. Solid boxes denote first-tier categories. Resource Systems, Resource Units, Governance Systems, and Actors are the highest-tier variables that contain multiple variables at the second tier as well as lower tiers (see Table 1 for an updated list of second-tier variables within each of the top-tier categories). Action Situations are where all the action takes place as inputs are transformed by the actions of multiple actors into outcomes. Dashed arrows denote feedback from action situations to each of the top-tier categories. The dotted-and-dashed line that surrounds the interior elements of the figure indicates that the focal SES can be considered as a logical whole, but that exogenous influences from related ecological systems or social-economic-political settings can affect any component of the SES. These exogenous influences might emerge from the dynamic operation of processes at larger or smaller scales than that of the focal SES.



the highest-tier variables that contain multiple variables at the second tier as well as lower tiers. Action Situations are where all the action takes place as inputs are transformed by the actions of multiple actors into outcomes. Feedback occurs from action situations to each of the top-tier categories. The focal SES can be considered as a logical whole, but exogenous influences from related ecological systems or social-economic-political settings can affect any component of the SES. These exogenous influences might emerge from the dynamic operation of processes at larger or smaller scales than that of the focal SES.

Pictures are an incomplete representation of the full range of meaning intended to be included in a general concept, and we are concerned that our presentation of the SES framework may convey the mistaken impression that it is static in nature. The feedback paths (Fig. 2) suggest that the consequences of action situations may spread to any of the other top-tier variables, but our experience is that this interpretation is not immediately obvious to all observers. To be clear, we interpret all of the factors included in the top-tier categories (RS, RU, A, and GS in Fig. 2) to be, at least potentially, both inputs to and outputs from one or more action situations. Action situations take as inputs the values of the SES top-tier categories at time t and generate changed values of at least some of those factors at time t + 1.

Recognizing action situations

The IAD framework attaches prominence to the concept of an action situation in which actors in positions make choices among available options in light of information about the likely actions of other participants and the benefits and costs of potential outcomes. The initial versions of the SES framework (Ostrom 2007, 2009) implicitly incorporated the action situation within the box labeled as interactions and outcomes (Fig. 2). Initial feedback on these versions of the SES framework suggested that the action situation needed to be explicitly denoted in the base figure.

Accordingly, Ostrom (2010) used the occasion of her Nobel Prize acceptance speech to change the label of the Interactions and Outcomes to also include the broader term Action Situations. This simple step cemented a close connection between decades of work on the IAD framework and the newly established SES

Table 1. Second-tier variables of a social-ecological system. Source: Adapted from Ostrom (2009:421).

First-tier variable	Second-tier variables
Social, economic, and political settings (S)	S1 – Economic development S2 – Demographic trends S3 – Political stability S4 – Other governance systems S5 – Markets S6 – Media organizations S7 – Technology
Resource systems (RS)	RS1 – Sector (e.g., water, forests, pasture, fish) RS2 – Clarity of system boundaries RS3 – Size of resource system RS4 – Human-constructed facilities RS5 – Productivity of system RS6 – Equilibrium properties RS7 – Predictability of system dynamics RS8 – Storage characteristics RS9 – Location
Governance systems (GS)	GS1 – Government organizations GS2 – Nongovernment organizations GS3 – Network structure GS4 – Property-rights systems GS5 – Operational-choice rules GS6 – Collective-choice rules GS7 – Constitutional-choice rules GS8 – Monitoring and sanctioning rules
Resource units (RU)	RU1 – Resource unit mobility RU2 – Growth or replacement rate RU3 – Interaction among resource units RU4 – Economic value RU5 – Number of units RU6 – Distinctive characteristics RU7 – Spatial and temporal distribution
Actors (A)	A1 – Number of relevant actors A2 – Socioeconomic attributes A3 – History or past experiences A4 – Location A5 – Leadership/entrepreneurship A6 – Norms (trust-reciprocity)/social capital A7 – Knowledge of SES/mental models A8 – Importance of resource (dependence) A9 – Technologies available
Action situations: Interactions (I) → Outcomes (O)	I1 – Harvesting I2 – Information sharing I3 – Deliberation processes I4 – Conflicts I5 – Investment activities I6 – Lobbying activities I7 – Self-organizing activities I8 – Networking activities I9 – Monitoring activities I10 – Evaluative activities O1 – Social performance measures (e.g., efficiency, equity, accountability, sustainability) O2 – Ecological performance measures (e.g., overharvested, resilience, biodiversity, sustainability) O3 – Externalities to other SESs
Related ecosystems (ECO)	ECO1 – Climate patterns ECO2 – Pollution patterns ECO3 – Flows into and out of focal SES

framework. In effect, the other components of the SES framework constitute a fuller elaboration of the relevant contextual factors that contribute to a definition of the situation confronting actors located within an SES. The patterns of behavior actors exhibit can then be characterized with reference to the second-tier and lower-tier variables included in the SES Action Situations category.

In both the IAD and SES frameworks, feedback paths link outcomes of action situations back to the contextual variables, thus conveying an explicitly dynamic structure to both frameworks. Admittedly, the dynamic aspect is not as apparent as it might be in other graphical formulations, but we are following a long tradition of using state variables and dynamic processes to represent how a complex system changes over time. All of the factors listed in the SES framework are best interpreted as parameters or state variables in place at a given point in time. Outcomes of any of the processes we call action situations might influence the values of the system at later times.

Generalizing users to actors

The SES framework drew the attention of researchers investigating diverse types of resources, including several studying highly technical systems of infrastructure networks. For such applications, it is important to consider the behavior of third parties who are not direct users or consumers of the product or service in question. For this reason, the term "User" seemed inappropriately restrictive. In a meeting held in Delft in May 2010, participants agreed that the category "Actors" was more inclusive than "Users," and this change was recommended for any future application. As noted by Hinkel et al. (*unpublished manuscript*), the category Users is now treated as a subcategory of Actors.

Hinkel et al. (*unpublished manuscript*) also introduce a set of rules that should guide decisions about making changes in this framework. One of their suggestions is that after making a change in the terms used in any tier, it is critically important to reexamine each of its subcategories or attributes at lower tiers to make sure that these same terms are meaningful for the new label. In some cases, the changes required are simple, as in the change from U1 (number of users) to A1 (number of actors). Other changes require more thought. For example, U3 (history of use) was reworded to A3 (history or past experiences) to allow for the influences of past experiences in any kind of relevant activity. Similarly, U9 (technology used) is now written as A9 (technologies available).

By replacing Users with Actors, we greatly expanded the potential range of application of this framework. We could now examine situations in which the set of direct participants in processes of resource extraction is not identical to the set of participants consuming the product of labor.

In the updated SES framework, groups of actors can be distinguished by the range of activities in which they are engaged. The list of relevant activities is, in turn, specified by the second-tier factors in the Interactions part of the Action Situations category. For different applications, it may be necessary to add additional processes to that list, but for now we leave these additions to subsequent research. However, analysts might interpret a User as a particular type of actor, one that is simultaneously engaged in the processes of harvesting, producing, and consuming resource units.

Multiple versions of top-tier components

Initially, the SES framework was presented as if the focal action situation involved only one set of users inhabiting one overarching governance system, who were dependent on a particular type of resource unit, which were in turn extracted from a particular resource system. The possibility of multiple governance settings or ecosystems was incorporated in the outlying Social, Economic, and Political Settings and Related Ecosystems categories (Fig. 2). However, the initial figures made it appear as though the framework allowed only one instance of each of the first-tier components.

In practical examples, some researchers identified more than one resource system, or more than one relevant resource unit, as well as multiple user groups. For example, in his analysis of *acequias* (irrigation ditches) in New Mexico, Cox (2010, 2014) treats a network of irrigation canals and infrastructure and an underlying set of shallow aquifers as two separate subcomponents of the overall resource system.

We now prefer to use a representation that explicitly allows for the coexistence of multiple instances of each of the top-tier components. Each of the top-tier components of the SES framework can exist in multiple manifestations in any particular application (Fig. 2). Different sets of actors may be engaged in extracting or producing different types of resource units drawn from one or more resource systems, and their activities may be guided by rules drawn from overlapping governance systems. The analysis of focal systems involving irrigation systems, for example, requires specification of at least two action situations: one that focuses on how the physical system is maintained and a second that focuses on water distribution. Further, there may be two related resource systems: surface water and groundwater.

Allowing each of the first-tier components to exist in multiple versions is a major revision of the framework as it was originally presented. It also imposes an additional task on any analyst using this framework, namely, the specification of how different instances of first-tier components are related to each other. For example, actors engaged in extracting resource units from one resource system may not have rights to participate in rule-making activities for that same system. In other settings, the same actors may be engaged in the full range of activities from extraction and rule-making to sanctioning (McGinnis 2011*b*). A single framework needs to be able to encompass both of these configurations.

After considering alternative formulations, we decided to treat each instance of a single category as an element of the set of potential empirical referents of that conceptual category. To continue with the *acequias* example, each network of interconnected irrigation canals and each aquifer can be treated as an instance of the Resource Systems category. For some applications, it may be useful to aggregate all aquifers into a single resource system, but for other purposes it is useful to consider them separately. For some resource questions, it might be more appropriate to treat the entire irrigation-aquifer system as a single integrated water resources system or the watershed of the river as a whole. On the social side, it may also be desirable to treat the river valley as a single integrated community for some research questions, whereas other circumstances will require consideration of each tribal community or political jurisdiction as separate entities. In addition, each actor type must be associated with the range of activities or interactions in which that type of actor is involved.

Differentiating among diverse relationships

Allowing for multiple instances of each of the top-tier concepts highlights another issue. The SES framework is an ontology, in the sense that it defines a language of terms and specifies a series of logical relationships among these terms. As we attempted to elaborate this underlying logical structure, it became clear that these categories can be linked together in more than one way. This topic is covered in detail by Hinkel et al. (*unpublished manuscript*), so we can be brief here. Some relationships are compositional in form, such as the resource units that are contained within a resource system or the actors who are jointly influenced by the operation of a particular governance system. Alternatively, a resource system can be said to generate resource units that may be consumed in many forms. Other factors identified in the SES framework are attributes attached to instances of that class of entities, such as the number of actors involved in harvesting activities or the physical extent of the resource system under consideration. Still other attributes must be associated to aggregations of units or refer to properties that emerge at higher levels of aggregation. Finally, instances of different governance systems may interact with each other and with other top-tier components in a wide variety of ways. These interactions can be interpreted as instances of the action situation component and may involve a large number of instances from one, two, three, or all four of the primary top-tier components.

The updated framework

All of the aforementioned modifications are incorporated into the new framework (Fig. 2). Multiple boxes are used for each subcomponent to illustrate the potential for concurrent operation of multiple instances of each of these first-tier components. Labels are added to the direct links to highlight the different logical nature of these connections. Resource systems may be composed of multiple types of resource units. Each governance system has authority over some defined sets of actors, and its outcomes effectively define the nature of the actors and the options available to them. The entire range of relevant governance systems and resource systems set the conditions under which action situations take place.

Labels were revised to reflect the specific changes in the framework (Table 1). In addition, a few additional forms of interaction have been added to the original list of action situations. For example, the *activities* required for monitoring should be considered as forms of interaction (and thus within the Action Situations category) that are logically distinct from the monitoring *rules* included under the Governance Systems category. Evaluative processes are included in the list of interactions, and O1, O2, and O3 have been designated as Outcome Criteria.

After reexamining the initial labels assigned to the second-tier factors under the initial Resource Units category, we decided that RU6 (distinctive markings) should be replaced by RU6 (distinctive characteristics). Although markings make sense for application to such tangible resources as animals, that term does not seem appropriate for all possible applications. Further, other characteristics of living entities identified by ecology, such as the breeding season and locations, frequently affect the outcomes of action situations.

To summarize, the new framework (Fig. 2, Table 1) incorporates the following changes from versions of the SES framework initially presented by Ostrom (2007, 2009, 2010).

1. Labels for first-tier categories are changed.
2. Actors (A) replaces Users (U), and each Ux is changed to Ax for second-tier attributes in that category.
3. Action Situations is added to the label for Interactions and Outcomes (as in Ostrom 2010).
4. Multiple instances of first-tier categories may be included in applications.
5. Labels summarize the logical relationships between first-tier categories (Fig. 2). Specifically, resource units are considered to be parts of (or drawn out of) broader resource systems, and governance systems define and set rules for actors.
6. Monitoring activities are included as a particular instance of the Action Situations category, with the rules under which monitoring takes place remaining under Governance Systems.
7. Evaluative activities are included as another action situation, and Outcome Criteria are specified as such.
8. Changes in the list of relevant social, political, or economic settings include the addition of Technology as a potential source of exogenous shocks, and generalization of market incentives to any factors relating to markets and government resource policies to other potentially relevant governance systems.
9. RU6 (distinctive characteristics) replaces RU6 (distinctive markings), with the expectation that Distinctive Markings would be moved to the next lower tier.
10. "Levels" was deleted from Harvesting Levels (I1) to keep the focus on interactions rather than outcomes.

These changes were made in the interests of generalizability by extending the SES framework to apply to complex SESs in which multiple sets of actors consume diverse resource units extracted from multiple interacting resource systems in the context of overlapping governance systems. The framework is summarized as it is understood by authors of the studies reported in this special issue (Fig. 2, Table 1).

TOWARD FUTURE EXTENSIONS

We now discuss two issues that we consider to be critically important for the future development of this mode of analysis: the framework's potential relevance for a wider range of goods and services and its incomplete representation of the nature of governance institutions.

Technical systems, goods, and services

We are convinced that the SES framework may potentially be applicable to questions of the governance of an artificially constructed technological system such as a power grid or telecommunications system. However, there are important differences in the ways in which primary users experience their interaction with a social-ecological-technical system (SETS; R. Künneke and M. Finger, *unpublished manuscript*). Fish drawn from a fishery can be identified as discrete entities, but people dependent on electric power tend to see its delivery more in terms of a continuous service rather than the purchase of discrete units. Another important difference is that there may be a clear separation between people who have the technical expertise to understand the construction and maintenance of an SETS and those who are merely concerned about continued access to this resource.

Frankly, we do not find it easy to specify exactly how an SETS differs from an SES. The social side seems the same in both instances, even if the ultimate users of a technical resource do, in most cases, lack any direct knowledge of resource dynamics. However, the SES framework as expanded here can incorporate many different kinds of actors, ranging from those who extract resource units or build technical infrastructure to those whose only interest lies in enjoying uninterrupted access to a resource service. There is an important distinction between the relatively natural dynamics found in ecological systems and the constructed dynamic process of complex technical systems, but the distinction between natural ecology and artificial technology is not as clear-cut as it may initially appear. After all, it is virtually impossible to find any ecological system in the contemporary era that is entirely free from human interference, nor are we aware of any SETS in which the continued operation of the relevant technology bears no dependence on naturally occurring phenomena.

Our discussions on the relationship between SESs and SETSs highlight another aspect of SESs, namely their importance in the delivery of services that are difficult to conceive as discrete units or products. For example, a forest can provide critical services in terms of water storage and purification, whether or not these ecosystem services are assigned an explicit economic value. Our preferred interpretation is that a resource unit need not be required to be as easily divisible as are most private goods. A public good is, by definition, consumed collectively and cannot be divided into discrete subunits. However, if a resource unit is not divisible, then it might be possible to treat it as a single unit.

Members of the SES Club considered changing the name of the Resource Units first-tier category to Resource Services and Units, but ultimately, we decided that this change would not be consistent with the procedures reported by Hinkel et al. (*unpublished manuscript*). In particular, some of the second-tier labels in their current form would no longer be meaningful when applied to this new interpretation, so this change would generate unnecessary confusion.

Governance institutions and systems

Of all the top-tier SES components, the initial list of factors for Governance Systems now seems to us to be the least compelling. Hindsight suggests that the initial selection of the particular subcategories might have been guided by a different logic than for the other top-tier components. Even though other researchers have used these categories to organize their analyses, we remain unsatisfied with the current set of second-tier categories for governance systems.

One difficult issue concerns the status of collective actors, including the organizations listed as second-tier characteristics in the Governance Systems category. It is our understanding that actors in the SES framework may be collective entities, but that, in most instances, a specific individual can be identified as acting as an agent on behalf of that entity. The rules that define and govern the responsibilities of the role of agent should then be included as properties of the relevant governance system. In this way, a government organization, for example, might appear in two different top-tier categories of the SES framework, depending on the topic under consideration. When an analyst is concerned about the actions taken by the agents of that organization, attention should be directed to the Actors category, but attention should be directed to the Governance Systems category whenever it becomes necessary to explain the capabilities and responsibilities of that agent. By a similar logic, the norms that an actor considers relevant to his or her actions in a given setting can be treated as attributes of that actor, whereas the broader repertoire of norms available to individuals within the relevant social and cultural setting might best be interpreted as attributes of the governance system as a whole. We realize that not everyone will find this strict separation between structure and agency to be compelling, but it would be unreasonable to expect that any single representation can be equally satisfying for the full range of social scientists and policy analysts. We strive for precision to be perfectly clear about our intended meanings.

Slight variations in the second-tier Governance System variables already occur in the SES literature. Ostrom and Cox (2010:458) highlight rules, property systems, and network structures as the key characteristics of governance systems. They also add third-tier variables, differentiating rules into operational, collective, and constitutional; differentiating property-rights systems into private, public, common, and mixed; and highlighting centrality, modularity, connectivity, and number of levels as the key distinguishing properties of different network structures.

In the hope of triggering further investigation, we offer the following tentative list of potential second-tier (and selected third-tier) factors under the Governance Systems category (Table 2).[2] This list is significantly different from the list included in the original versions of the SES framework, as well as the updated version (Table 1). All of the factors included in those lists are still here, albeit in different locations.

It remains to be seen whether any rearrangement along these lines would be a productive direction for future elaboration. We propose these changes in the hope of making the logical underpinning of the second-tier factors in this category more closely related to the logic used in defining the other categories. Thus, we begin with GS1* as a specification of the relevant policy area (environment, trade, health, etc.), in a manner analogous to the resource sector variable that begins the list of Resource System characteristics. Asterisks signify that these are suggestions for, and not changes to, the official structure of the SES framework.

For governance systems, there are two kinds of scale that need to be considered: the geographic range (GS2*) as well as the size of the population (GS3*) that participates in, or is subject to, that system of governance. In some instances, the population will be members of a jurisdiction defined in geographic terms, but in other instances, the population may be defined on a functional

Table 2. Alternative list of second-tier properties for governance systems (GS*).†

Second-tier variable	Third-tier variables
GS1* – Policy area	
GS2* – Geographic scale of governance system	
GS3* – Population	
GS4* – Regime type	
GS5* – Rule-making organizations	Public sector organizations (government agencies, etc.) Private sector organizations (for-profit) Nongovernmental, nonprofit organizations Community-based organizations Hybrid organizations
GS6* – Rules-in-use	Operational-choice rules Collective-choice rules Constitutional-choice rules
GS7* – Property-rights systems	
GS8* – Repertoire of norms and strategies	
GS9* – Network structure	
GS10* – Historical continuity	

†Asterisks denote the tentative nature of these suggestions.

basis, as in the special-purpose cross-jurisdictional (i.e., Type II) governance organizations described by Hooghe and Marks (2003).

Regime type (GS4*) moves to a more macro level by specifying the logic upon which the overarching governance system is organized. The term "regime" can be used in different ways, distinguishing between democratic and autocratic systems of governance or between monocentric and polycentric systems (Ostrom et al. 1961).

Within any governance system, different types of organizations will be responsible for crafting and/or implementing different kinds of rules. The next two factors specify the nature of these organizations (GS5*) and the nature of the rules these organizations generate and/or implement (GS6*). The initial list of second-tier factors in Ostrom (2007, 2009) specified only governmental and nongovernmental organizations, but we have expanded this list (now on the third tier) to include private corporations, community-based organizations, and hybrid organizational forms that combine aspects of public, private, and voluntary organizations. Any of these rule-making organizations may operate at different scales, from local, regional, or national to global. All of these types of organizations can play important roles in shaping the conditions under which rules-in-use are enacted in increasingly complex systems of governance.

Four of the second-tier factors listed in the original list are subsumed within our proposed new category of rules-in-use (GS6*). Drawing on the IAD framework, we distinguish among rules directed at operational decisions, those guiding collective choices, and those relating to constitutional-level questions. However, monitoring and sanctioning rules were initially listed as separate second-tier variables under Governance Systems (Ostrom 2007, 2009), in recognition of their special importance in previous research (see, e.g., Ostrom 1990). On further reflection, we realized that rules related to monitoring or sanctioning can occur in any of these three levels and thus should be treated as subcategories of rules-in-use at each of these levels (as shown in Table 2).

Given their importance, it is worth distinguishing among relevant rules that are promulgated or otherwise established at the level of the governance system and their actual implementation in operational-level action situations. Rules concerning permissible forms of punishment are demarcated at the constitutional level; rules concerning the assignment of monitoring responsibilities and specification of the magnitudes of sanctions are defined at the collective-choice level; and rules governing implementation are realized at the operational-choice level.

More generally, any of the policy tools or policy instruments (Sterner 2003) that have been used by governmental or other policy agents can be decomposed into constitutional-, collective-, and operational-choice components. For example, a cap-and-trade scheme begins with the constitutional choice of what resources can be legitimately subject to this constructed market, followed by the collective choices of the allowable aggregate levels of extraction or use and the number and size of tradable units, and finally, the operational-level trades among participants as well as the innovative technological responses that such a system is intended to inspire.

Rules that relate to ownership of property can also fall within each of these IAD categories. At the constitutional level, broad parameters are set concerning what can be considered someone's property, collective-choice decisions include what forms of property can be expropriated for the use of public purposes, and operational-level aspects distinguish among those actors with access, withdrawal, management, exclusion, and alienation. However, as emphasized by Schlager and Ostrom (1992), property-rights systems are not rules. Instead, property-rights systems define relations among people in relation to things, and specify both duties and obligations. Given the obvious importance of property-rights systems to the study of SESs, we include this factor as our proposed GS7*.

Although rules, norms, and shared strategies are included as alternative forms of institutional statements in the grammar of institutions (Crawford and Ostrom 1995), norms per se have received less explicit attention by scholars working with either the IAD or SES frameworks. Still, we think it is important to include in our list of governance system characteristics a term (GS8*) encompassing the entire repertoire of norms or shared strategies that are available for the use of actors engaged in a particular setting. In effect, this term reflects the myriad ways in which culture affects decisions regarding SESs.

Network structure (GS9*) refers to the connections among the rule-making organizations and the population subject to these rules. Third-tier variables could include, for example, the measures of centrality, modularity, connectivity, and number of levels, as used by Ostrom and Cox (2010).

The last item on our proposed list, historical continuity (GS10*), is included to distinguish between systems of governance that have been in place for long periods of time and those that are more recent in form. All forms of governance have deep roots in historical precedents, but some systems are more inclined toward stasis and others toward more flexible modes of response.

Although other attributes might be relevant, we stop at this point because this list is meant to be suggestive and to inspire subsequent investigation. This list is similar to that used previously by Ostrom and her coauthors (Basurto et al. 2013). Their listing uses GS1* through GS6*, but includes property rights (GS7*) as a subcategory under GS6*. Their remaining second-tier categories include Norms and Strategies, and Network Structure, which correspond to our GS8* and GS9* (Table 2). Historical continuity (GS10*) is not included in their list, which instead designates both Monitoring and Sanctioning as second-tier variables under the Governance Systems heading. As we argue above, the associated rules should be included under the rules-in-use category and associated activities under the Interactions and Outcomes category, which is not explicitly included by Basurto et al. (2013). We hope that the procedure articulated by Hinkel et al. (*unpublished manuscript*) will help minimize similar confusion in subsequent applications of the SES framework.

CONCLUSION

In conclusion, we return to the original inspiration behind the SES framework, namely, to develop diagnostic tools for use by scholars or practitioners concerned with understanding the determinants of sustainability in complex SESs. Diagnosis is a routine activity of medical professionals, and it plays an absolutely critical role in health care, but it is not immediately obvious what the appropriate analogy would be for the activities of social or ecological researchers.

Medical professionals ask questions about an individual's symptoms to ascertain the nature of the underlying health problem that the individual faces. Medical textbooks include incredible amounts of detail, only a small portion of which is relevant to particular diagnoses or treatments. Making the proper diagnosis is an essential step toward effective treatment. This process of diagnosis cannot be automated, but instead requires trained professionals to draw upon their organized understanding of the relevant fields of scientific study.

The SES framework offered here is intended to provide institutional analysts, ecologists, policymakers, and concerned citizens with the foundation for a similar form of organization for the knowledge relevant to the diagnosis of the properties of specific SESs. Ultimately, we hope a more fully elaborated framework can serve as a useful guide for analysts seeking to enhance the prospects of effective and sustainable outcomes. If nothing else, such a framework can contribute by prompting analysts to ask certain types of questions and to investigate certain aspects of any given situation.

Application of the SES framework to particular cases requires a three-step process. In the first step, the analyst must select a focal level of analysis by answering such questions as: What types of interactions and outcomes related to a particular resource system (or group of systems) and related resource units (or other relevant goods and services) are most relevant to my analytical or diagnostic concerns? What types of actors are involved? Which governance systems influence the behavior of these actors?

Hinkel et al. (*unpublished manuscript*) detail procedures that can help answer these questions; particularly helpful is their clarification of the distinction between resource systems and resource units. Still, the framework per se can take us only so far. Theory, augmented by puzzles from past research that are not yet reconciled with accepted explanations, must guide the selection of which variables are likely to be most important in a particular setting. Of course, alternative theories might suggest the importance of different sets of variables. Even within a single theory, specific models will posit different functional relationships or causal pathways, and the analyst must choose which alternative explanations are most deserving of his or her attention. Here is where the critical concerns of research design become most important, as the analyst selects which cases and what kinds of observations of those cases can best provide the analytical leverage needed to be able to draw valid inferences from a particular research project.

In the second step of any application of the SES framework, researchers must select which variables should be measured and how these indicators can be implemented. At this step, the framework is especially useful in assuring that some potentially critical factor has not been overlooked.

Third, and finally, the SES framework facilitates the communication of results across research communities. The specific meaning of each concept or the particular indicators used to measure concepts may differ considerably when moving from one empirical setting to another, but the first- and second-tier categories should remain equally relevant to all applications. Having this common base of shared terms increases the chances that cumulative progress can be made, making it easier for researchers trained in different disciplines and studying different resources in different places to compare their findings and to engage in mutually beneficial exchanges of information.

We recognize that many challenges remain to be overcome. A complete representation of dynamic linkages among concurrent action situations operating in complex SESs remains a distant goal, but the modifications discussed here point in promising directions for subsequent research. In addition, the empirical articles in this special issue demonstrate how much we can learn from efforts to apply this general framework to the analysis of particular cases. In each instance, new aspects take on increased importance, even as lessons are drawn from applications of similar concepts to quite different ecological settings. All of this work is very exciting, and we can only hope that the SES framework continues to inspire such high-quality research and, especially, that it can facilitate communication among scholars from a broad array of disciplines working on diverse resources in many different parts of the world.

FOOTNOTES

1. *Corresponding author's note:* In the process of making revisions in response to reviewers' comments, I have endeavored to remain as close as possible to positions that Ostrom expressed during our collaboration. However, in some cases, I had to introduce a few points of my own, and in this article I note those points of the argument that are my sole responsibility.

2. *Corresponding author's note:* I made final revisions to Table 2 after Ostrom's death. Thus, this particular list cannot be treated as Ostrom's last word on the matter, but instead as my interpretation of our common understanding at that time. A similar list is used by Basurto et al. (2013) in an article that was also completed after Ostrom's death, but which I did not see until after its acceptance for publication.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6387

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