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Governing trade-offs in ecosystem services and disservices to achieve human-wildlife coexistence

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Equitable and effective human-wildlife coexistence requires governing trade-offs in ecosystem services and disservices across stakeholder groups.

Abstract

Sustaining wildlife populations, which provide both ecosystem services and disservices, represents a worldwide conservation challenge. The ecosystem services and Ostrom's social-ecological system frameworks have been adopted across natural and social sciences to characterize benefits from nature. Despite their generalizability, individually they do not include explicit tools for addressing the sustainable management of many wildlife populations. For instance, Ostrom's framework does not specifically address competing perspectives on wildlife, while the ecosystem services framework provides a limited representation of the social and governance context wherein such competing perspectives are embedded. Here, we develop a unified Social-Ecological framework of Ecosystem Disservices and Services (SEEDS) that advances both frameworks by explicitly acknowledging the importance of competing wildlife perspectives embedded in the social and governance contexts. SEEDS emulates the hierarchical structure of Ostrom's social-ecological systems, but adds subsystems reflecting heterogeneous stakeholder views and experiences of wildlife-based services and disservices. We propose a list of variables to facilitate operationalizing SEEDS and initiate a broader discussion about the key variables for analysis across human-wildlife systems. We also suggest steps to implement the new framework and connect it with other existing approaches in social-ecological research. In conclusion, SEEDS can guide analyses across systems or within individual systems to provide new insights and management options for sustainable human-wildlife coexistence.

Introduction

Ecosystems and their biodiversity are sources of irreplaceable benefits for human societies (MEA 2005). Nevertheless, ecosystems, or ecosystem components, can also damage human well-being or property and result in costs to society (Shackleton et al. 2016). This contradictory characteristic of ecosystems creates challenges for conservation, such as in the case of the management of wildlife populations that provide both benefits, and costs to human societies (Dickman 2010). Several analytical frameworks exist to assess the benefits from nature and to advance the sustainable management of ecosystems. Two such frameworks — ecosystem services (ESF) (Daily 1997) and Ostrom's social-ecological systems (SESF) (Ostrom 2007, 2009) — provide valuable perspectives toward addressing these challenges. However, they do not explicitly tackle conservation challenges where stakeholders experience both costs and benefits of ecosystems, especially when these occur at different spatial or temporal scales. The ESF focuses on identifying and valuing the costs and benefits to human well-being from ecosystems, i.e., ecosystem services (Naidoo et al. 2008) and disservices, respectively (Shackleton et al. 2016), referred here jointly also as (dis)services. However, ESF lacks a consistent representation of social interactions relevant for decision-making at individual and institutional levels (Chan et al. 2012). In contrast, Ostrom's SESF groups social and ecological characteristics in subsystems but only represents the perspective of service beneficiaries (Leslie et al. 2015). Here, we summarize the structures and merge the strengths of these two frameworks (Partelow & Winkler 2016) to create a Social-Ecological framework for Ecosystem Disservices and Services (SEEDS). We discuss a step-by-step implementation of SEEDS in human-wildlife systems, which we define here as social-ecological systems within which a wildlife population of conservation concern, or of other cultural or material value is also a source of damages or threats to human wellbeing. It is imperative to find sustainable solutions for human-wildlife systems because many threatened species (Carter et al. 2012) and human populations around the world depend on them simultaneously for their survival (DeMotts & Hoon 2012).

The ecosystem services framework

The accelerated pace at which we are losing biodiversity and associated services due to human activities (IPBES 2016) suggests that the irreplaceable benefits of ecosystems are not fully accounted for in decision-making. The ESF was proposed to integrate the benefits to society from biodiversity and ecosystems into governance (Figure 1) (Daily et al. 2009) by translating ecological processes and functions into entities of value for human societies. Recent conceptual advances aid the operationalization of ESF in land-use planning and policy. Examples include: expanding the ESF to include multiscale relationships between services (Scholes et al. 2013), feedbacks to service production through governance (Birgé et al. 2016), indirect and direct drivers on service production (MEA 2005) and multidimensional service values beyond instrumental or use values (Chan et al. 2012). An expanding area of research is related to ecosystem service trade-offs, which are decreases in quality or quantity of services that occur due to the supply of other services (Raudsepp-Hearne et al. 2010). In contrast, disservices represent negative externalities of functioning ecosystems and service production, e.g., disease transmission by wildlife to humans and domestic animals (Shackleton et al. 2016). Although both refer to costs that can arise through decisions to enhance or preserve certain services, research on service trade-offs (Raudsepp-Hearne et al. 2010; Felipe-Lucia et al. 2015) is considerably more advanced than research on the distribution of disservices among stakeholders. Thus, although trade-offs have been at the forefront of ecosystem service research (IPBES 2016), emerging social interactions resulting from differences and often unequal distribution of disservices among stakeholders are often not included in value-based solutions.

The ecosystem service literature addresses wildlife populations and the myriad of services they provide, including sanitation (Morales-Reyes et al. 2015), tourism revenues (Naidoo et al. 2016), subsistence harvest (Golden et al. 2014), and cultural and recreational values (Bateman et al. 2010). However, merely quantifying and comparing services provided against the costs to preserve them can overlook other important factors that influence the supply of those services. For instance, the African tourism revenue generated by live elephants exceeds the anti-poaching costs estimated to stop population declines but poaching continues at high levels, putting the species and its services at risk (Naidoo et al. 2016). Incorporating the conflicting perspectives of people who gain from elephant tourism and of those who gain from ivory trade or incur risks from the presence of elephants might shed additional light on the observed outcomes. Indeed, elephants can also cause disservices such as damages to human property (Margalida et al. 2014) or loss of human life and health (Naughton et al. 1999). Disparate uses of wildlife and associated management priorities reflect underlying conflicts and mistrust between stakeholders (Dickman 2010), who likely receive different combinations of services or disservices, perceive them differently, or have different values (Biggs et al. 2017b).

Ecosystem services and disservices can occur at different spatial and temporal scales, further complicating the issue. For example, cultural services provided by African wildlife are enjoyed globally, while crop and livestock damages and the loss of human life are primarily experienced locally (DeMotts & Hoon 2012). Therefore, the operationalization of ESF would benefit from developments that explicitly incorporate social and governance interactions around ecosystem services and disservices.

The social ecological systems framework

Interactions among system components and stakeholders are central to the approach of SESF to identifying the combinations of attributes that lead to sustainable outcomes in common-pool resource systems, such as fisheries, timber, and irrigation water (Ostrom 2007, 2009). Many of these resources are crucial to the economies and livelihoods of human communities but without coordination for long-term conservation, resources can be depleted through individual users following their short-term interest (Berkes et al. 2006). Facilitating norms for coordinated resource use can lead to sustainable management, but success depends on numerous attributes of the system (Gutiérrez et al. 2011). Using SESF, researchers can consider systematically relevant characteristics by organizing them hierarchically into subsystems: the *resource*, the *resource units*, the *users*, and the *governance* subsystems (Figure 1). The *resource* subsystem groups variables that characterize the resource extraction system, e.g., the size, economic sector and productivity, whereas the *resource units* subsystem describes the ecological characteristics and market value of the resource, e.g., the individual animals in the resource population of interest. The *users* subsystem groups variables describing the users of the resource, and the *governance* subsystem includes variables describing the formal and informal management of the system (Ostrom 2007, 2009).

The SESF has led to important insights into sustainable management of common-pool resources, emphasizing the importance of trust and leadership among resource users, as well as distance to markets, and efficient monitoring and sanctioning systems (Gutiérrez et al. 2011; Leslie et al. 2015). However, these analyses incorporate often only the perspective of resource users, and assume that no ecosystem disservices are experienced. This assumption can be allowed in common-pool resource systems, but to leverage the analytical power of Ostrom's SESF for systems with different characteristics, we need to adapt the structure of the framework to the reality of human-wildlife systems by explicitly including also disservices.

The Social-Ecological framework for Ecosystem Disservices and Services

We propose a unified framework combining the social and governance analysis of the SESF with the services and disservices focus of the ESF – the Social-Ecological framework for Ecosystem Disservices and Services (SEEDS). We also draw on the concept of spatial and temporal scales, recognizing that interactions between human well-being and biodiversity can occur both within and across scales (Scholes et al. 2013; Birgé et al. 2016). This new framework has three aims: first, provide a better conceptual basis for understanding human-wildlife systems; second, identify a set of critical variables that would help standardize information across systems and serve as a template for data gathering; and third, facilitate analyses of data across systems to identify common attributes or leverage points that lead to positive social and conservation outcomes in human-wildlife systems. As a diagnostic tool, SEEDS can be used to break down the components of a human-wildlife system, systematically guide consideration of relevant factors and identify drivers of conflict on a case-by-case basis. The insights derived from this diagnostic implementation can then support social-ecological approaches to conservation planning (Ban et al. 2013). The application of SEEDS can also guide future research by helping identify knowledge gaps important for understanding system interactions or anticipating outcomes of potential interventions.

Importantly, working closely with local communities to implement SEEDS will incorporate different stakeholder values and inform the development of coexistence strategies that have broad stakeholder support (Biggs et al. 2017b). The potential users of SEEDS include local decision-makers, conservation planners, community leaders, organizations, and researchers interested in better understanding human-wildlife systems and in achieving positive social and conservation outcomes. The legitimacy of the SEEDS user and the involvement of local stakeholders are essential to a successful implementation of SEEDS (Posner et al. 2016).

Structurally, SEEDS maintains the hierarchical structure of SESF by grouping system attributes into subsystems, but complements it with components that explicitly account for services and disservices (Figure 1). Since stakeholders may have multiple perspectives regarding wildlife that reflect varied relationships with biodiversity (Biggs et al. 2017b), the service and disservice components are included in the *resource* and *resource users* subsystems. Therefore, instead of the *resource* subsystem of SESF (Ostrom 2007), we propose *services* and *disservices* subsystems, each characterizing the type of service or disservice and the spatiotemporal scale at which they are experienced (Figure 2). Instead of the *users* subsystem, we create *service recipients* and *disservice recipients* subsystems. The *governance* subsystem includes information on state, municipal and community institutions, and non-governmental organizations (NGOs) at local, national or international scales that are involved in the management of (dis)services. The governance of services and disservices is sometimes intertwined. For instance, many conservation NGOs are investing in the development of coping strategies with local farmers to minimize wildlife disservices while promoting conservation and just allocation of services (DeMotts & Hoon 2012). The *wildlife* subsystem replaces the *resource units* subsystem and groups variables describing the ecology of the wildlife species considered in the system (Figure 1 & 2).

Interactions among the subsystems influence the outcomes in the human-wildlife system and provide insight into unforeseen or unwanted feedbacks and relationships between services and disservices that need to be addressed for better coexistence (Figure 2). For example, insufficient sharing of economic benefits from ecotourism or inefficient compensation systems are reasons for which local populations can grow intolerant of conservation organizations and wildlife itself (DeMotts & Hoon 2012). While cost and benefit sharing systems result from formal and informal governance structures, the extent to which the cost/benefit sharing is effective, accessible, or fairly distributed depends on interactions among the (dis)service subsystems, the governance subsystem, and the (dis)service recipients (e.g., are they willing and able to participate in cost or benefit sharing programs?). Using SEEDS to analyze the entire human-wildlife system can help conservation practitioners and decision-makers identify which subsystem components or interactions are driving social-ecological outcomes. Furthermore, interactions can feedback to subsystems, leading to further complexity. Through monitoring based on SEEDS and implementing adaptive management (Birgé et al. 2016), stakeholders and local practitioners can identify the actions and interactions that lead to desired outcomes.

Here, we propose a list of variables for each subsystem (Figure 2) to support the operationalization of SEEDS. We do not assume our list to be exhaustive – stakeholders and researchers familiar with a particular system will be best able to identify which variables are most salient for that system – and we hope that it will initiate a wider discussion about identifying the variables relevant for human-wildlife coexistence across systems. Variables in the *services* and *disservices* subsystems specifically quantify the costs and benefits to humans from wildlife populations and can be tracked to illustrate trends in services and disservices over time. These subsystems also include variables capturing the scale of service and disservice (e.g., local, regional, national, global) because discrepancies in scale between services and disservices are a driver of conflict (DeMotts & Hoon 2012). The *governance* subsystem captures aspects of formal and informal governance that may be important for management of (dis)services related to wildlife populations, e.g., the extent of corruption (Anthony et al. 2010), level of bureaucracy (Barua et al. 2013) and local community involvement (Smith et al. 2012). The *service* and *disservice recipients* subsystems identify the characteristics of stakeholders experiencing ecosystem services and disservices which may influence human-wildlife conflict, including their gender, ethnic, economic, socio-political, and geographic distribution (DeMotts & Hoon 2012). These subsystems also include variables related to individual's tolerance and stewardship behaviors, attitudes, including participation in organizations and social networks that can influence social norms and decision-making (Burt 2000; Lin 2002). Local leadership, which can indicate improved coordination in solving conflicts or sharing compensation (Gutiérrez et al. 2011), is included here as well. The *wildlife* subsystem captures functional and life history traits that can affect recovery rates from illegal hunting such as generation time, or the severity of threat to human life such as animal body mass (Naughton et al. 1999).

Implementation of SEEDS

We propose a 7-step approach that seeks to characterize each of the subsystems in a logical and sequential way (Fig. 3). The activities outlined below are not intended to be an exhaustive list nor is the order of the steps unchangeable. For example, the system boundary (Step 1) may need to be redefined after the attributes of the *wildlife units* subsystem have been examined (Step 2). However, using the 7-step approach as a template when analyzing human-wildlife systems ensures thorough consideration of essential components.

Defining the system boundaries (Step 1). Determining the spatial boundaries of the system depends on who conducts the analysis and the focus of the analysis. If the focus is a single species, the system boundary might largely be defined by boundaries of distinct population units (Leslie et al. 2015). For example, the analysis might encompass the entire range of a species if that animal is geographically constrained, such as on an island. In contrast, the spotted hyena (*Crocuta crocuta*), which both depredates livestock (i.e., disservice), but also removes dangerous organic waste from the landscape (i.e., service), occurs across much of sub-Sahara Africa (O'Bryan et al. 2018). In that case, defining the system of interest around a distinct population of spotted hyenas, such as in peri-urban areas of northern Ethiopia, would be more relevant to understand different dynamics at finer resolutions than considering the whole range of the species (Abay et al. 2011). It is also important to consider that human-wildlife systems often comprise several co-occurring wildlife species that provide bundles of services and disservices. Moose (*Alces alces*) and gray wolves (*Canis lupus*), for example, form a tightly linked predator-prey system, with each species providing various services (e.g., ecotourism revenue from wolf watching, moose hunting) and disservices (e.g., moose-vehicle collisions, reduction of game species by wolves). In this case, the system boundary would be defined based on bundles of where those services and disservices of the co-occurring species overlap (Martín-López et al. 2017). Lastly, if the emphasis is on a specific administrative unit, such as a protected area, then the system boundary would encompass a sufficiently large area that accounts for important political, social and ecological linkages to the protected area (Hansen et al. 2011). Whether one treats factors and processes as external to the system of interest depends on how boundaries are defined. If the system boundary encompasses a protected area, for example, then the market forces driving tourism to the reserve would be considered external to the system.

Define the wildlife units subsystem (Step 2). Information on the wildlife units of interest includes attributes regarding species behavior, biology, life-history, ecology, personality, and population trends and threats. These data can come from primary (e.g., new data collection) and secondary sources (e.g., government reports) as well as from local or indigenous communities, such as from traditional ecological knowledge (Berkes et al. 2000). Combined, this information helps us understand which interventions or conservation policies are likely to be most effective. For cognitively advanced species, for example, the simultaneous use of lights, audio playbacks, and adverse taste or scent conditioning can be effective non-lethal methods for reducing wildlife disservices, such as crop damage or livestock depredation (Barrett et al. 2018). Detailed information on an animal’s ecology, habitat, and food requirements can also help predict services and disservices. Big cat species attract tourists from around the world and are cultural symbols; however, because they are obligate carnivores requiring large amounts of meat they are more likely to kill livestock when wild prey numbers drop below minimum thresholds (Khorozyan et al. 2015).

Define the service and disservice subsystems (Step 3). Next, the types and spatiotemporal patterns of services and disservices that wildlife provide are defined. Although some species are often associated with either services or disservices, attention should be paid to including both. For example, leopards (*Panthera pardus*) kill livestock and pose risks to human safety, yet leopards surrounding Mumbai, India are known to consume feral dogs, which not only reduces bite and rabies incidents but also reduces dog management costs (Braczkowski et al. 2018). Multiple scales should also be considered. At broader regional scales, vultures provide widespread services by removing carcasses and recycling organic matter; whereas, at local scales farmers can experience disservices associated with occasional vulture predation on livestock (Margalida et al. 2014; Morales-Reyes et al. 2015). At this step, it is important to recognize the power imbalances in the system, which can make certain services and disservices less visible to decision-makers (Felipe-Lucia et al. 2015). Here, the SEEDS implementer would benefit from recent developments in ecosystem service research that help identify and catalogue (dis)services based on stakeholders input (Chan et al. 2012). A considerable challenge at this stage of the process is explicitly including diverse stakeholder perspectives, which will require effective insulation of the implementer from the power imbalances and political pressures in the system (Chan et al. 2012).

Define the recipients of the services and disservices (Step 4). After characterizing the (dis)services subsystems, attributes of the recipients are defined, including demographics, spatial distributions, attitudes and norms, and membership or participation in various organizations. For example, in the case of elephants, disservice recipients primarily include farmers who directly or indirectly incur costs from property damage. Whereas, service recipients include tourists, employees of tourist operations, local businesses that benefit from tourists, individuals who value elephants for aesthetic and cultural reasons, and those who benefit from selling ivory. Indeed, heated debate about ivory trade can be thought of as a conflict between two types of service recipients with different value structures. Referred to as a “taboo tradeoff,” one group views the death of elephants for ivory as morally unacceptable and another group views the legal trade of ivory as a means to promote conservation (Biggs et al. 2017b). Because the provision of (dis)services is, in part, a function of human-wildlife interactions, the geographic distributions of both wildlife and people influence who is a recipient of (dis)services. In Nepal, farmers who lived farther from the city and were from marginalized ethnic groups were more likely to attribute tigers (*Panthera tigris*) with disservices (Carter et al. 2014). In addition, participation or membership in certain organizations can affect how stakeholders perceive (dis)services in the system considering that even purely functional associations for information exchange can lead to deeper social relationships and common values (Bodin & Crona 2009).

Define governance subsystem (Step 5). Governance of human-wildlife interactions is often a mosaic of institutions, policies, and practices. Furthermore, for a single species, governing bodies can exist at local, national, and international scales and include non-governmental organizations (NGOs). For example, gray wolf packs in and surrounding Yellowstone National Park are managed by the U.S. National Park Service and three surrounding state agencies with several NGOs promoting various management options (e.g., hunting wolves, reducing conflict with ranchers, buying land to increase landscape connectivity). Identifying the different governing bodies is important because they can have different missions and management approaches, making development of coexistence strategies across jurisdictions a challenging task (Smith et al. 2016). Furthermore, the specifics of any cost and benefit sharing programs should be defined. For example, programs to compensate property damage from wildlife exist in many places; however, their effectiveness is equivocal and depends on a number of factors, such as whether compensation is contingent on property protection measures already in place (Carter et al. 2016; Nyhus 2016). Likewise, payments for ecosystem services or revenue-sharing programs are economic tools that can increase wildlife services, by allocating the monetary benefits from wildlife to different stakeholder groups (Gómez-Baggethun et al. 2010). Defining attributes of property rights to wildlife and the process of making decisions about wildlife is also important because they can strongly influence who accesses wildlife (dis)services. Indeed, reconciling different, or clarifying, property rights to wildlife constitutes a key challenge in achieving coexistence (DeMotts & Hoon 2012; Treves et al. 2017). Similarly, issues about legitimacy, accountability, and power dynamics in decision making are germane to sustainable human-wildlife systems (Redpath et al. 2017).

Identify interactions among subsystems and resultant outcomes (Step 6). Because human-wildlife systems can be complex, identifying interactions among subsystems and their resultant outcomes in SEEDS in a non-trivial task that constitutes the bulk of investigation. Working closely with a range of stakeholders (e.g., local communities, government authorities, researchers, NGOs) is especially important during this step as they can shed light on the nuanced, highly contextual factors shaping human-wildlife interactions and outcomes, some of which are unanticipated. For instance, policies enacted by the European Union in response to Bovine Spongiform Encephalopathy outbreaks limited the availability of food resources (SEEDS interaction – Figure 2) for Eurasian griffon vultures (*Gyps fulvus*; Margalida et al. 2014). The resulting food shortages may have contributed to the apparent increase in vulture attacks on livestock, which resulted in retaliatory killing by ranchers (SEEDS outcome – Figure 2; Margalida et al. 2014). Similarly, culling of the European badger (*Meles meles*) to reduce transmission of bovine tuberculosis to cattle in Britain (SEEDS interaction) actually increased the spread of the disease in space (SEEDS outcome), because the social instability caused when badgers are killed is thought to increase opportunities for disease transmission (Bielby et al. 2014). Human-wildlife systems are constantly changing, and therefore iteratively documenting the SEEDS interactions and outcomes that alter the provisioning of wildlife (dis)services over time is important (Ruckelshaus et al. 2015). For instance, when double-crested cormorants (*Phalacrocorax auritus*) in the Great Lakes Basin, USA, were endangered in the 1970s, local communities viewed them as an iconic and important avian species, but as cormorant numbers have rebounded people are increasingly associating them with greater disservices, such as posing risks to recreational fisheries and island vegetation (Muter et al. 2009). Finally, attention should be given to understanding the mechanisms driving change in human-wildlife interactions and (dis)services; co-adaptation between humans and wildlife and broad-scale patterns of modernization can shift how people perceive the costs and benefits associated with wildlife (Carter & Linnell 2016; Bruskotter et al. 2017).

Identify where changes can be made (Step 7). Using SEEDS to integrate a diversity of contexts, perspectives, data, and foci of inquiry can help reveal key knowledge gaps and leverage points for promoting human-wildlife coexistence in a given system. By viewing wildlife and humans as fellow actors in shared landscapes, SEEDS can facilitate new areas of interdisciplinary research such as how social networks, governance structures, or power relations influence the distributions of wildlife (dis)services. Likewise, a greater understanding of the *wildlife units* subsystem and its interactions with other subsystems can elucidate methods for evaluating and predicting how wildlife will respond to varying social-ecological conditions (Bunnefeld et al. 2011). Furthermore, deliberative, participatory processes (e.g., collaborative learning, structured decision making) with different stakeholders, especially the recipients of (dis)services, will help ensure that insights from SEEDS are effectively and ethically applied on-the-ground and in conservation planning processes (Ban et al. 2013). These processes can facilitate joint exploration of consequences of different actions (Maxwell et al. 2015) and of desirable outcomes, and therefore facilitate adoption of new practices or interventions. For example, a recent “Theory of Change” for engaging communities as key players in combating illegal wildlife trade accounts for key enabling and disabling conditions for successful interventions (Biggs et al. 2017a).

Conclusion

SEEDS is well suited for aligning and integrating a range of conservation frameworks and approaches with the expectations and priorities of local stakeholders. For instance, several frameworks proposed in the field of human-wildlife systems (Henle et al. 2013; Carter et al. 2016) could provide input at different steps of SEEDS, especially in understanding interactions and outcomes. Moreover, SEEDS could be modified to analyze services and disservices in other SES by developing specific subsystems based on the biodiversity or ecosystem component of interest, e.g., an *invasive species* subsystem would replace *wildlife* to understand the services and disservices associated with an invasive species (Pejchar & Mooney 2009).

Panaceas do not exist for complex problems in social-ecological systems (Ostrom 2007), including systems where human and wildlife have to share landscapes. Nevertheless, there is a tendency in the literature to reduce systems to a limited perspective, focusing either on managerial solutions in isolation (Mateo-Tomás et al. 2012), or describing the cultural and social dynamics (DeMotts & Hoon 2012). The absence of long-term and durable solutions in most cases highlights that these limited perspectives might be insufficient to address the challenges of human-wildlife coexistence. Here, we have described how SEEDS builds on the strengths of the existing social-ecological frameworks to better understand the drivers and interactions shaping coexistence and conflict in human-wildlife systems. Further use and development of SEEDS will hopefully enable practitioners, researchers, and local communities to synthesize their knowledge in order to facilitate the sustainable coexistence of humans and wildlife.

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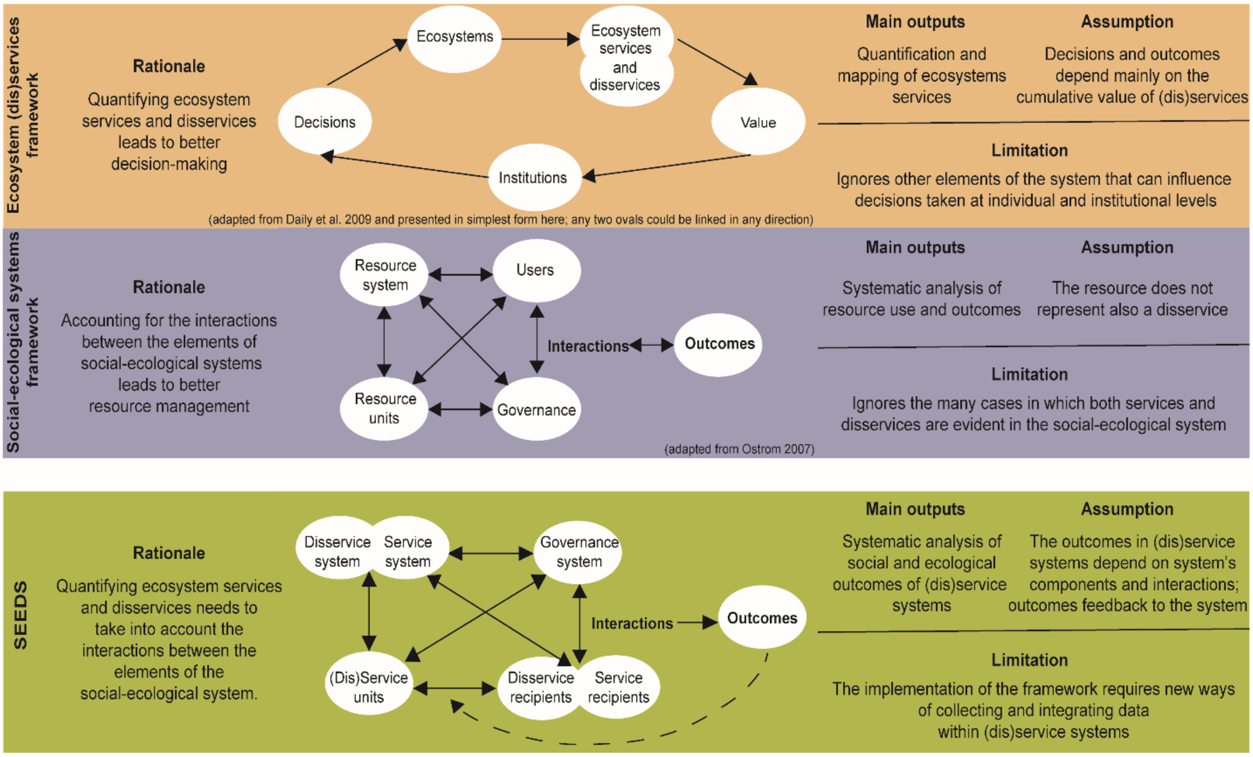
Figure captions

Figure 1. Summary of relevant characteristics of the frameworks of Ecosystem Services, Social-Ecological Systems, and of the unified Social-Ecological framework for Ecosystem Disservices and Services (SEEDS).

Figure 2. The Social-Ecological framework for Ecosystem Disservices and Services (SEEDS) can be operationalized by identifying and measuring the variables (grey columns) and their indicators (white columns) that best characterize each subsystem within the human-wildlife system. We present a provisional, non-exhaustive list of variables, potential interactions, and outcomes that can be identified by incorporating ecosystem disservices and services in analyses of human-wildlife systems.

Figure 3. Steps for analyzing human-wildlife systems according to SEEDS. These steps enable systematic, qualitative analysis of a human-wildlife system. Applying these steps to multiple human-wildlife systems can then enable quantitative analyses across systems to provide generalizable insights.



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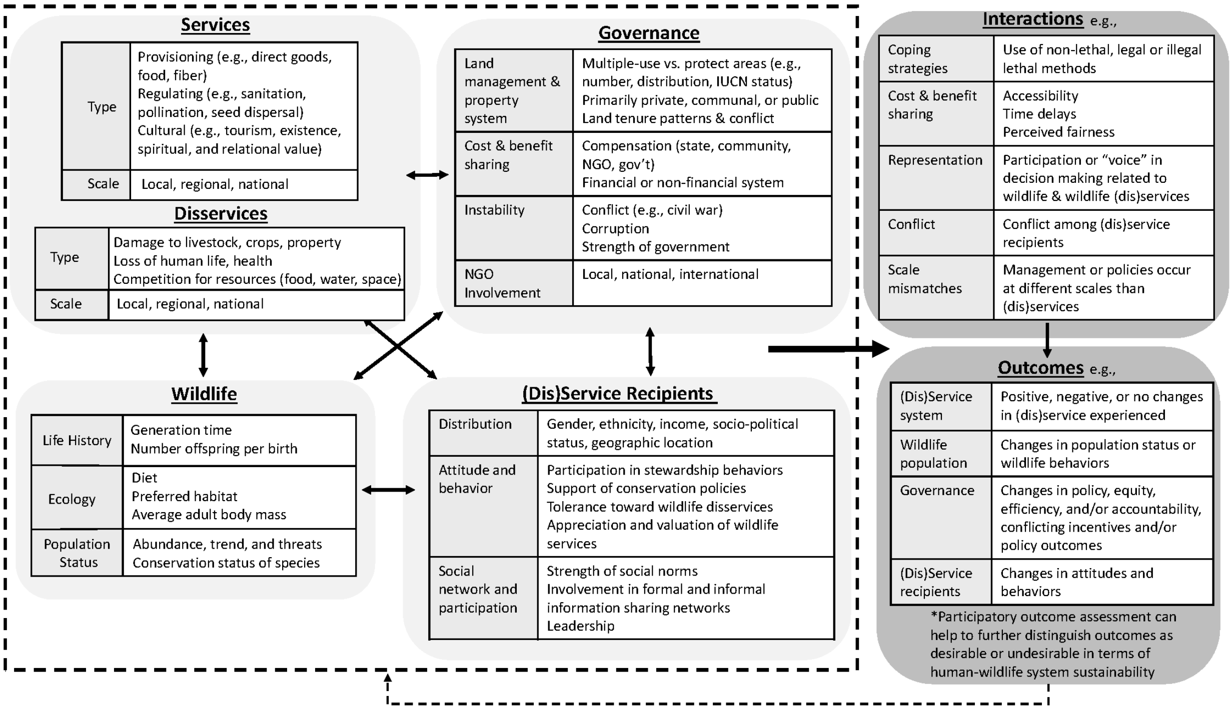

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