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REVIEW

A Review of Social Dilemmas and Social-Ecological Traps in Conservation and Natural Resource Management

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Abstract

Successful conservation depends as much on people working together as it does on sound science and good governance. Research on cooperation in businesses, economics, psychology, and natural resource management has identified shared social and social-ecological dynamics, reviewed and categorized in this article that can create unwanted surprises and problems for conservation efforts. Cooperation may fail when: (1) individual and group benefits are in conflict (social dilemmas) or (2) social-ecological systems become caught in problem-causing and problem-enhancing feedbacks (SES traps). Knowing about and recognizing these dynamics can help decision makers to understand and change key elements of problems and learn from the experiences of others. Social dilemmas have winners and losers, and involve give-some or take-some choices; SES traps are lose-lose situations. Solutions to problems of cooperation in conservation contexts involve identifying the conservation objective and context, diagnosing systemic social dilemmas and SES traps, and developing practical solutions that work with group processes and individuals toward shared and positively reinforcing goals, goal structures, and expectations. Research on cooperation in conservation has largely ignored problems of scale, scaling, and group heterogeneity. The field would benefit from a shift from a probabilistic, empirical approach to a stronger theory-driven, mechanistic, and more diagnostic approach.

Introduction

The importance of "creative cooperation" for conservation was noted over 30 years ago in one of conservation biology's seminal texts (Soule 1986, p.11). As the scale of conservation initiatives has increased, the need for cooperation in conservation continues to grow (Guerrero *et al.* 2015). In many locations, conservation is also expected to contribute to community development objectives via collaborations between conservation biologists, NGOs, and local communities (Berkes 2004). Deep understandings of cooperation and how it can be achieved are therefore essential for effective conservation practice. The literature on cooperation has not been previously synthesized in a conservation context, however, and the mechanisms underlying the success or failure of cooperative efforts in conservation (e.g., through creation of unintended feedbacks; Larrosa *et al.* (2016)) remain unclear.

A lack of cooperation in conservation may arise for many reasons. Individual willingness to cooperate, for example, may be reduced by differences in values and perceptions, problematic interpersonal dynamics, asymmetries in power, or a lack of clarity on benefits and tradeoffs (e.g., Waylen *et al.* 2010; Dharmawan *et al.* 2016; Paloniemi *et al.* 2017). However, resolving one or more of these concerns (e.g., by providing more scientific information and improving community representation in decision making) does not always work. Although each failure may appear unique, research has identified a number of recurring system dynamics that can create unwanted surprises and/or problems in efforts to solve problems of resource use and management. Recognizing these dynamics in conservation can help people to understand their own difficulties and learn from the experiences of others when resolving them.

The scope of this review includes conservation and natural resource management and related research in economics, psychology, and business management. I will: (1) explain management syndromes and propose a new typology of dilemma and trap situations in natural resource management; (2) present a comprehensive summary, based on an exhaustive literature search, of different kinds of dilemma and trap; (3) explain some of the additional complexities that may arise in conservation management; and (4) discuss potential solutions to social dilemmas.

Introducing management syndromes

"Management syndromes" are characteristic sets of co-occurring actor and system behaviors, such as overharvesting or social conflict, that negatively impact natural resources and/or the communities that depend on them. Formal analysis of management syndromes as a paradigm for research on global sustainability was proposed by Schellnhuber *et al.* (1997) and Lüdeke *et al.* (1999). Clark *et al.* (2005) have argued that the "semi-quantitative, yet fully formalized techniques... employed in syndromes analysis, hold a huge potential for... scientific description of complex systems characterized by strong nature–society interactions." Some examples of specific management syndromes that have received attention in conservation biology include shifting baseline syndrome (Pauly 1995; Papworth *et al.* 2009), Sahel syndrome (Lüdeke *et al.* 1999), and the "pathology of natural resource management" (Holling & Meffe 1996).

The literature on management syndromes in conservation can be traced to three different schools. The first and oldest of these focuses on social dilemmas, which are also referred to as "social traps" (e.g., Platt 1973; Barry & Bateman 1996). This school draws heavily on perspectives on human behavior derived from economics, game theory, evolutionary theory, and experimental psychology. It includes many mechanistic and experimental approaches to human behavior and contains a considerable wealth of detail and ideas. A good overview of this literature is provided by Van Lange *et al.* (2013).

Second, there is a body of research in ecology and environmental science that uses a systems perspective to diagnose and resolve or avoid social-ecological traps (e.g., Lebel *et al.* 2011; Enfors 2013). To avoid potential confusion with "social trap," I will limit my use of "trap" to discussions of social-ecological systems (SES) traps. SES traps describe core natural and human elements of conservation management problems, focusing on key dynamics such as feedbacks between different system components and their influence on social-ecological adaptation and transformation (Carpenter & Brock 2008; Enfors 2009). Analyses of SES traps generally do not use or offer in-depth perspectives on actor motivations and psychology.

Third, there has been a considerable amount of conservation-related research on the problems of sustainable management and resource harvesting. This literature deals with styles of management (e.g., command and control management, adaptive management) and the management problems that commonly arise in social-ecological systems (Holling & Meffe 1996; Walters 1997; Gunderson 1999; Gunderson & Light 2006). It differs from the SES trap literature by largely ignoring or simplifying the complexity of social feedbacks to managers and resource users (often excluding people as actors in ecological models) and in its focus on how to manage variance in the supply of ecosystem services (Carpenter & Brock 2006). Its primary *modus operandi* has been to use a scenario-based or pseudoexperimental modeling approach to inform management decisions (e.g., Wadsworth *et al.* 2000), without questioning manager goals and motivations. For example, the parameters of an ecological limit to growth model of an expanding herbivore population in a small protected area may be manipulated to explore alternative management strategies (Starfield & Bleloch 1991). Many management problems, such as failures of adaptive management efforts (Walters 1997), can be more deeply understood from the perspective of individual motivations as either social dilemma or SES trap situations.

A framework for management syndromes in conservation

Strictly speaking, a dilemma is a form of logical problem to which there are only two alternative solutions or responses, and both are unfavorable. Responses to logical dilemma problems in philosophical argument generally involve either exposing the dilemma as a fallacy, reframing it as a compromise, or finding a third solution that the original problem statement did not consider. For example, on islands off the coast of South Africa, endangered White Pelicans feed on the chicks of endangered Cape Gannets and Cape Cormorants (Mwema *et al.* 2010). Should managers enhance the survival of the pelicans by letting them forage on other endangered species; or protect gannets and cormorants, with negative impacts on the pelican population? The horns of this dilemma can be escaped by identifying the other assumptions on which the argument is predicated, which include: (1) that the pelicans have no alternate food source (they do); (2) that a single choice must be followed (it would also be an option to sometimes favor one species and sometimes the other); (3) that impacts on juvenile survivorship are sufficient to affect population sizes of both species (currently unclear); and (4) that protection is a viable option (on uninhabited offshore islands).

Platt (1973) defined social dilemmas explicitly as situations in which there is opposition between a highly motivating short-term reward (or punishment) for an action and its long-term consequences. Social dilemmas also include situations in which individual and group benefits are in conflict (Barry & Bateman 1996). In game theory, a dilemma game is one in which all players have dominating positions that result in a deficient equilibrium (Dawes 1980; Macy & Flache 2002). Van Lange *et al.* (2013) have proposed an all-inclusive definition of social dilemmas as "situations in which a noncooperative course of action is (at times) tempting for each individual in that it yields superior (often short-term) outcomes for self, and if all pursue this noncooperative course of action, all are (often in the longer-term) worse off than if all had cooperated."

These definitions of social dilemmas are distinct from definitions of SES traps, which are viewed as persistent, self-reinforcing system dynamics (i.e., situations that are maintained by strong feedback loops) with negative outcomes for people and/or ecosystems (Carpenter & Brock 2008; Enfors 2009; Cinner 2011; Enfors 2013). Cinner (2011), for example, defined SES traps as occurring when "feedbacks between social and ecological systems lead toward an undesirable state that may be difficult or impossible to reverse." It is taken for granted here that "undesirable" describes the perspective of all of the actors in the problem situation, reflecting the principle that both individuals and groups generally emerge as losers in SES traps. SES traps do not necessarily involve true dilemmas, in the form of conflicts between individual or near-term outcomes and collective or long-term consequences. Poverty traps and rigidity traps, for example, involve both short- and long-term losses to both individuals and society (Carpenter & Brock 2008; Kim & Loury 2014).

Many other kinds of "trap" described in the SES literature are better described as social dilemmas. A "gilded trap," for instance, occurs when group actions resulting from economically attractive opportunities outweigh concerns over associated social and ecological risks or consequences (Steneck *et al.* 2011). If fishing in a fleet yields economic benefits for a group, high financial rewards for individuals within the group can create a strong reinforcing feedback that deepens the trap. Its fundamental dynamic is that of a classical social dilemma in which short-term and long-term benefits are traded off against each other.

Such confusion arises easily because the study of management syndromes in the context of conservation and natural resource management has lacked a clear organizing framework that integrates perspectives on social dilemmas and SES traps. Brewer & Kramer (1986) made an important distinction between "give some" and "take some" dilemmas. Give-some problems involve a higher cost or loss to the individual than to the group, while take-some problems involve a higher cost or loss to the group. Although this division does not directly include "give or take some" (GOTS) dilemmas, which share elements of both (McCarter *et al.* 2011), it provides a sensible organizing framework from which GOTS dilemmas can also be approached.

If we define SES traps strictly as situations in which both individuals and groups stand to lose, then contrasting group outcomes (positive or negative) against individual outcomes (positive or negative) suggest four fundamentally different kinds of management syndrome that are relevant to conservation (Figure 1). A wide range of examples (reviewed in Table 1) has been documented in each category. Many of these examples will be unfamiliar to conservation biologists. Awareness of traps and tradeoffs in politically sensitive situations is important, however, particularly for those who must navigate complex interpersonal dynamics in order to achieve conservation goals. Figure 1 and Table 1 provide examples against which a specific conservation problem can be considered. Once a management syndrome has been diagnosed, it becomes easier to solve.

Additional complexities

In complex decision-making situations, awareness of potential confounding factors and unexpected outcomes can help managers to plan and improve their approach. Resolution of social dilemmas and SES traps in conservation can be complicated by: (1) system dynamics; (2) the nature of lock-in; (3) questions of scale and heterogeneity; and (4) the psychology of choice and decision making.

System dynamics

SES trap and social dilemma situations develop over time. Changes in system dynamics can be counterintuitive and difficult to predict, particularly when they involve structural changes within a system rather than simple incremental change. It is important that the potential consequences and knock-on effects of conservation actions are considered carefully and critically before they are

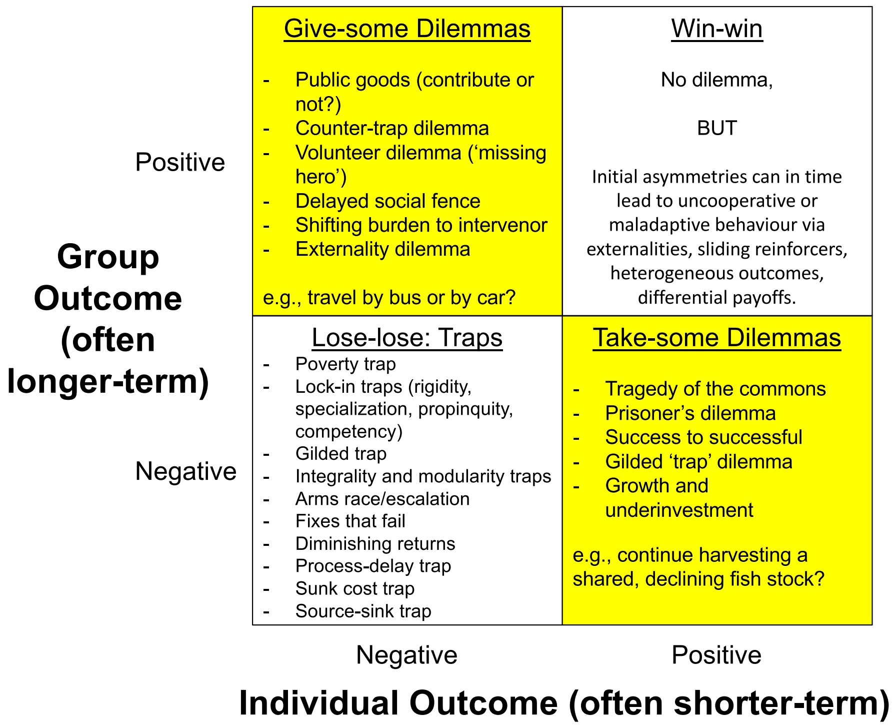

Figure 1 The three different kinds of management syndrome, and examples of each.
This framework contrasts the four different combinations of individual benefits and group benefits. The time scales for different actors are difficult to portray graphically, but as indicated by Platt (1973), the assignment of a lower value to more distant benefits plays an important role in social dilemma situations because individual costs and benefits are often, but not always, more immediately experienced, more tangible, and more sure to be received than group benefits. For example, deciding to take a bus rather than a car to work in order to reduce carbon dioxide emissions is a worthy long-term contribution to society, but its benefits to the individual are likely to be much less obvious than the convenience of driving. The social dilemmas and SES traps associated with each box are discussed in more detail in Table 1 and the following text.

undertaken. For example, the economist T. S. Jevons showed for the coal industry in England that more efficient use of coal had led to higher (not lower) net use (Alcott 2005). Similarly, efforts to reduce electricity consumption using energy-efficient vending machines led to greater overall environmental impacts by making machines more affordable (Polimeni 2012). Jevons's paradox illustrates how attempts to manipulate complex systems can backfire.

Another example of an unexpected system dynamic is termed the Streisand effect, after the singer Barbara Streisand (Zuckerman 2014). It refers to the phenomenon whereby an attempt to hide, remove, or censor a piece of information has the unintended consequence of publicizing the information more widely, usually facilitated by the Internet. Streisand complained to Google Earth about her house being too visible in their imagery, and publicity around her request led to thousands of people going online to see it. The Streisand effect may lead to surprises in conservation, for instance if agencies unintentionally build up much greater than intended public interest in a rare or fragile species by restricting habitat access and/or trying to conceal information on its location.

Clearly, if selfish and/or short-term behavior can increase the rewards for such behaviors, individuals may get stuck in a self-reinforcing feedback. In this way, the creation of social dilemmas and SES traps can show strong path dependence (i.e., a system's later dynamics depend strongly on its starting point). Boonstra & de Boer (2014) have argued that social dilemmas are better understood as processes than as situations, and that entering a dilemma or SES trap situation depends on a critical sequence of events at a critical juncture in time.

As problems develop, the nature of some actions or system elements may change. Actions that initially yield positive outcomes but start to produce progressively more negative outcomes, or small interventions that have a beneficial effect while larger interventions of the same kind have a negative effect, are termed "sliding reinforcers" (Costanza 1987). Recreational and medicinal drugs are examples of sliding reinforcers. In conservation

Table 1 A summary of the three different kinds of potentially problematic syndromes in conservation biology and natural resource management: give-some dilemmas, take-some dilemmas, and SES traps. This table summarizes dilemmas, traps, and "systems archetypes" from several different fields

Syndrome type and definition	Dilemma name	Explanation	Example(s)
Give-some dilemmas	Public goods dilemma or social fence	An action that results in some cost to an individual leads to an increased benefit for society, but only if sufficiently many people cooperate (Platt 1973).	Recycling, climate change (reducing carbon emissions), traffic congestion (e.g., taking public transport or avoiding car use).
	Delayed social fence dilemma	As above, but with a delay between action and outcome (Van Lange *et al.* 2013).	Reductions in charitable donations lead to closure of local conservation programs; loss of a conservation organization's positive culture due to employees' unwillingness to engage in extra role (or organizational citizenship) behaviors, such as helping new employees adjust.
	Volunteer dilemma or missing hero dilemma	Achieving a goal that benefits the group depends on the willingness of one or more individuals to give up their time or incur other costs (Barry & Bateman 1996).	Attend meetings and social events with potential conservation donors; leading a group-written scientific paper or proposal, or organizing a workshop.
	Countertrap dilemma	Similar to missing hero; the cost of encouraging give-some behaviors or countering take-some behaviors becomes too high for an individual (Platt 1973).	A conservation manager's short-term personal interest in avoiding a bothersome confrontation with a protected area visitor or employee precludes action that will create long-term benefits.
	Shifting burden to intervenor	A different kind of give-some dilemma in which a well-meaning external agent provides short-term intervention to solve a problem and becomes central to its continued solution. Following their departure, the system degrades or collapses (Senge 1990).	Common dilemma for aid agencies and conservation NGOs that focus on problem solving or conservation efforts without sufficient capacity building.
	Externality dilemma, also termed an "asymmetric trap"	Differences in the costs or rewards experienced by individuals who exert equivalent effort can lead those receiving higher costs or lower benefits becoming less cooperative, reducing overall group benefits (Murnighan *et al.* 1990).	Jealousy or corruption within a conservation organization can lead to in-fighting and a reduction in its effectiveness.
Take-some dilemmas	Tragedy of the commons	A common property resource is overexploited when individuals seek additional benefits by taking more than their fair share (Hardin 1968).	Many common conservation problems: overgrazing, overfishing, overhunting.

(*Continued*)

Table 1 Continued

Syndrome type and definition	Dilemma name	Explanation	Example(s)
	Success to the successful; winner-takes-all; economics over ecosystems	A successful individual is able to access more resources and use them become increasingly more successful, leading to rising social inequity and injustice at the group level (Senge 1990).	Capitalism; habitat fragmentation by development; takeovers of indigenous property for protected area creation.
	Gilded "trap" dilemma	A collective, operating unsustainably, makes such high profits that they are unwilling to lower their harvesting levels to reduce environmental impact (Steneck *et al.* 2011).	Overfishing on the high seas.
	Growth and underinvestment	As a company or a conservation initiative grows, individuals extract too much of the benefit and fail to invest sufficient resources in continued success (Senge 1990).	A conservation organization that focuses on species conservation without engaging in outreach and providing benefits to the surrounding human community "takes" conservation benefits but slowly loses local credibility and political support, eventually leading to a failure of the initiative.
	Prisoner's dilemma	In situations where the potential payoff from defecting is higher but less assured than that of cooperating, individuals may decide to defect (Dawes 1980).	Corruption in conservation. A single corrupt individual may be able to benefit unfairly from conservation-derived revenue, but if several individuals help themselves to proceeds or extort bribes, then the entire initiative may lose credibility and collapse.
Lose-lose syndromes: SES traps	Poverty trap	Escaping poverty requires having capital to invest in a business. Those living in poverty have no capital and struggle to raise it (Rosenstein-Rodan 1961).	"Hungry people cannot do conservation"; fishermen living in poverty overexploit fish stocks because they see no alternative.
	Integrality and modularity traps	Integrality traps occur when a firm or organization remains integrated even if technology becomes more modular. The firm must then develop an administrative approach to accomplish what other firms achieve through the market. Modularity traps describe the inverse; getting stuck in a modular way of doing things when it makes better sense to be integrated (Nonaka & Takeuchi 1995).	Integrality: protected area managers who insist on doing all their own research and monitoring, when university researchers could do it more efficiently and more cheaply; or refuse to outsource loss-making accommodation or catering services. Modularity: having endangered species conservation plans developed and applied individually, by state or province, instead of nationally, can lead to local inefficiencies and potential overall failure.

(*Continued*)

Table 1 Continued

Syndrome type and definition	Dilemma name	Explanation	Example(s)
	Lock-in traps: rigidity, specialization, competency, and propinquity traps	A set of closely allied traps that reflect an unwillingness to change.	Lack of flexibility is common in governmental resource management agencies, where people are often kept too busy "doing what they have always done" to confront change.
		Rigidity trap: organizations cannot or will not change an approach during a crisis because management structures/institutions are too inflexible to adapt (Gunderson 1999, Butler & Goldstein 2010).	Rigidity, specialization, and competency traps are common in conservation biology when better approaches and/or new information are developed but conservation organizations refuse to adopt them. For example, new management perspectives on fire suppression were slow to be adopted by fire specialists in the United States. Failure to move on both harms the individual and wastes group resources.
		Specialization trap: an individual or organization becomes specialized in a single area and becomes redundant when conditions change (Levitt & March 1988).	
		Competency trap: a person or organization becomes good at doing something and keeps doing it that way, even when better ways of doing it are available—hence gradually becomes obsolete.	
		Propinquity trap: new solutions are assumed to be similar to previous solutions, curtailing original and more effective solutions. Maturity traps (hiring only seasoned workers or using only tried and trusted solutions) and familiarity traps (favoring the familiar over better but less familiar alternatives) are specific cases of the same phenomenon (Ahuja & Morris Lampert 2001).	Like rigidity traps, propinquity traps arise in conservation when organizations are reluctant to embrace entirely new ideas and approaches, even when current methods are failing. For example, management of rhinoceros poaching focused for many years almost entirely on controlling illegal hunting, even when it became obvious that this was only part of the solution.
	Arms race (escalation)	Competition between continually evolving competitors leads to increasingly specialized and expensive investment in defense or competition for one kind of situation, both reducing available capital for other ventures and creating vulnerabilities in other areas.	In protecting populations of endangered species, increasingly sophisticated poachers and antipoaching operations.

(*Continued*)

Table 1 Continued

Syndrome type and definition	Dilemma name	Explanation	Example(s)
	Fixes that fail	An attempted solution fails to work. Instead of trying a different approach, a greater quantity or higher level of the same solution is attempted (Senge 1990).	Many common problems in natural resource management. For example, captive breeding programs that try to release increasingly more individuals into sink areas; constructing more and more accommodation to try to revive failing ecotourism initiatives; efforts to control supply without considering demand.
	Diminishing returns	After an initially promising period, the marginal return on an investment begins to decline. Eventually, expenditure to achieve the same return becomes too high to maintain. By then, the expenditure is locked-in (Boserup 1981).	Common in situations where resources or habitats are spatially distributed. Initial efforts focus on nearer and richer resource patches and/or populations that are easiest to conserve; subsequent efforts must go further and exploit (or conserve) less rich patches, leading to increased costs and declining returns. In conservation, may occur in land-purchasing programs.
	Process-delay trap	When there is a lag between an action and a system response, managers can become trapped in a reactive cycle that erodes political trust and support (Senge 1990).	Habitat restoration or population protection for a slowly growing or late-maturing organism may take decades to yield obvious benefits, leading to claims of conservation failure and abandonment of programs. For example, sea turtle conservation, assessment of effectiveness of marine no-take zones.
	Sunk cost trap or Concorde effect	Rational decisions are impeded by the amount of effort or capital that has already been invested in a project or product, even though this is not directly relevant to decisions about its future (Arkes & Ayton 1999).	Classical problem in monitoring, where many long-term monitoring efforts that are useless for management or scientific knowledge are perpetuated simply because they exist. Also arises in such cases as unsuccessful captive breeding programs, refusal to change poorly designated protected area boundaries, and allowing existing infrastructure (roads, buildings, boat landings) to dictate future development plans for protected areas.
	Source-sink trap	This is a spatially explicit trap in which an area that is a net producer of organisms or other mobile resources (a source) is physically or economically connected to another area that is a net consumer (a sink). Resource depletion in the sink area can deplete the source population and/or reduce its growth rate and benefits (Dias 1996).	Ecological trap: sink areas in buffer zones of protected areas (van der Meer *et al.* 2014).

contexts, sliding reinforcers can include such phenomena as the construction of infrastructure (roads may allow an area to benefit from ecotourism, but also facilitate the entrance of undesirable influences, such as poaching); gradual changes in the demands of resource users (e.g., unreasonable expectations for increases in hunting quotas that were originally designed to facilitate responsible co-management); pesticide and fertilizer use (small amounts can improve crop yields, but overuse harms the environment); and deliberately introduced exotic species, such as biocontrol agents, that are initially beneficial but subsequently become invasive.

Feedbacks may influence the values of two variables of interest in the same direction simultaneously, meaning that correlations and other simple statistics are not suited to detecting them. In general, detecting the effects of conservation actions on social-ecological dynamics and feedbacks requires monitoring elements of both the social and the ecological system (Reyers *et al.* 2013) and making sense of change through a formal systems model that refers to a suitable baseline (Cumming & Collier 2005; Cumming *et al.* 2005).

The nature of lock-in

Lock-in of social dilemmas occurs when it is difficult for individuals or groups to change their behaviors without incurring a large penalty (whether social, political, or economic). Platt (1973) described three forms of locked-in situations in collective action (group action) problems: the invisible hand, the invisible fist, and the invisible chain. The invisible hand, following Adam Smith, emphasizes the role of markets and aggregated individual choice in creating and stabilizing group norms. Repeated interactions between people lead to an accepted set of norms and behaviors that guide individual actions without necessarily requiring formal expression. The invisible fist, by contrast, arises when competition does not produce stability, but instead leads to escalation or elimination. Platt (1973) placed arms races in this category. Last, the invisible chain arises when repeated interactions between two or more people form "self-maintaining systems" that can be both detrimental and very hard to get out of. Platt (1973) used the example of a married couple in an abusive relationship; interactions between governments and other stakeholders can fall into similarly negative and distrustful patterns.

Other authors have proposed additional forms of lock-in. Path dependence, for example, may create or maintain lock-in to a particular solution, either through its continued influence on a society (e.g., via spatially segregated geographies, such as postapartheid settlement patterns in South Africa, that have high inertia; Vanderschuren & Galaria (2003)) or because events in the past reduce the range of solutions that people are willing to consider as currently acceptable. For example, achieving cooperation between different user groups along a river catchment may become much harder if there is a history of past conflict between groups (Cumming 2011).

Nested traps involve locked-in behavior at many interrelated levels of analysis (Platt 1973; Barry & Bateman 1996). Resolving problems in these situations is difficult, because parts of the system may be ready for change while others are not (Westley *et al.* 2002); Allison & Hobbs (2004), for example, suggest that macroeconomic influences have locked-in elements of natural resource management in Western Australian agriculture in ways that are extremely difficult for regional governments to overcome.

For conservation managers, the problem of lock-in must be considered from two perspectives; internally (i.e., that of their own organization and its goals), and externally (i.e., that of stakeholders.) Resolving internal lock-in problems may require a reassessment of organizational priorities, which in turn means initiating change and self-reflection within the organization. External lock-in problems may be harder to resolve, and either acknowledged or included within the problem-solving approach (e.g., if a partner refuses to modify their data collection protocol even though much of the information it generates is irrelevant) or left unresolved until a suitable window of opportunity for change arises.

Questions of scale and heterogeneity

One of the most fundamental system attributes in any dilemma or SES trap situation is that of group size. Many social variables, such as levels of trust and reciprocity, are influenced by the number of people in a group. As human groups grow or shrink, they may move into trap situations to which they would be less vulnerable if they were smaller or larger. The structure of interactions within a group is also important for system dynamics (Cumming 2016). Control over system behaviors may reside at one level, or at several different hierarchical levels within an organization. Differences in the nature of system control dictate the nature of the solutions that are needed, and in particular, whether actions should target individuals or groups. Barry & Bateman (1996) differentiate between private and dispersed problem solving; private problem solving can often be undertaken by a single individual, whereas dispersed problems require group processes to resolve.

Group size and the nature of control relate closely to questions of heterogeneity; or more specifically, to differences between the stakeholders who are engaged in a particular conservation situation. Larger groups are usually more heterogeneous than small groups in a number of ways, including race, gender, educational background, personality types, and relevant character traits. Heterogeneity may function as a strength or a weaknesses in conservation problem solving. The proportion of altruists within a group, for example, can have important implications for group dynamics (Fehr & Fischbacher 2003). Heterogeneous outcomes can inhibit cooperative behavior, for example, if people perceive that others in the group will receive higher payoffs despite making equivalent contributions (Murnighan *et al.* 1990; Barry & Bateman 1996).

Managers who are aware of the potential costs and benefits arising from heterogeneity can actively maintain a suitable level of heterogeneity among their employees; make members of minorities feel included and accepted within the group; and invite known altruists to participate in conservation initiatives. Similarly, as conservation organizations or working groups grow larger, leaders must learn to delegate power, to ensure that different voices within the group are heard, and to accept the additional transaction costs (e.g., more time spent discussing possible solutions) that arise from greater heterogeneity.

The psychology of choice and decision making

Publications in conservation and ecology journals seldom consider manager motivations and individual psychology in any depth (Clements *et al.* 2016). Although game theory explains how rational humans should behave to maximize their own self-interest, groups are seldom truly rational. More useful perspectives on cooperation have been developed in psychology: specifically, interdependence theory and goal expectation theory.

Interdependence theory proposes that the way in which goals are structured determines how individuals interact (Deutsch 1949; Johnson & Johnson 2005). Group cohesion (e.g., in a business or a stakeholder group) is provided by shared goals. Goal structure is defined as the nature of interdependence within the group. *Positive interdependence* exists when people can attain their goals if, and only if, the other individuals in the group also attain their goals. *Negative interdependence* exists when people perceive that they can only attain their goals if others in the group do not attain their goals (Johnson & Johnson 2005). Positive interdependence leads to "promotive action," in which individuals promote the success of others, while negative interdependence leads to "oppositional action" (Deutsch 1949). Importantly, people's choices and resulting interactions with others depend on their perceptions of whether interdependence within the group is positive, negative, or absent (independent). Deutsch (1949) proposed that cooperation tends to induce further cooperation, while opposition induces further opposition. It is therefore more likely that people compromise or make unselfish choices, and continue to do so, in situations where positive interdependence is clear. For example, in managing water supply and demand, changing stakeholder perceptions of water from a limited resource that others are depleting (negative goal structuring) to that of a shared resource that will only be available if everyone adjusts their water usage (positive structuring) can have a significant political impact (Olsson *et al.* 2004). For conservation, interdependence theory suggests that it is important that leaders present a clear goal structure to participants; that they make decisions transparently and inclusively; and that conservation action is not perceived as preferentially benefitting a single individual or group.

Goal expectation theory (Pruitt & Kimmel 1977) proposes that cooperation depends on individuals both having a goal of mutual cooperation *and* expecting others to cooperate. These assumptions are particularly important in public goods dilemmas (De Cremer & Stouten 2003). For example, people are less likely to litter if they feel that others are also taking care not to do so. For conservation managers and decision makers, goal expectation theory suggests that both leading by example and public recognition of the contributions of collaborators to group objectives are important for success.

A large number of experimental games have been developed to further explore the basis of cooperation, both for individuals and groups (Dufwenberg *et al.* 2011). This research has produced some intriguing outcomes with high relevance for conservation. For example, behavior is determined by utility (i.e., the total satisfaction received from an action, such as consuming a good or service), not only by its payoff. Depending on net utility, which generally includes moral and relational elements, actions with lower payoffs may be favored; and cooperation is reduced when decision makers view a social dilemma as a business decision, rather than as an ethical decision or a social decision (Van Lange *et al.* 2013). Conservation managers should therefore be willing to appeal to the values of stakeholders and to present conservation goals in ways that connect clearly to their core beliefs.

Last, human idiosyncrasies influence the likelihood of entering a dilemma or trap situation. For example, people tend to overlook distant times, places, and failures, creating a set of "learning myopias" (Levinthal & March 1993) that can influence their actions and make it harder to learn from the experiences of others. Similarly, the desire to measure performance and set targets can itself become a trap; Campbell's law proposes that "The more any quantitative social indicator is used for social decision making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor" (Campbell 1979). In conservation initiatives, awareness of the risks of learning myopias and of setting potentially prescriptive performance targets can help managers to avoid these issues by deliberately considering distant times, places, and failures; and periodically re-evaluating the value and impact of quantitative social indicators and individual performance measures.

Potential solutions

Proposed solutions to social dilemmas and SES traps have ranged from general theoretical observations to specific practical suggestions. Social science as a discipline has not been strongly solution-oriented (Watts 2017), however, and it can be difficult to identify areas of consensus within the existing literature. Solutions to dilemma and trap situations in conservation have three main components: (1) assessment of the conservation context; (2) diagnosis of which dilemmas and/or traps are most relevant; and (3) implementation of practical solutions (see also Waltner-Toews & Kay 2005).

Assessment of the conservation context

The context in which conservation is being undertaken, and the objectives of the conservation manager or organization, are central to cooperation. Conservation objectives provide a frame of reference against which the value of an individual action can be assessed (Game *et al.* 2014). Many discussions of social dilemmas and SES traps have also disregarded the thorny contextual questions of perception and subjectivity; notably, concerns over power dynamics, asymmetric outcomes, and potential winners and losers (Robbins 2004). Even in situations where mediation rather than direct intervention is required, a mandate is required for intervention. In sociopolitical situations, the means by which an end is attained are often more important than the end itself (Adger & Jordan 2009). In addition, the success of interventions in social dynamics typically depends on the negotiation of shared belief structures and recognition that a problem exists. When there are multiple stakeholders and the objectives of different actors are unclear, the conservation context can be defined—and potentially influenced—through formal processes of stakeholder engagement, problem framing, and scenario planning (Peterson *et al.* 2003; Poteete *et al.* 2010; Sterling *et al.* 2017).

Diagnosis of dilemmas and SES traps

Dilemma and SES trap situations in conservation often occur when different actors (whether individuals or organizations) have different agendas, understandings, and/or costs and benefits. Conservation managers and stakeholders do not necessarily see the "bigger picture" system dynamics and feedbacks that make conservation problems hard to resolve. For example, in understanding deforestation and its relationship to agriculture, the importance of slowly changing system variables such as soil fertility, groundwater levels, or societal attitudes can be particularly difficult to identify in the absence of a systems approach (Walker *et al.* 2006).

Several authors have proposed that the best way to diagnose a problem situation is to run scenario planning or resilience analysis workshops with stakeholders (Walker *et al.* 2002). Systems models are key elements of such processes (Addison *et al.* 2013). Participatory workshops facilitate a public discourse around the problem and can lead to a shared understanding of the problem, making it simpler to agree upon and implement solutions. Participatory workshops can also inflame conflict and entrench existing differences (Friedman & Cousins 1996), however, and so it is important that participants are selected carefully and constructively engaged prior to public debate.

Dawes (1980) reviewed game-playing studies and identified knowledge, morality, and trust as important elements of solutions to social dilemmas. Actors who are seeking to resolve social dilemmas must build individual and group relationships first, before attempting to achieve change, and wait patiently for windows of opportunity in which to influence outcomes. Some of the most successful examples of cooperation in conservation have been supported by the behind-the-scenes, community-building efforts of a charismatic leader (Olsson *et al.* 2004). The widespread nature of cooperation problems suggests that awareness of simple archetypal systems models of social dilemmas and SES traps (e.g., as presented by Senge 1990), and efforts to apply them, would be valuable for diagnosis (Bennett *et al.* 2005).

Implementation of practical solutions

Platt (1973) made six practical suggestions for resolving social dilemmas: (1) change the delay (to bring long-term rewards forward, or make consequences bear more directly on behavior); (2) add counter-reinforcers, such as social incentives, sanctions, or punishments; (3) change the nature of the long-run consequence; (4) improve the benefits but not the costs of a better alternative (e.g., coke zero vs. coke classic, electronic cigarettes); (5) get outside help in changing the reinforcement patterns of feedback loops; and (6) set up a superordinate authority, such as a complaints commission, to deal with issues. For example, in catchment-based water management, solutions in each of these six categories may include: (1) introducing real-time monitoring systems to ensure that individual users do not exceed their allocations; (2) public naming of defectors (noncooperators) or the creation of better legal instruments to fine defectors for overuse; (3) communicating scientific understanding to make future benefits of water conservation clearer; (4) helping farmers to use less water more effectively, for example, by leveling fields; (5) setting up meetings with individuals from other, more successful catchment management groups to share success stories; and (6) creating a new governing body, such as a catchment management authority, with the appropriate mandate from stakeholders.

Barry & Bateman (1996), building on Platt's suggestions in the context of social diversity problems, emphasize the importance of considering multiple levels of analysis. They grouped solutions to social dilemmas into three categories: (1) informational solutions, which are directed at the social-cognitive processes of individuals; (2) group-structure solutions, which directly manage the structure and process of the organization and/or subunits; and (3) structural solutions, which seek to modify the dynamics of a dilemma or an SES trap by redefining its structure. For water management, informational solutions might change people's perceptions of the short- and long-term costs of their water use; group-structure solutions might include holding stakeholder workshops to build better social relations, or reorganizing the monitoring process of the catchment management authority and giving it greater authority to intervene; while structural solutions might involve fundamental changes to the nature of the problem, for example, by encouraging farmers to shift away from water-intensive cropping systems to other crops, livestock, or livelihoods.

Van Lange *et al.* (2013) and Balliet *et al.* (2011) provide more recent reviews of potential solutions to dilemma situations. As they point out, Ostrom's design principles for institutions (Ostrom 1990; Ostrom *et al.* 2007) provide a well-established basis for resolving many takesome dilemmas. Notable features of Ostrom's principles include an emphasis on local sanctioning and reward, monitoring, and easily accessible conflict resolution. Internal mechanisms such as effective communication, building internal trust, and facilitating reciprocity among the people who face social dilemma and trap situations can play key roles in resolving them (Van Lange *et al.* 2013).3

Scaling dilemma and SES trap solutions to larger scales remains a difficult problem, and there are relatively few examples of successful global solutions. The Montreal Protocol and the resolution of the acid rain problem are perhaps the best examples (Levy 1995; Beron *et al.* 2003). As Ostrom herself acknowledged, each situation has its own unique elements, and there are no panaceas for natural resource management. Greater awareness of social dilemmas and SES traps, and some of their potential solutions, can nonetheless help those who are involved in managing natural resources to work more effectively within the sociopolitical contexts of conservation, policy, and management.

Future directions

I have argued that understanding and achieving cooperation is fundamental to the success of conservation. Although the principles of cooperation are well established (Dawes 1980; Barry & Bateman 1996) and have been successfully applied in many conservation contexts (Brown 2002), research on cooperation in conservation has a tendency to explore the same principles repeatedly in different case studies without drawing on mechanistic models or advancing theory. For example, Ostrom's principles for the community-based natural resource management of common property resources have been shown to work well under some circumstances, but remain probabilistic (correlative) rather than diagnostic (mechanism-based; Cox *et al.* 2010). Uncertainties about the impacts of heterogeneity and scale on cooperation, both within groups and spatially across landscapes, remain largely unresolved. With globalization, climate change, and transboundary resource management becoming increasingly important in many ecosystems, building successful cooperation at broad scales has become one of the most important conservation concerns of our time. Given the mechanistic overlap between social dilemmas and SES traps, the availability of a large number of empirical case studies of cooperation in conservation, and growing understandings of individual-level mechanisms in behavioral economics, the time appears ripe for the development of quantitative systems models and hypothesis-based exploration of proposed mechanisms of conservation cooperation, coupled with broad-scale experiments, as ways of improving conservation theory and practice.

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