Chapter 24

COMMON-POOL RESOURCES AND INSTITUTIONS: TOWARD A REVISED THEORY*

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Abstract

In the conventional theory of common-pool resources, participants do not undertake efforts to design their own governance arrangements. Substantial empirical evidence exists, however, that many common-pool resources are self-governed. Thus, in this chapter, I briefly review the conventional theory of common-pool resources. Then, I provide an overview of the empirical studies that test this theory in experimental laboratories. In the third section, I provide an overview of the empirical studies of this theory conducted in field settings. Since research in the lab and in the field both provide evidence that appropriators from common-pool resources do self-organize, the fourth section is devoted to the presentation of an initial theory of self-organization focusing on the benefit-cost calculus of individual appropriators. Two major theoretical puzzles remain, having to do with the effect of the size of a group and its heterogeneity.

Keywords

common-pool resources, institutional analysis, laboratory experiments, comparative case studies, self-organized user groups

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1. Introduction

Common-pool resources are systems that generate finite quantities of resource units so that one person's use subtracts from the quantity of resource units available to others [E. Ostrom, Gardner and Walker (1994)]. Irrigation systems are among the most important types of common-pool resources [E. Ostrom (1992a)]. Most common-pool resources are sufficiently large that multiple actors can simultaneously use the resource system and efforts to exclude potential beneficiaries are costly. When the resource units (e.g., water) are highly valued and many actors benefit from appropriating (harvesting) them for consumption, exchange, or as a factor in a production process, the appropriations made by one individual are likely to create negative externalities for others.

The "tragedy of the commons" will occur in highly valued, open-access commons where those involved and/or external authorities do not establish an effective governance regime [G. Hardin (1968)]. Governance regimes regulate one or more of the following:

- who is allowed to appropriate resource units;
- the timing, quantity, location, and technology of appropriation;
- who is obligated to contribute resources to provide or maintain the resource system itself;
- how appropriation and obligation activities are to be monitored and enforced;
- how conflicts over appropriation and obligation activities are to be resolved; and
- how the rules affecting the above will be changed over time with changes in the performance of the resource system and the strategies of participants.

A self-governed common-pool resource is one where actors, who are major appropriators of the resource, are involved over time in making and adapting rules within collective-choice arenas regarding the inclusion or exclusion of participants, appropriation strategies, obligations of participants, monitoring and sanctioning, and conflict resolution. Some common-pool resources that are located far from centers of governmental authority are governed entirely by appropriators and are not governed at all by external authorities. In most modern political economies, however, it is rare to find any resource systems – including the treasuries of private for-profit corporations – that are governed *entirely* by participants without rules made by local, regional, national, or international authorities also affecting key decisions [V. Ostrom (1991, 1997)]. Thus, in a self-governed system, participants make many, but not necessarily all, rules that affect the sustainability of the resource system and its use.

In the conventional theory of the commons, participants do not undertake efforts to design their own governance arrangements. Substantial empirical evidence exists, however, that many common-pool resources are self-governed. Thus, in this chapter, I first briefly review the conventional theory of common-pool resources. Then, I provide an overview of the empirical studies of this theory conducted in experimental laboratories. In the third section, I provide an overview of the empirical studies of this theory conducted in field settings. Since research in the lab and in the field both provide evidence that appropriators from common-pool resources do self-organize, the fourth section is devoted to the presentation of an initial theory of self-organization focusing

on the benefit-cost calculus of individual appropriators. Two major theoretical puzzles remain, which are discussed in the fifth section before the chapter concludes with a brief sixth section.

2. The conventional theory of common-pool resources

Since the important early studies of open-access fisheries by Gordon (1954) and Scott (1955), most theoretical studies by political economists have analyzed simple common-pool resource systems using relatively similar assumptions [Feeny, Hanna and McEvoy (1996)]. In such systems, it is assumed that the resource generates a highly predictable, finite supply of one type of resource unit (one species, for example) in each relevant time period. Appropriators are assumed to be homogeneous in terms of their assets, skills, discount rates, and cultural views. They are also assumed to be short-term, profit-maximizing actors who possess complete information. In this theory, *anyone* can enter the resource and appropriate resource units. Appropriators gain property rights only to what they harvest, which they then sell in an open competitive market. The open access condition is a given. The appropriators make no effort to change it. Appropriators act independently and do not communicate or coordinate their activities in any way.

> In this setting, as the incisive analysis of Gordon and Scott demonstrates, each fisherman will take into account only his own marginal costs and revenues and ignores the fact that increases in his catch affect the returns to fishing effort for other fishermen as well as the health of future fish stocks ... [E]conomic rent is dissipated; economic overfishing, which may also lead to ecological overfishing, is the result [Feeny et al. (1996, p. 189)].

Many textbooks in resource economics and law and economics present this conventional theory of a simple common-pool resource as the only theory needed for understanding common-pool resources more generally [see Dasgupta and Heal (1979); for a different approach, see Baland and Platteau (1996)]. With the growing use of game theory, appropriation from common-pool resources is frequently represented as a one-shot or finitely repeated, Prisoner's Dilemma game [Dawes (1973), Dasgupta and Heal (1979)]. These models formalize the problem differently, but do not change any of the basic theoretical assumptions about the finite and predictable supply of resource units, complete information, homogeneity of users, their maximization of expected profits, and their lack of interaction with one another or capacity to change their institutions.

3. A common-pool resource in the laboratory

The structure of Gordon's time-independent model (1954) has been used as the foundation to create a series of baseline laboratory experiments that examine the empirical generality of the conventional theory [Walker, Gardner and Ostrom (1990)].

In these experiments, eight subjects are similarly endowed with either 10 or 25 tokens in each period of a finitely repeated game. Any or all of these tokens can be invested in a joint activity with the mathematical structure of a quadratic production function (the common-pool resource) or in an alternative activity that generates a fixed return per token (similar to investing time in wage labor). Subjects are privately paid at the end of the experiment based on the total returns obtained during the experiment and earn between $15 to $25 per experiment lasting from 1 to 1.5 hours. In this stark institutional setting, appropriators are not allowed to communicate. Given the payoff parameters, a group investment of 36 tokens yields the optimal level of investment. The noncooperative Nash equilibrium for a finitely repeated game is for each subject to invest 8 tokens in the common-pool resource (regardless of the number of tokens provided as an endowment). Thus, the predicted outcome is for a total group investment of 64 tokens. The outcome reached at the predicted Nash equilibrium is 39 percent of the joint optimum that could be earned.

In these baseline experiments, subjects make investment allocations to the common-pool resource that are well above optimum. Significant rent dissipation occurs as predicted. The Nash equilibrium is the best predictor of the average level of outcomes achieved for low-endowment experiments. In the high-endowment setting, average outcomes are far from Nash in early rounds but approach Nash in later rounds. In this series of experiments, as well as others [see E. Ostrom, Gardner and Walker (1994)], virtually *no* evidence supports the prediction that individual appropriators follow Nash equilibrium strategies. In many experiments, no single subject adopted the Nash equilibrium strategy even though the average outcome approximated that predicted using a Nash equilibrium. A further result that is not predicted by the theory is that the amount of tokens invested by subjects is affected by token endowments. Yields as a percentage of optimum are much lower in the high-endowment (25-token) experiments than in the low-endowment (10-token) experiments.

Overall, the prediction of excessive appropriation from a common-pool resource by appropriators who are constrained not to communicate but unconstrained by prior appropriation rules is supported by evidence from experimental studies. These conditions are roughly analogous to unorganized, large groups of actors appropriating from an international commons. Many common-pool resources, however, are contained within a single country where a smaller number of actors may be able to communicate, coordinate strategies, and even find means to enforce these strategies themselves.

3.1. Communication in the laboratory

While the basic model involved no communication, evidence from the field shows individuals making and keeping contingent promises to one another. Frequently, no external authorities are present to enforce these agreements. Communication has also increased the level of cooperation achieved in many public good experiments [see E. Ostrom and Walker (1997), for citations]. The theoretical role of communication in noncooperative game theory, however, is problematic. Words alone are viewed as frail

constraints – or cheap talk – when individuals face settings with dominant strategies to overuse a resource. The inability to make enforceable agreements is a core assumption of noncooperative game theory that has been adopted extensively as the modeling tool of preference in resource economics. Thus, common-pool resource theory has treated the ability to communicate as inessential and unlikely to change results unless the individuals involved can call on external agents to enforce agreements. Consequently, it is important to examine the effect of allowing face-to-face communication in common-pool resource games similar to the baseline experiments briefly described above.

The impact of communication on outcomes has been explored in three experimental designs. In the first, subjects are given an opportunity to communicate only once and then return to make a series of independent decisions. In the second, subjects are given an opportunity to communicate before each decision round. In the third, subjects have to pay in order to communicate, and communication is authorized only when the subjects voluntarily contributed a predetermined sum. In all three conditions, agreements made by subjects are *not* enforced by the experimenters. After communication, each subject subsequently makes his or her own independent and anonymous appropriation decision.

Subjects use their communication opportunities to discuss the number of tokens that gains the most money for the group and to agree on a formula for allocating those tokens to each other so as to achieve their perception of optimality. Subjects in repeated, high-endowment, common-pool resource games, with only one opportunity to communicate, obtain an average percentage of net yield above that obtained in baseline experiments without communication (55 percent compared to 21 percent). Subjects in repeated, high-endowment, common-pool resource games, with *repeated opportunities* to communicate, obtain an average percentage of net yield that is substantially above that obtained in baseline experiments without communication (73 percent compared to 21 percent). In low-endowment games, the average net yield is 99 percent as compared to 34 percent. Repeated communication opportunities in high-endowment games lead to higher joint outcomes (73 percent) than in one-shot communication (55 percent), as well as lower defection rates (13 percent compared to 25 percent) [E. Ostrom, Gardner and Walker (1994)]. In the costly communication experiments, subjects obtained outcomes that averaged around 80 percent of optimum as contrasted to 34 percent. Consequently, the capacity to communicate in these experiments enables subjects to achieve higher levels of return than when no communication is allowed [see also Messick, Allison and Samuelson (1988)]. In low-endowment settings – analogous to a set of farmers cutting trees from a forest with handsaws – repeated opportunities to communicate enable participants to achieve near-optimality. In high-endowment settings – analogous to a setting where the farmers have powerful chain saws – repeated opportunities to communicate enable participants to improve their returns substantially, but the temptation to defeat is greater, and defections occur more often.

Communication in a repeated situation enables subjects to accomplish three potentially important activities. First, it enables those involved to identify the joint strategy that would enable them to get close to an optimal return [Ledyard (1995)]. The first topic normally discussed is what joint strategy obtains the highest return for the group.

Identifying the optimal joint strategy could change the beliefs that each player has about the likely strategies to be adopted by others. If this were all that occurred, communication would involve strictly a coordination role. Second, the capacity to communicate provides an opportunity for the group to come to an overt agreement about what each person should do. Agreeing on a joint strategy and observing that the agreement is followed by most players allows participants to gain trust in one another and to risk a strategy other than that of a Nash equilibrium. Third, in those experiments where communication occurs between every decision round, subjects could exercise a form of sanctioning by verbally chastising the group if there was evidence that defection from an agreement had occurred. While subjects did not know which member of their group had defected from an agreement, they knew the outcomes achieved, and thus whether anyone invested more tokens than their agreement. They could use the opportunity for communication to criticize untrustworthiness and those who took advantage of others.

Moir (1995) explored whether the efficacy of communication was based primarily on the first coordination activity rather than on contracting and gaining trust or using verbal sanctions. Moir clearly told subjects in a common-pool resource game what joint strategy would gain them the highest group outcomes. Telling subjects about the symmetric optimum had no effect on the level of appropriation in the remaining rounds of the experiment, with the exception of the round immediately following this announcement [Moir (1995, p. 36)]. Isaac, McCue and Plott (1985) also overtly told subjects (in a public good experiment) the joint strategy that would maximize their group payoffs and found that this information did not change the level of noncooperation that existed prior to the exogenous provision of this information. Communication facilitates the exchange of information about what strategies lead to optimal outcomes, but it also plays a more crucial role in gaining agreement and trust and in allowing verbal criticisms as a nonmonetary form of generalized sanctions [Orbell, van de Kragt and Dawes (1988)].

3.2. Monitoring and sanctioning in the laboratory

In the field, appropriators not only communicate and "jaw bone" one another, they frequently authorize one another to patrol a resource and ascertain if anyone is appropriating beyond agreed-upon levels. In a game-theoretical model of self-organized monitoring and sanctioning related to irrigation systems, Weissing and Ostrom (1991, 1993) establish that multiple equilibria exist in such games, including some where monitoring is ineffective or counterproductive. There is one set of equilibria, however, where unauthorized behavior – stealing water, in this case – is held in check. To hold cheating in check, however, requires that monitors be sufficiently rewarded for discovering a cheater so as to overcome their costs of monitoring activities. Consequently, self-governed common-pool resources depend upon appropriators gaining rewards – either internal or external – from monitoring and sanctioning one another.

While face-to-face communication in the laboratory substantially increases the joint returns obtained by subjects, the nonbinding aspect of this institution is less effective

when the temptation to cheat on an agreement is strong, such as with subjects with high endowments. E. Ostrom, Gardner and Walker (1994) designed a series of experiments to explore whether subjects in a laboratory setting would take costly actions in order to sanction one another overtly. The sanctioning mechanism is added to the baseline appropriation game described above with one additional feature: costless information is provided to subjects about the individual tokens invested during every round. The personal identity of each of the eight subjects is not revealed, since the display only indicates the computer number of a subject that is not related to the order in which subjects sat in the experimental lab. After 10 rounds without a sanctioning mechanism, subjects are given new instructions. These assign them the capability to incur a cost (a fee) after each appropriation decision in order to sanction another subject (who then is charged a fine). Subjects cannot discuss this new institutional rule with one another. The amount of the fines received by an individual is reported in writing to the subject who is being fined (but not the identity of the person(s) punishing them) and subtracted from their payoff for that round. It is possible for a subject to be fined by several others and in multiple rounds. At the end of the experiment, the experimenters subtract the total of all fees and all fines from subjects' total profits.

In experiments where the sanctioning institution is imposed by the experimenter and the subjects have no opportunity to communicate, Ostrom, Gardner and Walker find significantly more sanctioning than predicted. Subjects in these games sanction one another more when the cost of sanctioning is lower – thus exhibiting an economic response to the cost of sanctioning. Sanctioning is primarily directed to heavy investors in the common-pool resource. The average net yield increases from 21 percent with no sanctioning to 37 percent with sanctioning. When the costs of fees and fines are subtracted from average net yield, however, *net* yield drops to 9 percent. Subjects tend to *overuse* the sanctioning mechanism. It would appear that participants obtain a personal reward for sanctioning those who overinvest or whom they suspect have sanctioned them.

In experiments where communication and sanctioning are combined, on the other hand, the results are entirely different. With an imposed sanctioning mechanism and only a single opportunity to communicate, subjects achieve an average net yield of 85 percent. When the costs of fees and fines are subtracted, average net yield is still 67 percent. These represent substantial gains over baseline experiments where net yield averaged 21 percent. When subjects are given an opportunity to meet face-to-face, followed by an opportunity to vote on whether they would adopt a sanctioning mechanism, subjects who adopt a sanctioning mechanism achieve an average net yield of 93 percent. When the costs of fees and fines are subtracted, average net yield is still 90 percent. In addition, the defection rate from agreements is only 4 percent. Thus, subjects who use the opportunity to communicate to agree to a joint strategy and a majority vote for their own sanctioning mechanism achieve close to optimal results based entirely on the promises they make, their own efforts to monitor, and their own investments in sanctioning [see Moir (1995), for further extensions and replications]. This is especially impressive in the high-endowment environment.

In summary, evidence from controlled laboratory experiments of small groups of homogeneous appropriators possessing complete information about their endowments and the results of their actions provides strong support that when appropriators are not allowed to communicate, their behavior is consistent with the conventional theory of common-pool resources. When appropriators are allowed to communicate, however, they achieve substantially higher joint returns than when they cannot communicate. Appropriators given an opportunity to engage in costly monitoring and sanctioning are willing to pay these costs. And, when appropriators overtly discuss and agree on their own appropriation levels and sanctioning systems, they keep cheating on agreements at a very low level and achieve close to optimal results. Consequently, in small, well-specified environments where communication is possible, appropriators are willing to pay the costs involved to arrive at their own rules and actively monitor and enforce their rules, thereby achieving close to optimal results. The conventional theory does not explain behavior in such settings.

4. Common-pool resources in the field

A sufficient number of empirical examples exist where the absence of property rights and the independence of actors captures the essence of the problem facing appropriators that the broad empirical applicability of the conventional theory was not effectively challenged by field research until the mid-1980s. Until the work of the National Academy of Sciences' Panel on Common Property [National Research Council (1986)], the conventional theory of common-pool resources was applied to all common-pool resources regardless of the capacity of appropriators to communicate and coordinate their activities. The growing evidence from many studies of common-pool resources in the field, however, called for a serious re-thinking of the theoretical foundations for the analysis of common-pool resources [see Berkes (1986, 1989), Berkes et al. (1989), Bromley et al. (1992), McCay and Acheson (1987), E. Ostrom (1990)]. The consequence of these empirical studies is not to challenge the empirical validity of the conventional theory where it is relevant but rather its generalizability.

In the field, many common-pool resources are characterized by substantially higher levels of complexity than the base theory of homogeneous appropriators taking one type of resource unit from a resource system that generates a predictable flow of units. The rich case-study literature illustrates a wide diversity of settings in which appropriators dependent upon common-pool resources have organized themselves to achieve much higher outcomes than is predicted by the theory described above [Cordell (1989), Wade (1994), Ruddle and Johannes (1985), Sengupta (1991), Singleton (1998)].

Small- to medium-sized irrigation systems approximate these conditions and are, thus, an appropriate setting in which to examine these patterns of relationships quantitatively [Tang (1992)]. One resource unit – water – is the focus of efforts to organize and coordinate activities. Recent research on small- to medium-sized irrigation systems in Nepal has found a very substantial difference in performance between those

systems owned and governed by the farmers themselves as contrasted to those systems owned and operated (but in some cases not governed) by a national governmental agency.

While most farmers in Nepal own land, most own very small parcels of less than 1 hectare. They are relatively homogeneous with similar preferences in regard to obtaining water for rice production during the monsoon and winter seasons and for various crops during the spring. Farmers in Nepal have long had the authority to create their own water associations, construct and maintain their own systems, and monitor and enforce conformance to their rules [see Shivakoti and Ostrom (2002), Lam, Lee and Ostrom (1997)]. The irrigation systems constructed and maintained by farmers tend to rely on low-tech construction techniques including building nonpermanent headworks from mud, trees, and stones. International aid agencies have provided considerable funding to government agencies in an effort to upgrade the engineering standards.

In a detailed analysis of data from 150 farmer-governed and national government irrigation systems in Nepal, Lam (1998) develops three performance measures: (1) the physical condition of irrigation systems, (2) the quantity of water available to farmers at different seasons of the year, and (3) the agricultural productivity of the systems. Using multiple regression analysis techniques so as to control for environmental differences among systems, Lam finds several variables strongly related to these dependent variables. One is the form of governance of the system. Holding other variables constant, irrigation systems governed by the farmers themselves perform significantly better on all three performance measures. This variable has the largest explanatory power of any variable in Lam's analysis, including the physical size of the system, terrain characteristics, and the number of farmers.

Thus, farmers with long-term ownership claims, who can communicate, develop their own agreements, establish the positions of monitors, and sanction those who do not conform to their own rules, are more likely to grow more rice, distribute water more equitably, and keep their systems in better repair than is done on government systems. While there is variance in the performance of these Nepali systems, and also among the 47 farmer-governed systems in the Philippines described by de los Reyes (1980), few perform as poorly as government systems, holding other relevant variables constant. Since many of the government systems rely on high-tech engineering, the capability of farmers to increase agricultural production on their "primitive systems" while they also provide the labor to maintain and operate the system, is particularly noteworthy.

5. On the origin of self-governed common-pool resources

Evidence from the field research thus challenges the generalizability of the conventional theory. While it is generally successful in predicting outcomes in settings where appropriators are alienated from one another or cannot communicate effectively, it does not provide an explanation for settings where appropriators are able to create and sustain agreements to avoid serious problems of overappropriation. Nor does it predict

well when government ownership will perform appropriately or how privatization will improve outcomes. A fully articulated, reformulated theory encompassing the conventional theory as a special case does not yet exist. On the other hand, scholars familiar with the results of field research substantially agree on a set of variables that enhance the likelihood of appropriators organizing themselves to avoid the social losses associated with open-access, common-pool resources [McKean (1992, 2000), Wade (1994), Schlager (1990), Tang (1992), E. Ostrom (1990, 1992a, 1992b), Baland and Platteau (1996), E. Ostrom, Gardner and Walker (1994)]. Drawing heavily on Ostrom (1992b, pp. 298–299) and Baland and Platteau (1996, pp. 286–289), considerable consensus exists that the following attributes of resources and of appropriators are conducive to an increased likelihood that self-governing associations will form.

Attributes of the resource:

R1. Feasible improvement: Resource conditions are not at such a point of deterioration that it is useless to organize, or so underutilized that little advantage results from organizing.

R2. Indicators: Reliable and valid indicators of the condition of the resource system are frequently available at a relatively low cost.

R3. Predictability: The flow of resource units is relatively predictable.

R4. Spatial extent: The resource system is sufficiently small, given the transportation and communication technology in use, that appropriators can develop accurate knowledge of external boundaries and internal microenvironments.

Attributes of the appropriators:

A1. Salience: Appropriators are dependent on the resource system for a major portion of their livelihood.

A2. Common understanding: Appropriators have a shared image of how the resource system operates (attributes R1, R2, R3, and R4 above) and how their actions affect each other and the resource system.

A3. Discount rate: Appropriators use a sufficiently low discount rate in relation to future benefits to be achieved from the resource.

A4. Distribution of interests: Appropriators with higher economic and political assets are similarly affected by a lack of coordinated patterns of appropriation and use.

A5. Norms of trust, reciprocity, and punishment: Appropriators trust one another to keep promises and relate to one another with reciprocity.

A6. Autonomy: Appropriators are able to determine access and harvesting rules without external authorities countermanding them.

A7. Local leadership and prior organizational experience: Appropriators have learned at least minimal skills of organization through participation in other local associations or learning about ways that neighboring groups have organized.

Many of these variables are in turn affected by the type of larger regime in which users are embedded. Larger regimes can facilitate local self-organization by providing accurate information about natural resource systems, providing arenas in which participants can engage in discovery and conflict-resolution processes, and providing

mechanisms to back up local monitoring and sanctioning efforts. The probability of participants adapting more effective rules in macroregimes that facilitate their efforts over time is higher than in regimes that ignore resource problems entirely or, at the other extreme, presume that all decisions about governance and management need to be made by central authorities.

The key to further theoretical integration is to understand how these attributes interact in complex ways to affect the basic benefit-cost calculations of a set of appropriators (A) using a resource [E. Ostrom (1990, Ch. 6)]. Each appropriator i ($i \in A$) has to compare the expected net benefits of harvesting continuing to use the old rules (BO) to the benefits he or she expects to achieve with a new set of rules (BN). Each appropriator i must ask whether his or her incentive to change (D_i) is positive or negative.

$$D_i = BN_i - BO_i.$$

If D_i is negative for all appropriators, no one has an incentive to change. If D_i is positive for some appropriators, they then need to estimate three types of costs: $C1$ – the up-front costs of time and effort spent devising and agreeing upon new rules; $C2$ – the short-term costs of adopting new appropriation strategies; and $C3$ – the long-term costs of monitoring and maintaining a self-governed system over time (given the norms of the community in which they live). If the sum of these expected costs for each appropriator exceeds the incentive to change, no appropriator will invest the time and resources needed to create new institutions. Thus, if

$$D_i < (C1_i + C2_i + C3_i)$$

for all $i \in A$, no change occurs.

In field settings, everyone is not likely to expect the same costs and benefits from a proposed change. Some may perceive positive benefits after all costs have been taken into account, while others may perceive net losses. Consequently, the collective-choice rules used to change the day-to-day operational rules related to appropriation affect whether an institutional change favored by some and opposed by others will occur. For any collective-choice rule, such as unanimity, majority, ruling elite, or one-person rule, there is a minimum coalition of appropriators, $K \subset A$, that must agree prior to the adoption of new rules. If for any individual k, a member of K,

$$D_k \leqslant (C1_k + C2_k + C3_k),$$

no new rules will be adopted. And if for at least one coalition $K \subset A$, it is such that

$$D_k > (C1_k + C2_k + C3_k),$$

for all members of K, it is feasible for a new set of rules to be adopted. If there are several such coalitions, the question of which coalition will form, and thus which

rules will result, is a theoretical issue beyond the scope of this entry. This analysis is applicable to a situation where a group starts with an open access set of rules and contemplates adopting its first set of rules limiting access. It is also relevant to the continuing consideration of changing operational rules over time.

The rule used to change institutional arrangements in field settings varies from reliance on the decisions made by one or a few leaders, to a formal reliance on majority or super-majority vote, to reliance on consensus or near-unanimity. If there are substantial differences in the perceived benefits and costs of appropriators, it is possible that K appropriators will impose a new set of rules on the $A - K$ other appropriators that strongly favors those in the winning coalition and imposes losses or lower benefits on those in the losing coalition [Thompson, Mannix and Bazerman (1988)]. If expected benefits from a change in institutional arrangements are not greater than expected costs for many appropriators, however, the costs of enforcing a change in institutions will be much higher than when most participants expect to benefit from a change in rules over time. Where the enforcement costs are fully borne by the members of K, operational rules that benefit the $A - K$ other appropriators lower the long-term costs of monitoring and sanctioning for a governing coalition. Where external authorities enforce the rules agreed upon by K appropriators, the distribution of costs and benefits is more likely to benefit K and may impose costs on the $A - K$ other appropriators [see Walker et al. (2000)].

The attributes of a resource (listed above) affect both the benefits and costs of institutional change. If resource units are relatively abundant (R1), there are few reasons for appropriators to invest costly time and effort in organizing. If the resource is already substantially destroyed, the high costs of organizing may not generate substantial benefits. Thus, self-organization is likely to occur only after appropriators observe substantial scarcity. The danger here, however, is that exogenous shocks leading to a change in relative abundance of the resource units occur rapidly, and appropriators may not adapt quickly enough to the new circumstances [Libecap and Wiggins (1985)].

The presence of frequently available, reliable indicators about the conditions of a resource (R2) affects the capacity of appropriators to adapt relatively soon to changes that could adversely affect their long-term benefit stream [Moxnes (1996)]. A resource flow that is highly predictable (R3) is much easier to understand and manage than one that is erratic. In the latter case, it is always difficult for appropriators (or, for that matter, for scientists and government officials) to judge whether changes in the resource stock or flow are due to overharvesting or to random exogenous variables [see Feeny, Hanna and McEvoy (1996) for a discussion of these issues related to the collapse of the California sardine industry)]. Unpredictability of resource units in microsettings, such as private pastures, may lead appropriators to create a larger common-property unit to increase the predictability of resource availability somewhere in the larger unit [Netting (1972), Wilson and Thompson (1993)]. The spatial extent of a resource (R4) affects the costs of defining reasonable boundaries and then of monitoring them over time.

The attributes of the appropriators themselves (listed above) also affect their expected benefits and costs. If appropriators do not obtain a major part of their income from a

resource (A1), the high costs of organizing and maintaining a self-governing system may not be worth their effort. If appropriators do not share a common understanding of how complex resource systems operate (A2), they will find it extremely difficult to agree on future joint strategies. Given the complexity of many common-pool resources – especially multispecies or multiproduct resources – reasoning about how these systems work may be counterintuitive even for those who make daily contacts with the resource. In resources that are highly variable (R3), it may be particularly difficult to understand and to sort out those outcomes stemming from exogenous factors and those resulting from the actions of appropriators. Of course, this is also a problem facing officials as well as appropriators. Appropriators with many other options, who thus discount the importance of future income from a particular resource (A3), may prefer to "mine" one resource without spending resources to regulate it. They simply move on to other resources once this one is destroyed, assuming there will always be other resources available to them.

Appropriators who possess more substantial economic and political assets may have similar interests to those with fewer assets (A4) or they may differ substantially on multiple attributes. When the more powerful have similar interests, they may greatly enhance the probability of successful organization if they invest their resources in organizing a group and devising rules to govern that group. Those with substantial economic and political assets are more likely to be a member of K and thus have a bigger impact on decisions about institutional changes. Olson (1965) long ago recognized the possibility of a privileged group whereby some members bear a disproportionate share of the costs of organizing to provide public goods (such as the organization of a collectivity). On the other hand, if those with more assets also have low discount rates (A3) related to a particular resource and lower salience (A1), they may simply be unwilling to expend inputs or may actually impede organizational efforts that might lead to their having to cut back on their productive activities.

Appropriators who trust one another (A6) to keep agreements and use reciprocity in their relationships with one another face lower expected costs involved in monitoring and sanctioning one another over time. Appropriators who lack trust at the beginning of a process of organizing may be able to build this form of social capital [Coleman (1988), E. Ostrom (1992a)] if they initially adopt small changes that most appropriators follow before trying to make major institutional changes. Autonomy (A7) tends to lower the costs of organizing. A group that has little autonomy may find that those who disagree with locally developed rules seek contacts with higher-level officials to undo the efforts of appropriators to achieve regulation. [See Libecap (1995) for a discussion of the efforts to use the courts to challenge the validity of *de facto* governance of inshore fisheries in the U.S.; see also Alexander (1982).] With the legal autonomy to make their own rules, appropriators face substantially lower costs in defending their own rules against other authorities. Prior experience with other forms of local organization (A7) greatly enhances the repertoire of rules and strategies known by local participants as potentially useful to achieve various forms of regulation. Further, appropriators are more likely to agree upon rules whose operation they understand from prior experience, than upon

rules that are introduced by external actors and are new to their experience. Given the complexity of many field settings, appropriators face a difficult task in evaluating how diverse variables affect expected benefits and costs over a long time horizon. In many cases, it is just as difficult, if not more so, for scientists to make a valid and reliable estimate of total benefits and costs and their distribution.

The growing theoretical consensus does not lead to a conclusion that most appropriators using common-pool resources will undertake self-governed regulation. Many settings exist where the theoretical expectation should be the opposite: appropriators will overuse the resource unless efforts are made to change one or more of the variables affecting perceived costs or benefits. Given the number of variables that affect these costs and benefits, many points of external intervention can enhance or reduce the probability of appropriators agreeing upon and following rules that generate higher social returns. But both social scientists and policymakers have a lot to learn about how these variables operate interactively in field settings and even how to measure them so as to increase the empirical warrantability of the growing theoretical consensus. Many aspects of the macroinstitutional structure surrounding a particular setting affect the perceived costs and benefits. Thus, external authorities can do a lot to enhance the likelihood and performance of self-governing institutions. Their actions can also seriously impede these developments as well. Further, when the activities of one set of appropriators, A, have "spillover effects" on others beyond A, external authorities can either facilitate processes that allow multiple groups to solve conflicts arising from negative spillovers or take a more active role in governing particular resources themselves.

Researchers and public officials need to recognize the multiple manifestation of these theoretical variables in the field. Appropriators may be highly dependent on a resource (A1), for example, because they are in a remote location and few roads exist to enable them to leave. Alternatively, they may be located in a central location, but other opportunities are not open to them due to lack of training or a discriminatory labor market. Appropriators' discount rates (A3) in relation to a particular resource may be low because they have lived for a long time in a particular location and expect that they and their grandchildren will remain in that location, or because they possess a secure and well-defined bundle of property rights to this resource [see Schlager and Ostrom (1992)]. Reliable indicators of the condition of a resource (R2) may result from activities that the appropriators themselves do – such as regularly shearing the wool from sheep [see Gilles and Jamtgaard (1981)] or because of efforts to gather reliable information by appropriators or by external authorities [Blomquist (1992)]. Predictability of resource units (R3) may result from a clear regularity in the natural environment of the resource or because storage has been constructed in order to even out the flow of resource units over both good and bad years. They may have autonomy to make their own rules (A6) because a national government is weak and unable to exert authority over resources that it formally owns, or because national law formally legitimates self-governance – as is the case with Japanese inshore fisheries.

When the benefits of organizing are commonly understood by participants to be very high, appropriators lacking many of the attributes conducive to the development of

self-governing institutions may be able to overcome their liabilities and still develop effective agreements. The crucial factor is not whether all attributes are favorable but the relative size of the expected benefits and costs they generate as perceived by participants. While all of these variables affect the expected benefits and costs of appropriators, it is difficult – particularly for outsiders – to estimate their impact on expected benefits and costs given the difficulty of making precise measures of these variables and weighing them on a cumulative scale. Further empirical analysis of these theoretical propositions is, thus, dependent on the conduct of careful comparative over-time studies of a sufficiently large number of field settings using a common set of measurement protocols [see Gibson, McKean and Ostrom (2000)].

6. On the design principles of robust, self-governed common-pool resource institutions

Of course, the performance of self-governed common-pool resource systems varies across systems and time. Some self-governed common-pool resource systems have survived and flourished for centuries, while others falter and fail. As discussed above, some never get organized in the first place. In addition to the consensus concerning the theoretical variables conducive to self-organization, considerable agreement also exists about the characteristics of those self-governing systems that are robust in the sense that they survive for very long periods of time utilizing the same basic rules for adapting to new situations over time [Shepsle (1989)].

The particular rules used in the long-surviving, self-governing systems varied substantially from one another. Consequently, it is not possible to arrive at empirical generalizations about the particular types of rules used to define who is a member of a self-governing community, what rights they have to access a common-pool resource and appropriate resource units, and what particular obligations they face. It is possible, however, to derive a series of design principles that characterize the configuration of rules that are used. By "design principles" I mean an "element or condition that helps to account for the success of these institutions in sustaining the [common-pool resource] and gaining the compliance of generation after generation of appropriators to the rules in use" [E. Ostrom (1990, p. 90)]. Robust, long-term institutions are characterized by most of the design principles listed in Table 1. The farmer-owned irrigation systems in Nepal analyzed by Shivakoti and Ostrom (2002) and Lam (1998), for example, are characterized by most of these design principles. Fragile institutions tend to be characterized by only some of these design principles. Failed institutions are characterized by very few of these principles [see, for example, Schweik, Adhikari and Pandit (1997), Morrow and Hull (1996), Blomqvist (1996)].

These principles work to enhance the shared understanding of participants of the structure of the resource and its appropriators and of the benefits and costs involved in following a set of agreed-upon rules. Design Principle 1 – having rules that clearly define who has rights to use a resource and the boundaries of that resource – ensures

Table 1
Design principles illustrated by long-enduring common-pool resource institutions

1. Clearly Defined Boundaries

Individuals or households with rights to withdraw resource units from the common-pool resource and the boundaries of the common-pool resource itself are clearly defined.

2. Congruence

A. The distribution of benefits from appropriation rules is roughly proportionate to the costs imposed by provision rules.

B. Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions.

3. Collective-Choice Arrangements

Most individuals affected by operational rules can participate in modifying operational rules.

4. Monitoring

Monitors, who actively audit common-pool resource conditions and appropriator behavior, are accountable to the appropriators and/or are the appropriators themselves.

5. Graduated Sanctions

Appropriators who violate operational rules are likely to receive graduated sanctions (depending on the seriousness and context of the offense) from other appropriators, from officials accountable to these appropriators, or from both.

6. Conflict-Resolution Mechanisms

Appropriators and their officials have rapid access to low-cost, local arenas to resolve conflict among appropriators or between appropriators and officials.

7. Minimal Recognition of Rights to Organize

The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

For common-pool resources that are part of larger systems:

8. Nested Enterprises

Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Adapted from: E. Ostrom (1990, p. 90).

that appropriators can clearly identify anyone who does not have rights and take action against them.

Design Principle 2 involves two parts. The first is a congruence between the rules that assign benefits and the rules that assign costs. The crucial thing here is that these rules be considered fair and legitimate by the participants themselves [see McKean (1992)]. In many settings, fair rules are those that keep a relative proportionate relationship between

the assignment of benefits and of costs. In irrigation systems, for example, rules that allocate water to different farmers according to the amount of land they own as well as that allocate duties for costs of operation and maintenance using the same formula, are usually considered by farmers to be fair (as well as effective from an agricultural perspective). The second part of this design principle is that both types of rules be well-matched to local conditions such as soils, slope, number of diversions, crops being grown, etc.

Design Principle 3 is concerned with the collective-choice arrangements used to modify the operational rules of regular operation of the resource. If most appropriators are not involved in modifying these rules over time, the information about the benefits and costs as perceived by different participants is not fully taken into account in these efforts to adapt to new conditions and information over time. Appropriators who begin to perceive the costs of their system as being higher than their benefits and who are prevented from making serious proposals for change, may simply begin to cheat whenever they have the opportunity. Once cheating on rules becomes more frequent for some appropriators, others will follow suit. In this case, enforcement costs become very high or the system fails.

No matter how high the level of agreement to an initial agreement is, there are always conditions that tempt some individuals to cheat (even when they perceive the overall benefits of the system to be higher than the costs). If one person chooses to cheat while others conform to the rules, the cheater is usually able to gain substantially to the disadvantage of others. Thus, without monitoring of rule conformance – Design Principle 4 – few systems are able to survive very long at all. The sanctions that are used, however, do not need to be extremely high in the first instance. The important thing about a sanction for an appropriator who has succumbed to temptation is that his or her action is noticed and that a punishment is meted out. This tells all appropriators that cheating on rules is noticed and punished without making all rule infractions into major criminal events. If the sanctions are graduated (Design Principle 5), however, an appropriator who breaks rules repeatedly and who is noticed doing so eventually faces a penalty that makes rule-breaking an unattractive option. While rules are always assumed to be clear and unambiguous in theoretical work, this is rarely the case in field settings. It is easy to have a disagreement about how to interpret a rule that limits appropriation activities or requires input resources. If these disagreements are not resolved in a low-cost and orderly manner, then appropriators may lose their willingness to conform to rules because of the ways that "others" interpret them in their own favor (Design Principle 6).

Design Principles 7 and 8 are related to autonomy. When the rights of a group to devise their own institutions are recognized by national, regional, and local governments, the legitimacy of the rules crafted by appropriators will be less frequently challenged in courts, administrative and legislative settings. Further, in larger resources with many participants, nested enterprises that range in size from small to large enable participants to solve diverse problems involving different scale economies. By utilizing base institutions that are quite small, face-to-face communication can be utilized for

solving many of the day-to-day problems in smaller groups. By nesting each level of organization in a larger level, externalities from one group to others can be addressed in larger organizational settings that have a legitimate role to play in relationship to the smaller entities.

7. Theoretical puzzles

In addition to the consensus concerning the variables most likely to enhance self-organization and the design principles characterizing successful, long-term governance arrangements, many unresolved theoretical issues still exist about the self-governance of common-pool resources. Two major theoretical questions relate to the effect of the size and heterogeneity of groups using a resource on their capability to organize effectively.

7.1. Size of group

The effect of the number of participants facing problems of creating and sustaining a self-governing enterprise is unclear. Drawing on the early work of Olson (1965), many theorists argue that size of group is negatively related to solving collective-action problems in general [see also Buchanan and Tullock (1962)]. Many results from game theoretical analysis of repeated games conclude that cooperative strategies are more likely to emerge and be sustained in smaller rather than larger groups [see synthesis of this literature in Baland and Platteau (1996)]. Scholars who have studied many user-governed irrigation and forestry institutions in the field have concluded that success will more likely happen in smaller groups [see, for example, Barker et al. (1984), Cernea (1989)].

On the other hand, several studies of multiple sites have not found that size was positively related to success in organizing. While most of the 37 farmer-governed irrigation systems studied by Tang (1992) were relatively small, ranging in size from 7 to 300 appropriators, he did not find any statistical relationship within that size range between the number of appropriators or the amount of land being irrigated and performance variables (1992, p. 68). In Lam's multiple regression analysis of the performance of a much larger set of irrigation systems in Nepal ranging in size up to 475 irrigators, he also did not find any significant relationship between either the number of appropriators or the amount of land included in the service area with any of the three performance variables he studied (1998, pp. 114–115). Further, in a systematic study of forest institutions, Agrawal (2000) did not find smaller forest user groups as able to undertake the level of monitoring needed to protect forest resources as moderately sized groups.

One of the problems with a focus on size of group as a key determining factor is that many other variables change as group size increases [Chamberlin (1974), R. Hardin (1982)]. If the costs of providing a public good related to the use of a common-pool resource, say a sanctioning system, remain relatively constant as group size increases,

then increasing the number of participants brings additional resources that could be drawn upon to provide the benefit enjoyed by all [see Isaac, Walker and Williams (1993)]. Marwell and Oliver (1993, p. 45) conclude that when a "good has pure jointness of supply, group size has a *positive* effect on the probability that it will be provided". On the other hand, if one is analyzing the conflict levels over a subtractable good and the transaction costs of arriving at acceptable allocation formulas, group size may well exacerbate the problems of self-governing systems. Since there are tradeoffs among various impacts of size on other variables, a better working hypothesis is that group size has a curvilinear relationship to performance.

7.2. Heterogeneity

Many scholars conclude that only very small groups can organize themselves effectively because they presume that size is related to the homogeneity of a group and that homogeneity is needed to initiate and sustain self-governance. Heterogeneity is also a highly contested variable. For one thing, groups can differ along a diversity of dimensions including their cultural backgrounds, interests, and endowments [see Baland and Platteau (1996)]. Each may operate differently.

If groups coming from diverse cultural backgrounds share access to a common resource, the key question affecting the likelihood of self-organized solutions is whether the views of the multiple groups concerning the structure of the resource, authority, interpretation of rules, trust, and reciprocity differ or are similar. In other words, do they share a common understanding (A2) of their situation? New settlers to a region may simply learn and accept the rules of the established group, and their cultural differences on other fronts do not affect their participation in governing a resource. On the other hand, new settlers are frequently highly disruptive to the sustenance of a self-governing enterprise when they generate higher levels of conflict over the interpretation and application of rules and increase enforcement costs substantially.

When the interests of appropriators differ, achieving a self-governing solution to common-pool resource problems may be challenging, but not insurmountable [see Baland and Platteau (1999)]. This problem characterizes some fisheries where local subsistence fishermen have strong interests in the sustenance of an inshore fishery, while industrial fishing firms have many other options and may be more interested in the profitability of fishing in a particular location than its sustained yield. The conflict between absentee livestock owners versus local pastoralists has also proved difficult to solve in many parts of the world.

Differential endowments of appropriators can be associated with both extreme levels of conflict as well as very smooth and low-cost transitions into a sustainable, self-governed system. Johnson and Libecap (1982) reason that the difference in the skills and knowledge of different kinds of fishers frequently prevents them from arriving at agreements about how to allocate quantitative harvesting quotas [see also Scott (1993)]. In this case, heterogeneity of endowments and of interests coincide. Heterogeneity of wealth or power may or may not be associated with a difference in interests. As

discussed above, when those who have more assets share similar interests with those who have fewer assets (A4), groups may be privileged by having the more powerful take on the higher initial costs of organizing while crafting rules that benefit a large proportion of the appropriators.

Appropriators do, however, design institutions in some settings that cope effectively with heterogeneities. In a series of laboratory experiments very similar to those discussed above, Hackett, Schlager and Walker (1994) divided appropriators into two groups. One group was endowed with three times the tokens of the other group. Despite this substantial heterogeneity in assets, subjects devised rules for investing in the common-pool resource at near-optimal levels when allowed to communicate. Lam (1998) did not find that differences in income among irrigators significantly affected the performance of their irrigation systems. Varughese and Ostrom (2001) examined the effects of locational differences, wealth disparities, and cultural differences on collective action among 18 different forest user groups in Nepal. They found no relationship between these sources of heterogeneity and the likelihood of successful collective action.

Even in a group that differs on many variables, if at least a minimally winning subset of K appropriators from an endangered but valuable resource are dependent on it (A1), share a common understanding of the situation (A2), have a low discount rate (A3), include some with more assets among their members (A4), trust one another (A5), and have autonomy to make rules (A6), it is more likely that expected benefits of governing this resource are greater than expected costs. Whether the rules agreed upon distribute benefits and costs fairly depends both on the collective-choice rule used and the type of heterogeneity existing in the community. Successful groups that have overcome the challenge of heterogeneity appear to have adopted rules that allocate benefits using the same formulae used to allocate duties and responsibilities (Design Principle 2A); appropriators who differ significantly in terms of assets will tend to agree to and follow such rules.

Neither size nor heterogeneity is a variable with a uniform effect on the likelihood of organizing and sustaining self-governing enterprises. The debate about their effect is focusing on the wrong variables. Instead of focusing on size or the various kinds of heterogeneity by themselves, it is important to ask how these variables affect other variables as they impact on the benefit-cost calculus of those involved in negotiating and sustaining agreements. Their impact on costs of producing and distributing information [Scott (1993)] is particularly important.

8. Conclusion

The conventional theory of common-pool resources, which presumed that external authorities were needed to impose rules on those appropriators trapped into producing excessive externalities on themselves and others, has now been shown to be a special theory of the conventional theory of common-pool resources. For appropriators to contemplate changing the institutions they face, a minimal winning coalition of them

has to conclude that the expected benefits from an institutional change will exceed the immediate and long-term expected costs. When appropriators cannot communicate and have no way of gaining trust through their own efforts or with the help of the larger political system within which they are embedded, the prediction of the earlier theory is likely to be empirically supported. Ocean fisheries, the atmosphere, and other global commons come closest to the appropriate empirical referents. If appropriators can engage in face-to-face bargaining and have autonomy to change their rules, they may well attempt to organize themselves. Whether they organize depends on attributes of the resource system and the appropriators themselves that affect the benefits to be achieved and the costs of achieving them. Whether their self-governed enterprise succeeds over the long term depends on whether the institutions they design are consistent with design principles underlying robust, long-living, self-governed systems. The theory of common-pool resources has progressed substantially during the past half century. There are, however, many challenging puzzles to be solved.

References

Agrawal, A. (2000), "Small is beautiful, but is larger better? Forest-management institutions in the Kumaon Himalaya, India", in: C. Gibson, M. McKean and E. Ostrom, eds., People and Forests: Communities, Institutions, and Governance (MIT Press, Cambridge, MA) 57–86.

Alexander, P. (1982), Sri Lankan Fishermen: Rural Capitalism and Peasant Society (Australian National University, Canberra).

Baland, J.-M., and J.-P. Platteau (1996), Halting Degradation of Natural Resources. Is There a Role for Rural Communities? (Clarendon Press, Oxford).

Baland, J.-M., and J.-P. Platteau (1999), "The ambiguous impact of inequality on local resource management", World Development 27(5):773–788.

Barker, R., E.W. Coward Jr, G. Levine and L.E. Small (1984), Irrigation Development in Asia: Past Trends and Future Directions (Cornell University Press, Ithaca, NY).

Berkes, F. (1986), "Local-level management and the commons problem: A comparative study of Turkish coastal fisheries", Marine Policy 10:215–229.

Berkes, F. (ed.) (1989), Common Property Resources: Ecology and Community-Based Sustainable Development (Belhaven Press, London).

Berkes, F., D. Feeny, B.J. McCay and J.M. Acheson (1989), "The benefits of the commons", Nature 340:91–93.

Blomquist, W.A. (1992), Dividing the Waters: Governing Groundwater in Southern California (Institute for Contemporary Studies Press, San Francisco, CA).

Blomqvist, A. (1996), Food and Fashion. Water Management and Collective Action among Irrigation Farmers and Textile Industrialists in South India (The Institute of Tema Research, Department of Water and Environmental Studies, Linköping, Sweden).

Bromley, D.W., D. Feeny, M. McKean, P. Peters, J. Gilles, R. Oakerson, C.F. Runge and J. Thomson (eds.) (1992), Making the Commons Work: Theory, Practice, and Policy (Institute for Contemporary Studies Press, San Francisco, CA).

Buchanan, J.M., and G. Tullock (1962), The Calculus of Consent (University of Michigan Press, Ann Arbor).

Cernea, M. (1989), "User groups as producers in participatory afforestation strategies", World Bank Discussion Papers No. 70 (World Bank, Washington, DC).

Chamberlin, J. (1974), "Provision of collective goods as a function of group size", American Political Science Review 68(2):707–716.

Coleman, J. (1988), "Social capital in the creation of human capital", American Journal of Sociology 91(1):309–335.

Cordell, J. (ed.) (1989), A Sea of Small Boats (Cultural Survival, Inc., Cambridge, MA).

Dasgupta, P.S., and G.M. Heal (1979), Economic Theory and Exhaustible Resources (Cambridge University Press, Cambridge).

Dawes, R.M. (1973), "The commons dilemma game: An N-person mixed-motive game with a dominating strategy for defection", Oregon Research Institute Research Bulletin 13:1–12.

de los Reyes, R.P. (1980), 47 Communal Gravity Systems: Organization Profiles (Ateneo de Manila University, Institute of Philippine Culture, Quezon City, Philippines).

Feeny, D., S. Hanna and A.F. McEvoy (1996), "Questioning the assumptions of the 'tragedy of the commons' model of fisheries", Land Economics 72(2):187–205.

Gibson, C., M. McKean and E. Ostrom (2000), People and Forests: Communities, Institutions, and Governance (MIT Press, Cambridge, MA).

Gilles, J.L., and K. Jamtgaard (1981), "Overgrazing in pastoral areas: The commons reconsidered", Sociologia Ruralis 21:129–141.

Gordon, H.S. (1954), "The economic theory of a common property resource: The fishery", Journal of Political Economy 62:124–142.

Hackett, S., E. Schlager and J. Walker (1994), "The role of communication in resolving commons dilemmas: Experimental evidence with heterogeneous appropriators", Journal of Environmental Economics and Management 27:99–126.

Hardin, G. (1968), "The tragedy of the commons", Science 162:1243–1248.

Hardin, R. (1982), Collective Action (Johns Hopkins University Press, Baltimore, MD).

Isaac, R.M., K. McCue and C.R. Plott (1985), "Public goods provision in an experimental environment", Journal of Public Economics 26:51–74.

Isaac, R.M., J. Walker and A. Williams (1993), "Group size and the voluntary provision of public goods: Experimental evidence utilizing large groups", Journal of Public Economics 54(1):1–36.

Johnson, R.N., and G.D. Libecap (1982), "Contracting problems and regulation: The case of the fishery", American Economic Review 72(5):1005–1023.

Lam, W.F. (1998), Governing Irrigation Systems in Nepal: Institutions, Infrastructure, and Collective Action (Institute for Contemporary Studies Press, Oakland, CA).

Lam, W.F., M. Lee and E. Ostrom (1997), "The institutional analysis and development framework: Application to irrigation policy in Nepal", in: D.W. Brinkerhoff, ed., Policy Analysis Concepts and Methods: An Institutional and Implementation Focus (JAI Press, Greenwich, CT) 53–85.

Ledyard, J.O. (1995), "Is there a problem with public goods provision?", in: J. Kagel and A. Roth, eds., The Handbook of Experimental Economics (Princeton University Press, Princeton, NJ) 111–194.

Libecap, G.D. (1995), "The conditions for successful collective action", in: R. Keohane and E. Ostrom, eds., Local Commons and Global Interdependence: Heterogeneity and Cooperation in Two Domains (Sage, London) 161–190.

Libecap, G.D., and S.N. Wiggins (1985), "The influence of private contractual failure on regulation: The case of oil field unitization", Journal of Political Economy 93:690–714.

Marwell, G., and P. Oliver (1993), The Critical Mass in Collective Action: A Micro-Social Theory (Cambridge University Press, New York).

McCay, B.J., and J.M. Acheson (1987), The Question of the Commons: The Culture and Ecology of Communal Resources (University of Arizona Press, Tucson).

McKean, M.A. (1992), "Management of traditional common lands (Iriaichi) in Japan", in: D.W. Bromley et al., eds., Making the Commons Work: Theory, Practice, and Policy (Institute for Contemporary Studies Press, San Francisco, CA) 63–98.

McKean, M.A. (2000), "Common property: What is it, what is it good for, and what makes it work?", in: C. Gibson, M. McKean and E. Ostrom, eds., People and Forests: Communities, Institutions, and Governance (MIT Press, Cambridge, MA) 27–56.

Messick, D.M., S.T. Allison and C.D. Samuelson (1988), "Framing and communication effects on group members' responses to environmental and social uncertainty", in: S. Maital, ed., Applied Behavioral Economics, Vol. II (Wheatsheaf, Brighton).

Moir, R. (1995), "The effects of costly monitoring and sanctioning upon common property resource appropriation", Working Paper (University of New Brunswick, Department of Economics, Saint John, New Brunswick).

Morrow, C.E., and R.W. Hull (1996), "Donor-initiated common pool resource institutions: The case of the Yanesha forestry cooperative", World Development 24(10):1641–1657.

Moxnes, E. (1996), "Not only the tragedy of the commons: Misperceptions of bioeconomics", Working Paper (Foundation for Research in Economics and Business Administration, SNF, Bergen, Norway).

National Research Council (1986), Proceedings of the Conference on Common Property Resource Management (National Academy Press, Washington, DC).

Netting, R.McC. (1972), "Of men and meadows: Strategies of Alpine land use", Anthropological Quarterly 45:132–144.

Olson, M., Jr. (1965), The Logic of Collective Action: Public Goods and the Theory of Groups (Harvard University Press, Cambridge, MA).

Orbell, J.M., A. van de Kragt and R.M. Dawes (1988), "Explaining discussion-induced cooperation", Journal of Personality and Social Psychology 54(5):811–819.

Ostrom, E. (1990), Governing the Commons: The Evolution of Institutions for Collective Action (Cambridge University Press, New York).

Ostrom, E. (1992a), Crafting Institutions for Self-Governing Irrigation Systems (Institute for Contemporary Studies Press, San Francisco, CA).

Ostrom, E. (1992b), "The rudiments of a theory of the origins, survival, and performance of common-property institutions", in: D.W. Bromley et al., eds., Making the Commons Work: Theory, Practice, and Policy (Institute for Contemporary Studies Press, San Francisco, CA) 293–318.

Ostrom, E., R. Gardner and J.M. Walker (1994), Rules, Games, and Common-Pool Resources (University of Michigan Press, Ann Arbor).

Ostrom, E., and J.M. Walker (1997), "Neither markets nor states: Linking transformation processes in collective action arenas", in: D.C. Mueller, ed., Perspectives on Public Choice: A Handbook (Cambridge University Press, Cambridge) 35–72.

Ostrom, V. (1991), The Meaning of American Federalism: Constituting a Self-Governing Society (Institute for Contemporary Studies Press, San Francisco, CA).

Ostrom, V. (1997), The Meaning of Democracy and the Vulnerability of Democracies: A Response to Tocqueville's Challenge (University of Michigan Press, Ann Arbor).

Ruddle, K., and R.E. Johannes (eds.) (1985), The Traditional Knowledge and Management of Coastal Systems in Asia and the Pacific (UNESCO, Jakarta).

Schlager, E. (1990), "Model specification and policy analysis: The governance of coastal fisheries", Ph.D. Thesis (Indiana University, Bloomington, IN).

Schlager, E., and E. Ostrom (1992), "Property-rights regimes and natural resources: A conceptual analysis", Land Economics 68(3):249–262.

Schweik, C.M., K. Adhikari and K.N. Pandit (1997), "Land-cover change and forest institutions: A comparison of two sub-basins in the southern Siwalik hills of Nepal", Mountain Research and Development 17(2):99–116.

Scott, A.D. (1955), "The fishery: The objectives of sole ownership", Journal of Political Economy 63:116–124.

Scott, A.D. (1993), "Obstacles to fishery self-government", Marine Resource Economics 8:187–199.

Sengupta, N. (1991), Managing Common Property: Irrigation in India and the Philippines (Sage, New Delhi).

Shepsle, K.A. (1989), "Studying institutions: Some lessons from the rational choice approach", Journal of Theoretical Politics 1:131–149.

Shivakoti, G., and E. Ostrom (eds.) (2002), Improving Irrigation Governance and Management in Nepal (Institute for Contemporary Studies Press, Oakland, CA).

Singleton, S. (1998), Constructing Cooperation: The Evolution of Institutions of Comanagement (University of Michigan Press, Ann Arbor).

Tang, S.Y. (1992), Institutions and Collective Action: Self-Governance in Irrigation (Institute for Contemporary Studies Press, San Francisco, CA).

Thompson, L.L., E.A. Mannix and M.H. Bazerman (1988), "Negotiation in small groups: Effects of decision rule, agendas and aspirations", Journal of Personality and Social Psychology 54:86–95.

Varughese, G., and E. Ostrom (2001), "The contested role of heterogeneity in collective action: Some evidence from community forestry in Nepal", World Development 29(5):747–765.

Wade, R. (1994), Village Republics: Economic Conditions for Collective Action in South India (Institute for Contemporary Studies Press, San Francisco, CA).

Walker, J.M., R. Gardner and E. Ostrom (1990), "Rent dissipation in a limited-access common-pool resource: Experimental evidence", Journal of Environmental Economics and Management 19:203–211.

Walker, J.M., R. Gardner, A. Herr and E. Ostrom (2000), "Collective choice in the commons: Experimental results on proposed allocation rules and votes", The Economic Journal 110(460):212–234.

Weissing, F.J., and E. Ostrom (1991), "Irrigation institutions and the games irrigators play: Rule enforcement without guards", in: R. Selten, ed., Game Equilibrium Models II: Methods, Morals, and Markets (Springer-Verlag, Berlin) 188–262.

Weissing, F.J., and E. Ostrom (1993), "Irrigation institutions and the games irrigators play: Rule enforcement on government- and farmer-managed systems", in: F.W. Scharpf, ed., Games in Hierarchies and Networks: Analytical and Empirical Approaches to the Study of Governance Institutions (Campus Verlag, Frankfurt am Main; Westview Press, Boulder, CO) 387–428.

Wilson, P.N., and G.D. Thompson (1993), "Common property and uncertainty: Compensating coalitions by Mexico's pastoral Ejidatarios", Economic Development and Cultural Change 41(2):299–318.