

Common-Pool Resource Theory

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An August 2000 article in the *New York Times Magazine* reported on “the ruined fisheries of the Northeast.”¹ The cod, swordfish, and halibut fisheries no longer are economically viable. Only the lobster fishery remains productive, but it too is beginning to show signs of overharvesting. Fishers are using larger boats, spending more time at sea, setting more lobster traps, and harvesting increasingly smaller lobsters. Most lobsters harvested are just of legal minimum size, meaning that at most they have had one year in which to spawn and reproduce.² In the article a fisherman states, “I have no incentive to conserve the fishery, because any fish I leave is just going to be picked by the next guy.”³

Many would not find the description of the New England lobster fishery surprising. After all, it mirrors the dynamic described by Garrett Hardin in his article “The Tragedy of the Commons.”⁴ The New England fishers, just like Hardin’s herders, are locked in a deadly competition for resources, a competition from which they do not seem to be able to extricate themselves. As the fisherman quoted here noted, he faces few incentives to limit his harvest. Another will harvest whatever he conserves, and the fish stock will still be destroyed. The fishers collectively can limit their harvesting and preserve their fisheries, thus helping themselves in the process, yet that possibility appears remote because of the overwhelming temptations that each fisher faces to free-ride off of the others’ efforts. The fishers seem doomed, short of forceful intervention by an external authority.

What may surprise many is the description of a different lobster fishery in the same newspaper article. On the southern coast of Australia, fishers make a generous living from the sea by limiting their catches and

conserving the fish stocks.⁵ Through a combination of community norms, rules, and enforcement plus government regulation, Australian fishers have extricated themselves from a tragedy of the commons. The lobstermen limit themselves to sixty traps each (substantially fewer than the 800 traps commonly used by New England lobstermen). Associated with each trap is a license that the Australian government allocated among working fishers in the 1960s.⁶ The licenses are fully transferable, and, in fact, if an individual wants to enter the fishery, he must purchase licenses from working fishers willing to part with theirs. No longer do the lobstermen race to harvest as many lobsters as possible. They typically work eight-hour days up to 187 days per year (again, substantially fewer than the 240 days per year their American counterparts work).⁷ Furthermore, the lobster stock remains healthy with larger, older lobsters still regularly harvested. As one fisherman is quoted as saying, "Why hurt the fishery? . . . It's my retirement fund. . . . If I rape and pillage the fishery now, in ten years my licenses won't be worth anything."⁸

The Australian fishers are not like Hardin's herders. They have avoided a tragedy of the commons. Why have Australian, but not New England, fishers figured a way out of their tragedy? Hardin's model cannot account for such success; it predicts failure. Until recently, if one turned to the very best scholarly work, one would find only explanations and predictions of failure. This chapter argues, however, that this attitude is beginning to change. Over the past fifteen years, scholars and practitioners have concluded that the tragedy of the commons is no longer the only model available to account for human use of common-pool resources. Furthermore, not only are appropriators able to extricate themselves from tragedies, but theoretically grounded and empirically tested explanations of the conditions under which they are likely to do so have been realized. As such, scholarship addressing common-pool resource dilemmas, done largely (but not exclusively) in the developing world, now offers a compass to practitioners and scholars for anticipating both failure and success in overcoming these dilemmas.⁹

Having developed more complete explanations of cooperation and of resource users' ability to coordinate and govern their behavior, however, is still a far cry from putting such insights into practice. The purpose of this chapter is thus threefold: (1) to review how and why local

governance of common-pool resources has become an increasingly important approach to environmental management; (2) to review what we know about the conditions under which such governance is more likely to be adopted and to be successful when adopted; and (3) to assess the future strategic choices, challenges, and opportunities local governance poses for environmental management. In the process, the chapter demonstrates what contribution common-pool resource theory can make to the building of a results-based sense of common purpose in environmental governance.

Common-Pool Resources, Noncooperative Behavior, and the Tragedy of the Commons

Over the course of almost fifteen years, between 1954 and 1968, scholars developed a number of models of tragedy. H. Scott Gordon and Anthony Scott argued that open access conditions in fisheries lead to the economic destruction of fish stocks.¹⁰ Individual fishers do not attend to the costs that they impose on other fishers who harvest from the same stock. They consequently continue to fish beyond the point of maximizing the revenue of the fishery and dissipate the fishery's rents.¹¹ In some instances, the fishery may be rendered biologically as well as economically nonviable. Gordon called for government intervention in fisheries to limit fishers' harvesting efforts. Scott demonstrated that such undesirable economic and biological outcomes might be avoided by imposing a single owner on the fishery.

At approximately the same time that Gordon and Scott published their fishery analyses, game theory was rapidly developing, and one of the most well-known and widely popularized games in game theory—the prisoners' dilemma—emerged.¹² The game pits individual rationality against collective rationality as each of the participants chooses his or her actions independently of one another. Narrowly self-interested behavior makes all participants worse off than if they acted cooperatively. Cooperative behavior with the other participants exposes oneself to terrible exploitation, but the choice and the outcome are incontrovertible: act narrowly self-interested and achieve an outcome in which all are made worse off. Like Hardin's herders and Gordon and Scott's fishers, the

participants are trapped, unable to extricate themselves from the dilemma.

In 1965, Mancur Olson published a theory of collective action. Although substantially more nuanced than the preceding models—he explored conditions under which cooperation might emerge—the overall tenor of the work was less than positive.¹³ Even if individuals share a common goal, he concluded, they are unlikely to cooperate voluntarily in achieving that goal. As he states, “unless the number of individuals in a group is quite small, or unless there is coercion or some other special device to make individuals act in their common interests, *rational, self-interested individuals will not act to achieve their common or group interests.*”¹⁴ In almost every instance, free-riding behavior trumps cooperative behavior. Shortly thereafter, Hardin’s tragedy of the commons popularized ideas that were becoming well established and accepted within the economics and political economy disciplines.

Such simple but powerful models made a convincing case that individuals left to their own devices would collectively destroy shared resources. Such a stark conclusion found its way into governments’ and international aid organizations’ policy prescriptions.¹⁵ Swift and sure government intervention was needed to resolve and prevent commons tragedies. This policy prescription also dovetailed nicely with the goals and purposes of modern state building that was occurring in developing countries recently freed from the crush of colonialism. Only strong central states have the expertise and the resources to address the myriad problems of poverty, illiteracy, poor health, inadequate infrastructure, pollution, and natural-resource degradation.

Central governments acted forcefully. In the United States, for instance, the national government for the first time adopted strict laws establishing national standards for clean air and water.¹⁶ Among other actions, the Canadian government created the Department of Fisheries and Oceans to establish national fishery regulation and enforcement as means of protecting and enhancing fish stocks and of improving fishers’ welfare.¹⁷ Developing countries, such as Honduras, India, Nepal, the Philippines, and Tanzania, nationalized resources that local communities once held in common. International aid organizations invested heavily in

state capacity building so that governments would have the wherewithal to impose and enforce regulations. The dominant policy paradigm was state-centered control and regulation.

Over the past two decades, increasing dissatisfaction has emerged with the state-centered policy programs pursued. In many instances in which national governments and centralized bureaucratic agencies intervened, claimed ownership, built extensive infrastructure, or imposed management regimes, results have been disappointing. Most commercially valuable fish stocks are overharvested; government-owned or managed forests are degraded; many government-owned and operated irrigation projects are poorly maintained, and the health of many people the world over remains threatened by polluted air, unclean water, and exposure to toxic chemicals and wastes. In some instances, policymakers, analysts, and citizens came to realize that government-centered approaches, although successful in limiting and even reversing resource degradation, could not address single-handedly many environmental problems. In other instances, government-centered approaches failed and in their failure contributed to the worsening of environmental problems.

Furthermore, in the mid-1980s, policy scholars began questioning the general application of models patterned after the tragedy of the commons. Hundreds of cases were identified in which people managed to extricate themselves from environmental tragedies by cooperating and developing rules that carefully coordinated and limited their use of common-pool resources.¹⁸ The case studies demonstrated that individuals are not always helplessly trapped in tragedies of their own creation. Rather, the interaction between humans and common-pool resources and the variety of institutional arrangements that individuals devise to mediate those interactions are much more complex and varied than suggested by the fishery, prisoners’ dilemma, and collective action models.¹⁹

Still, certain questions needed answering if state-centered policies were going to be challenged, revised, and replaced: Under what conditions are appropriators likely to cooperate to devise self-governing institutions that allow them to address the multiple dilemmas they face? How well do such institutions perform, and how do they perform relative to government-centered institutions?

The Tragedy of the Commons Revisited

In 1985, the U.S. National Research Council convened a distinguished panel of scholars to investigate and report on self-governing institutional arrangements devised by appropriators to coordinate and limit their use of common-pool resources. That panel was the genesis of an international association of scholars and practitioners,²⁰ a newsletter,²¹ several research institutes,²² and numerous research programs. Out of that body of research has come a variety of findings that offer a more positive view of the chances of building common purpose in environmental governance when common-pool resources are involved.

One of the major research programs emerging from the National Research Council panel, and the one that is the primary focus of this chapter, is that of Elinor Ostrom.²³ Ostrom argues that in attempting to resolve common-pool resource dilemmas, appropriators must work through three closely related issues—supply, commitment, and monitoring.²⁴ Common-pool resource dilemmas emerge because individuals in interdependent situations do not coordinate their actions, which leads to outcomes in which all appropriators are made worse off. Better outcomes might be achieved if individuals devised and adopted sets of rules that coordinated their use of the common-pool resource. However, those rules are public goods. Once provided, the rules benefit all appropriators, whether or not all appropriators contributed to their creation. Consequently, when supplying institutional arrangements that may resolve common-pool resource dilemmas, appropriators are confronted with collective action problems: obtaining voluntary contributions of time and resources needed to identify and negotiate a set of rules acceptable to most of them.

Even if appropriators successfully supply a set of rules, they must follow those arrangements most of the time to make them credible and effective. In many instances, however, they will face temptations to disobey the rules. As Ostrom asks, "How does one appropriator credibly commit himself or herself to follow a rotation system when everyone knows that the temptation to break that commitment will be extremely strong in future time periods?"²⁵

Monitoring to ensure that most appropriators are following the rules most of the time supports commitment to following the rules. Effective

monitoring discourages rule breaking and assures rule followers that they are not being taken advantage of by rule breakers. Yet monitoring is itself a public good—it accrues to all appropriators' benefit, regardless of whether they all contributed to monitoring. But without monitoring, commitments to following the rules are not credible, and without credible commitments to the rules, no rules will be devised and adopted.²⁶ Thus, the process of devising, implementing, and sustaining institutional arrangements that resolve common-pool resource dilemmas is fraught with difficulty.

Ostrom's emerging theory of common-pool resources and related research programs present a convincing argument that appropriators are capable of resolving common-pool resource dilemmas.²⁷ Also, the institutional arrangements that appropriators participate in devising, revising, implementing, and enforcing outperform institutional arrangements that government officials devise, revise, implement, and enforce. Thus, the theory of common-pool resources represents a significant and promising approach for the governance of natural resources and the resolution of critical environmental problems. What is more, the empirical research generated by these related research programs affords both practitioners and theorists a robust contingency theory suitable for guiding practice and building theory. Among other things, the programs offer insights into the conditions under which self-governance regimes are more or less likely to arise and under which long-term cooperation within these regimes is more or less likely to occur.

The Emergence of Cooperative Behavior

Whereas Ostrom's initial work focused on explaining the conditions that support long-term cooperation and coordination among appropriators, her more recent work has focused on identifying the conditions under which appropriators are likely to cooperate to devise governing arrangements. The attributes of common-pool resources that are supportive of the emergence of cooperation are:

1. *Feasible improvement.* Resource conditions are not at such a point of deterioration that it is useless to organize, nor are they so underutilized that little advantage results from organizing;

2. *Indicators.* Reliable and valid indicators of the condition of the resource system frequently are available at a relatively low cost;
3. *Predictability.* The flow of resource units is relatively predictable;
4. *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.²⁸

Appropriator attributes that support the emergence of cooperation include:

1. *Salience.* Appropriators are dependent on the resource system for a major portion of their livelihood or other important activity;
2. *Common understanding.* Appropriators have a shared image of how the resource system operates . . . and how their actions affect each other and the resource system;
3. *Low discount rate.* Appropriators use a sufficiently low discount rate in relation to future benefits to be achieved from the resource;
4. *Trust and reciprocity.* Appropriators trust one another to keep promises and relate to one another with reciprocity;
5. *Autonomy.* Appropriators are able to determine access and harvesting rules without external authorities countermanding them;
6. *Prior organizational experience and local leadership.* Appropriators have learned at least minimal skills of organization and leadership through participating in other local associations or through studying ways that neighboring groups have organized.²⁹

Characteristics of common-pool resources and characteristics of appropriators interact to affect the likelihood of appropriators engaging in the challenging and costly process of supplying rules. For instance, take the second appropriator condition—common understanding of the resource and how their actions affect it. How quickly and easily do appropriators arrive at such a conclusion? Arriving at a common understanding of the resource and of the effects of their actions on it will be more or less difficult to do depending on the number and types of reliable indicators of the resource condition available to them (resource characteristic two), the predictability of the resource (resource characteristic three), and the spatial

extent of the resource (resource characteristic four). In relatively simple settings, appropriators are likely to assess their situation more quickly and accurately. In more complex settings, such as in the West Basin case in California, described more fully later in the chapter, it may take years for appropriators to understand the problems they face. In West Basin, signs of trouble began to emerge in 1912, but it was not until the early 1940s that some appropriators began alerting others and organizing for rule changes.

Even if appropriator characteristic two is met, appropriators still must decide whether it is worthwhile engaging in processes of changing rules to address the common-pool resource dilemmas that confront them. If appropriators highly value the common-pool resource (appropriator characteristic one) and would like for it to remain viable (appropriator characteristic three), if they share some social capital among themselves that they can use to begin working together (appropriator characteristic four), and if they believe that they will benefit from proposed rule changes, then they are likely to attempt to undertake a rule change. Whether such an attempt will be successful depends on appropriators' autonomy to change rules (appropriator characteristic five) and their leaders' skills and assets (appropriator characteristic six).

The attributes of common-pool resources and of appropriators should not be considered necessary or sufficient for appropriators to engage in collective action to create or change institutional arrangements. Rather, the attributes should be thought of as conditions positively related to the emergence of collective action. In a setting in which all attributes are met, appropriators are very likely to engage in collective action, whereas in a setting in which only one attribute is met, appropriators are much less likely to engage in collective action. Between these two extremes, many outcomes are possible, depending on the values of the ten attributes in relation to one another. Also, Ostrom argues that the attributes of a given common-pool resource situation are themselves conditioned and affected by the larger institutional setting.³⁰ Under different institutional settings, the values and therefore the significance of the ten attributes are likely to change. In other words, the theory is contingent (that is, context matters) and configural (that is, the value of one variable depends on the values of the other variables). Thus, although the theory appears simple, at least on the surface, involving only ten variables, it is in fact quite complex.

Designing Long-Term Cooperation

According to Ostrom, appropriators are much more likely to commit themselves to and monitor institutional arrangements across many generations if the institutional arrangements are characterized by eight design principles. Ostrom was not willing to propose the principles as necessary conditions for long-term success; however, the principles do account for the success of institutional arrangements in sustaining common-pool resources and in gaining the compliance of generations of appropriators. The design principles are:

1. Individuals or households who have rights to withdraw resource units from the common-pool resource must be clearly defined, as must the boundaries of the common-pool resource itself. This is commonly referred to as the principle of exclusion.
2. Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.
3. Most individuals affected by the operational rules can participate in modifying them.
4. Monitors, who actively audit common-pool resource conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.
5. Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.
6. Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7. The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8. Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.³¹

Design principle one, exclusion, is critical if appropriators are to commit to following a set of institutional arrangements over time and to investing

in modifying them as circumstances warrant. Appropriators must be assured that they will capture the benefits of their actions. Exclusion, although critical, is insufficient, however, to ensure long-term commitment to the rules. The rules themselves must make sense: they must be crafted to the exigencies of the situation, and as the situation changes, the appropriators must have the ability to modify them. Accountable monitors and graduated sanctioning maintain appropriators' commitment to institutional arrangements. In many instances, the rules support monitoring by appropriators while they are using the common-pool resource. Finally, conflict resolution mechanisms and at least a minimal recognition of the right to organize prevent institutional regimes from unraveling because of internal strife or invasion from external governmental authorities.

These eight principles have received considerable support from in-depth research conducted across several different types of common-pool resources. A study I conducted, for example, examined thirty case studies of coastal fisheries located around the world, involving forty-four groups of fishers.³² The fishery cases demonstrate the importance of exclusion, carefully crafted rules designed by fishers, and monitoring.

Fishers commonly face several types of dilemmas, or conflicts, that require careful coordination if they are to be resolved. In addition to the overharvesting of fish, coastal fishers confront conflict over access to the most productive fishing grounds and over entanglement and destruction of incompatible types of gear.³³ In order to be resolved, these two types of dilemmas require fishers to exercise relatively high levels of control over access to their fishing grounds and to allocate themselves over the grounds. This must be done in such a way as to minimize destructive competition, whether for productive areas or among incompatible gear types. Of the forty-four subgroups of fishers in my study, thirty-three had adopted both access and harvesting rules.³⁴

F. T. Christy, a highly regarded fisheries analyst, argues that for fishers to exercise real control over their fishing grounds, they must utilize more restrictive rules than simple residency in the village or region nearest the fishery.³⁵ Among the thirty-three subgroups of fishers in my study, all used a residency rule and at least one additional rule to control access to their fishing grounds. Fishers also used combinations of twelve different access rules. The most common rule combined with a residency rule was a fishing

technology rule. Fishers specified that only particular types of fishing gear can be used in their fisheries. The next most common type of rule to combine with a residency rule was organization membership. In most cases, this rule required an individual to belong to the local fish cooperative. Other rules included owning a fishing license or participating in a lottery to allocate fishing spots. Among groups of fishers who exercised high levels of control over access, individuals not only had to be local residents, but they also had to meet additional qualifications before gaining entry to the fishery.

The thirty-three subgroups noted earlier also guided harvesting through the use of combinations of five different types of rules. Each subgroup adopted a rule of fishing at specific locations or spots. Fishers could not fish how and where they pleased; rather, rules allocated fishers across fishing grounds. In addition to a location rule, some subgroups adopted fish-size rules, others season rules, and yet others a taking-turns rule.

Although fishers from different fishing grounds located around the world adopted the same five general rules to guide their harvesting, the ways in which the rules were implemented or practiced varied substantially. The fishers crafted the specifics of their rules to fit the conditions of their grounds and their cultural norms and practices. Among coastal fishers along the Atlantic coast of Canada, lotteries commonly were used to allocate choice cod-fishing spots each year.³⁶ Coastal fishers from Alanya, Turkey, also used a lottery to allocate choice fishing spots. However, their lottery was used to make an initial allocation of spots, which the fishers then rotated through, switching spots each day until all fishers had fished all spots.³⁷

Even though all groups of fishers did not utilize lotteries to allocate spots, all groups of fishers devised rules that separated potentially conflictual gear types by dividing fishing grounds among different types of technologies. For instance, the fishers of Fogo Island, Newfoundland, in addition to using a first-in-time, first-in-right rule to allocate choice cod spots, adopted rules regulating how close competing gears could be set to one another. They also banned particular types of technologies from specific areas; for example, baitless hooks, called jiggers, were forbidden on the fishing grounds farthest from shore.³⁸ In general, among the thirty-three subgroups, access and harvesting rules were used to limit

entry, govern the use of space on the fishing grounds, control types of technologies, and mandate how those technologies were used.

My research also indicated that the rules selected made a difference. The groups of fishers who adopted more complete and varied sets of rules and who were able to exercise greater control over access were much more likely to experience fewer conflicts on their fishing grounds than fishers who devised limited sets of rules and who exercised less control over access. In any case, fishers who adopted rules were better off than fishers who had no rules governing access or harvesting.³⁹

Like fishery studies, irrigation studies have confirmed the importance of exclusion and carefully crafted rules (design principles one and two), the importance of appropriators participating in devising and modifying rules (design principle three), and the importance of monitoring and enforcing the rules (design principles four and five).⁴⁰ Because irrigation systems are common-pool resources, irrigators experience dilemmas in the operation and maintenance of such systems. In many instances, water is insufficient to meet all irrigators' needs all of the time. Water allocation rules must be established to share water across irrigators. As water becomes increasingly scarce, and as water demands are not satisfied, irrigators face increasing temptation to cheat on the rules. Furthermore, irrigation structures must be built and maintained, and rules must be established governing irrigator contributions. Again, irrigators face temptations to shirk or avoid their contributions because it is difficult to prevent them from enjoying the benefits of a system, even if they did not contribute to it.⁴¹

Y. S. Tang studied forty-three irrigation systems: twenty-nine farmer-owned and farmer-governed systems, and fourteen government-owned systems.⁴² He used three performance measures to capture the extent to which governing systems mitigated the multiple dilemmas experienced by irrigators—system maintenance, adequacy of water supply, and rule-following behavior.⁴³ High-performing cases were ranked positively on both rule conformance and maintenance, whereas low-performing cases were ranked negatively on rule conformance or maintenance or both. Among the fourteen government-owned systems, six performed highly and eight did not. Among the twenty-nine farmer-owned irrigation systems, only twenty-five had sufficient information concerning the three

performance measures. Of those twenty-five, eighteen performed highly and seven did not.

What accounts for the differences between high-performing and low-performing irrigation systems? Tang argues that among irrigation systems that perform well, rules that govern water allocation and maintenance activities are better crafted to the specific conditions of each irrigation system.⁴⁴ High-performing systems were associated with multiple rules that adequately limited access to the system and that fairly allocated water among the irrigators. Low-performing irrigation systems were characterized by a single simple rule set or by no rules at all. Access to the irrigation systems was not regulated adequately, and water allocation rules often did not work well.⁴⁵

Although low-performing irrigation systems have rules of access and allocation that are similar to those of high-performing systems, they are much more likely to be government owned rather than farmer owned. Because government officials are not directly subject to the irrigation rules that they devise, they face few incentives to design rules that ensure the effective operation of irrigation systems. Instead, they face incentives to devise rules that increase their political support and that lighten their administrative burdens. Conversely, because farmers directly experience the consequences of their rule-making decisions, they confront incentives to craft carefully the rules to their particular situations.⁴⁶

Monitoring and enforcement systems also differ between irrigator-owned systems and government-owned systems in some surprising and unusual ways. Government-owned systems appear to have ideal monitoring systems in place—full-time, paid guards. Farmer-owned systems appear to have questionable monitoring systems in place—part-time guards who are not paid.⁴⁷ However, guards in farmer-owned systems are much more likely to impose sanctions on rule breakers than are guards in government-owned systems. Furthermore, rule-following behavior is much more common in farmer-owned systems than in government-owned systems, whether guards are present or not.⁴⁸ Farmers who participate in devising their own irrigation rules are much more likely to follow, monitor actively, and enforce their rules.

The evidence from irrigation systems should not be interpreted to suggest that governments have no role to play in addressing common-pool

resource dilemmas. That would be as great an error as suggesting that only governments can resolve common-pool resource dilemmas. The issue is not whether governments should be involved; rather, it is *how* governments should be involved in addressing such dilemmas. Tang's evidence suggests that, in general, appropriators are better than government agencies at crafting governance structures that fit well to specific situations. Research by William Blomquist on the governance of groundwater basins in California suggests that governments can be of greatest benefit to appropriators by providing a supportive environment that encourages appropriators to devise their own solutions to the dilemmas that they face (that is, design principles six, seven, and eight).⁴⁹ Southern California is one of the most populated, rapidly growing regions of the United States. For instance, the population of Los Angeles County quintupled from 2,208,492 in 1930 to 8,863,164 in 1990.⁵⁰ During this same time, much of the county's land was transformed from farms to cities and suburbs. Southern California is also one of the driest regions of the United States. Subject to periods of extended drought, it receives from fifteen to twenty inches of rainfall per year.⁵¹

Fortunately, the area is blessed with a series of interconnected, relatively deep, and highly productive groundwater basins. The basins provide an important source of water and a relatively inexpensive but critical source of water storage. For instance, West Basin, located beneath the coastal area of Los Angeles County, is estimated to hold 6.5 million acre-feet of water.⁵²

West Basin provides an excellent example of the complex dilemmas that can besiege pumpers if access, use, and maintenance of a groundwater basin are not attended to appropriately. West Basin is relatively vulnerable. Because one of its boundaries adjoins the ocean, saltwater can pour into the basin if water levels along that boundary drop below sea level, contaminating the freshwater of the basin as well as its storage capacity. The basin itself is covered by clay soils that are relatively impermeable, preventing basin recharge through rainfall seeping into the ground or through constructed recharge ponds. Instead, it is recharged primarily through water discharges from Central Basin, the groundwater basin directly upstream of it.⁵³

West Basin began to experience degradation problems in 1912. By the end of the 1950s, "with water levels down 200 feet in some places, an

accumulated over-draft of more than 800,000 acre-feet, and a half-million acre-feet of salt-water underlying thousands of acres of land and advancing on two fronts, the groundwater supply in West Basin was threatened with destruction."⁵⁴ The West Basin appropriators had created a tragedy for themselves. Could they extricate themselves from it?

In 1943, appropriators created the West Basin Water Users Association. One of its first actions was to issue a report on the state of the West Basin based on federal, state, and county investigations. This report alerted everyone in the basin to the substantial dilemmas emerging. Next, it assisted its members in forming the West Basin Municipal Water District, which would contract with other water providers to import water into the basin. While cities sought to import water into the basin, three major water providers filed suit against all other basin pumpers to adjudicate groundwater rights and to limit pumping. The court subsequently defined all relevant participants and provided a forum for which agreements could be negotiated and actions taken to benefit the basin as a whole.⁵⁵

The judge asked the California Division of Water Resources to act as fact finder and to report on the physical condition of the basin. In 1952, a report was issued suggesting that pumping be limited to 30,000 acre-feet annually. Most major water producers in the basin were alarmed by the possibility of having to reduce their pumping by two-thirds. After substantial negotiations and conflict, in 1961, the court accepted the settlement offered by the parties: "It gave ninety-nine parties transferable 'adjudicated rights' totaling 64,064.09 acre-feet."⁵⁶

Although basin appropriators took steps to import additional water and to limit pumping, pumping still exceeded replenishment by 100 percent. The West Basin Water Users Association decided to explore the possibility of increasing the recharge to the basin, to align pumping more nearly with replenishment. Because the basin was recharged by flows from Central Basin, water users in Central Basin would have to cooperate. The West Basin Water Users Association worked with the Los Angeles County Flood Control District, which operated recharge projects in Central Basin, and with the Central Basin Water Users Association to create a stable, long-term replenishment program that would benefit both basins.

In 1960, the Central and West Basin Water Replenishment District was created and was financed by a pump tax. The district purchases imported

replenishment water from the Central Basin Municipal Water District. The Municipal Water District conveys the water to the recharge sites, which the Los Angeles County Flood Control District operates. In addition to replenishment activities, the Replenishment District worked with the Flood Control District to create a freshwater barrier along the coast to mitigate the intrusion of seawater into West Basin.⁵⁷ West Basin is no longer in critical overdraft.

Through a complex series of steps over the course of two and one-half decades, the appropriators of West Basin had confronted and addressed a series of dilemmas that had brought the basin to the edge of destruction. The appropriators had formed their own organization, worked cooperatively with other organizations, and called on high-level decision makers such as the state courts and the state legislature to devise solutions.

In sum, Ostrom's eight design principles are given strong support from the research on fisheries, irrigation systems, and groundwater basins. In the instances in which appropriators have designed well-performing governing arrangements in both fisheries and irrigation systems, the rules match the setting, whether the process involves carefully allocating portions of a fishing ground to a particular type of fishing gear or allocating water by farmers taking turns.⁵⁸ Indeed, even among the seven southern California groundwater basins that had governing arrangements, appropriators from each basin designed different types of rules. In the case of fisheries, mutual monitoring occurred as fishers ensured that no one invaded their allocated spot or that someone was not using banned gear that might become entangled with their own.⁵⁹ In irrigation systems, mutual monitoring was supplemented by appropriators who employed fellow irrigators to monitor rule-following behavior, and those monitors actively sanctioned rule violators.⁶⁰ West Basin appropriators relied on the court-appointed special water master to monitor their pumping activities. If the master identified a violation, however, it was up to the appropriators to pursue sanctions against the offending party.⁶¹

In the case of West Basin, the state of California provided a supportive institutional environment (design principles seven and eight). It provided courts that acted as low-cost conflict resolution mechanisms for the appropriators. Furthermore, it provided monitors and vital information

about the condition of the basin, and as a home-rule state, it recognized and supported appropriators in their search for solutions to their groundwater basin problems.

Common-Pool Resource Theory: Challenges, Choices, and Opportunities

As the preceding discussion illustrates, there is reason for optimism that a major animating principle of environmental governance (namely, the tragedy of the commons) is more contingent and conditional than it was previously thought to be. Moreover, empirical research is suggesting the conditions under which common-pool resource management is likely to produce a results-based sense of common purpose for protecting these types of threatened resources. A central animating purpose for environmental governance when common-pool resources are involved is knowing when and how to help catalyze, maintain, and nurture these types of self-governing institutions. Still, a variety of strategic challenges, choices, and opportunities exist that render the future application of the concept difficult to discern. Most notable are those associated with (1) appreciating its wider applicability, (2) coming to terms with its contextual and configurational nature, (3) defining community, and (4) catalyzing a results-based sense of common purpose.

Toward Wider Applicability?

Opportunities to extend local governance models to a broader range of settings than originally envisioned clearly exist. This did not always seem to be the case. Because most empirical evidence informing and testing common-pool resource theory was drawn initially from cases involving relatively small numbers of mostly homogeneous appropriators, even those who saw the promise of local-level, self-governance models questioned their wider applicability. Many inferred that such an approach likely was viable only in relatively small, simple, and isolated settings.⁶²

A second generation of empirical work belies such a claim, however. Research has failed to find a significant relationship between the likelihood of collective action and the numbers and heterogeneity of appropriators. Tang and Lam, for instance, find that size of group does not affect the likelihood of collective action in irrigation systems.⁶³ Similarly,

Varughese and Ostrom, in a study of eighteen forest user groups in Nepal, did not find a significant relationship between numbers of appropriators and the emergence of collective action.⁶⁴ Agrawal, in a study of five community forests in India, however, found that size may matter, but in a somewhat different way.⁶⁵ Size of user group did not affect appropriators' ability to engage in collective action, but it did affect the performance of the institutional arrangements devised by the appropriators. Very small forest communities struggled to collect the resources needed to engage in effective monitoring and sanctioning of locally designed rules. Moderate-size communities were able to tap into a larger resource base and engage in more effective monitoring and sanctioning of forest access and use.

Many researchers also incorrectly assumed that differences among appropriators (for example, in terms of skill at harvesting, technologies used, income, social status) would interact with area size and location to inhibit their ability to engage in collective action. In other words, individuals would find it much more difficult to agree on a set of institutional arrangements because their interests would differ significantly from one another.⁶⁶ Yet empirical findings thus far concerning area size, location, and heterogeneity suggest that appropriators of common-pool resources are capable of engaging in collective action under a wide and varied set of circumstances.

Varughese and Ostrom, for example, examined the effects of locational differences, wealth disparities, and sociocultural differences on the likelihood and success of collective action.⁶⁷ They found that differences in distance from forests, wealth, and sociocultural composition did not affect significantly levels of collective action.⁶⁸ Rather, the success of collective action was related significantly to the specifics of the self-governing regime created. The forests used by persons who had both devised *and* enforced rules of access and use were in much better condition than those used by persons who had devised rules but did not enforce them. They also were in better condition than those used by persons operating without rules. Lam, too, found that differences in income did not affect significantly the performance of irrigation organizations.⁶⁹

Thus even in relatively large and complex social settings, appropriators may devise and adopt governing arrangements. Collective action is not

restricted just to relatively small, simple, and isolated settings.⁷⁰ Recognition of this situation, in turn, brings a legitimate opportunity for policymakers to choose to extend self-governing models to a broader range of environmental and natural resources (ENR) management settings than previously appreciated.

Understanding Contextuality

A much more difficult challenge for incorporating theoretical insights into ENR governance is the contingent and configurel nature of the theory, which places a premium on local knowledge and context if policymakers are to choose appropriate and workable policies. As this chapter has demonstrated, a robust list of contingency factors exist, depend on how they interact with others, and depend for their success on policymakers accurately matching them (singly or in combination) to appropriate implementation contexts. An example of the contingent nature of the theory is provided by recent work on conjunctive water management.

Blomquist, Heikkila, and I examined and compared the conjunctive water management activities of local jurisdictions among three states—Arizona, California, and Colorado.⁷¹ Conjunctive water management refers to the coordinated use of surface water and groundwater as a means of developing additional water supplies and limiting the waste of existing supplies. The coordination of the two water sources typically occurs through recharge projects. Surplus surface water is stored, or recharged, in an underground basin for use at a later time.

Water appropriators who contemplate investing in recharge projects must have assurances that the water they store underground will be available to them at a later time. In other words, they must be able to exclude from access to the stored water those who did not contribute to their project. Thus, attribute four of Ostrom's common-pool resource theory—spatial extent—appears to be critical in building a sense of common purpose. The spatial extent of a basin must be such that water appropriators can gain control over the basin and exercise exclusion if they are to cooperate in conjunctive water management.

But consider the contingent and configurel nature of these conjunctive water management initiatives. In California, conjunctive water management activities occur *only* in basins in which appropriators have organized

themselves and have developed a set of institutional arrangements whereby they control access to and use of the basins.⁷² Yet, even though appropriators in Arizona and Colorado do not control access to and use of groundwater basins, they too actively and successfully engage in conjunctive water management. Why? The governments of Arizona and Colorado, unlike the government of California, have devised and allocated private-property rights in surface water, in groundwater, and in stored, or recharged, groundwater. Appropriators in Arizona and Colorado, because of their state-granted private-property rights in water, are assured that if they store water underground, they will be able to retrieve it at a later date because of their property rights in that water. They do not first have to gain control over a groundwater basin. Appropriators in California, on the other hand, must first gain control over their basin and define property rights in it (see the earlier discussion of the West Basin case) before they are sufficiently secure to invest in conjunctive water management projects.

Defining Community

Of course, the local knowledge and contextual information critical for designing workable rules and policies for common-pool resources is centered among appropriators. Thus, workable rules and policies require that appropriators choose to participate actively in governance. By the same token, however, empowering appropriators is fraught with its own strategic challenges, choices, and opportunities—many of them encapsulated within the concept of *community*. Providing aid and assistance to local communities to bolster their conservation activities is hardly a straightforward process. As noted, communities are not necessarily homogeneous political, social, and economic groupings that can be treated as single units. External interventions, if not carefully crafted to this reality, may result in tragic unintended consequences.

For instance, Lam, in his study of Nepal irrigation systems, noted instances in which the government of Nepal replaced crude mud-and-stick diversion works with permanent concrete diversion structures as a means of lessening irrigators' labor demands. The cooperative, self-governing institutional arrangements irrigators had devised promptly fell apart. Why? One of the major schisms within irrigation communities is between

irrigators at the head end of the canal who have first access to water and irrigators at the end of the canal who are at the mercy of those ahead of them for water.

One means policymakers have of addressing head-ender/tail-ender conflicts is choosing to develop multiple ties between the two groups. In the Nepalese irrigation systems prior to the change in diversion structures, head-enders had cooperated with tail-enders in developing fair water allocation methods. Similarly, tail-enders had cooperated with head-enders in rebuilding and maintaining the crude stick-and-mud diversion works. Once permanent diversion works were installed, however, head-enders, who no longer needed the labor of the tail-enders, stopped cooperating in allocating water.

ex Intracommunity divisions and inequities may also be exacerbated if policymakers decide to provide financial, technical, or legal aid to communities without considering who should receive the resources. Already powerful members of communities may gain control over those resources and use them in ways unintended by the donors.⁷³ Likewise, even understandable attempts to re-create "community" where it is believed once to have existed can have perverse effects. Re-creating community aims to help persons who rely on severely degraded resources to reclaim their livelihoods from those resources. The problem with such an approach is that no such community may have ever existed. The people subject to such interventions consequently may not be capable of taking advantage of the resources provided, or the resources may be inadequate or inappropriate for the task.

The government of the Philippines, for instance, adopted legislation granting Certificates of Ancestral Domain to communities. These certificates allowed communities greater autonomy in managing their resources. To qualify, communities had to demonstrate that they had lived continuously in communally bounded and defined territories, that they were governed by traditional leaders, and that they managed their natural resources in a sustainable manner.⁷⁴ Although no such communities existed on Palawan Island, one certificate was granted to two loosely grouped ethnic communities there. Little changed for these two communities after they received a certificate, however. They did not gain greater control over the resources they depend on for their livelihoods. As one

researcher concludes, the legislation creating the certificates only assumed community capacity and therefore failed to provide resources to create it.⁷⁵ "Capacity" means nothing if there is no means or discretion with which to exercise it."⁷⁶

Thus, as Agrawal and Gibson conclude, one key to implementing the insights of common-pool resource theory is for policymakers to avoid making heroic or romanticized assumptions about communities and their capacities. Most important, they should not assume that communities are small spatial units whose members are economically, politically, and socially homogeneous, and who share norms and beliefs that encourage resource conservation.⁷⁷ Developing and implementing policy based on those assumptions is sure to lead to failure and disillusionment. Agrawal and Gibson argue that implementation should be based instead on a careful understanding of the multiple actors and their diverse interests in using common-pool resources, the processes by which they interact with one another, and the institutional arrangements that structure their interaction.⁷⁸

Catalyzing Common Purpose?

The challenges of contingencies aside, scholars and policymakers *have* discovered the potential of local-level actors for governing and conserving natural resources. What remains, however, is determining how to unleash this potential appropriately for building a results-based sense of common purpose. This task, in turn, requires a fundamental choice involving how public managers and elected officials conceptualize the means and ends of environmental governance. For self-regulatory governance structures to succeed, officials will have to work with and encourage appropriators to govern themselves and solve their own common-pool resource dilemmas.

Numerous scholars and analysts have noted, however, that public managers, trained as experts, come to view themselves as active problem solvers and to view citizens, at best, as incapable of helping themselves and, at worst, as active and purposeful problem creators.⁷⁹ Furthermore, numerous legislative mandates direct and constrain managers. They also are expected dutifully to achieve multiple and often conflicting mandates in an administratively competent manner. In so doing, they often lose sight of the goals that they and their programs were intended to achieve.⁸⁰

As Mark Moore summarizes the dilemma, public managers adopt the mindsets of bureaucrats and administrators and not of facilitators and leaders.⁸¹

If the insights of common-pool resource theory are to be realized, ENR managers must reconceptualize their sense of role and purpose, both in their own and in legislators' minds. As Robert Reich proposes more generally, ENR managers must learn to facilitate public education and deliberation about public problems in a process of "civic discovery."⁸² Deliberation, in these instances, focuses on mutually identifying and defining problems with citizens, on considering alternative and coproduced solutions to these problems, and on discussing with citizens how solutions can be realized. Meanwhile, legislators must follow Moore's suggestion that they enable public managers to become "explorers who, with others, seek to discover, define, and produce public value."⁸³

Undertaking this reorientation is critical for common-pool resource management to succeed. No longer must public managers see resource appropriators as individuals who are trapped hopelessly in tragedies of the commons, but rather as individuals who are and must be active problem solvers. As this chapter has discussed, ENR managers must see appropriator participation as vital for two reasons. First, they must appreciate that appropriators possess critical time and place knowledge—about resources, about their own social norms, about the rules and practices that they follow. This knowledge, in turn, must be taken into account in formulating ENR policies in order to make them workable. Second, managers and legislators must understand that monitoring and enforcing policies will be less problematic if appropriators embrace those policies. Rule-following is likely to be high in that case, and appropriators are likely to engage in self-monitoring and enforcement.

To these ends, common-pool resource theory requires both flexibility and varied approaches to inclusivity. It points to numerous activities in which governments can engage, such as lowering the information and enforcement costs confronting appropriators and providing appropriators with fair conflict resolution mechanisms. In turn, while the activities that governments can engage in are many and varied, policymakers must invest in appropriators' governing capacities rather than in command-and-control policy prescriptions. Indeed, the theory points to the centrality of

allowing appropriators to devise their own solutions or at least to participate actively in problem solving, with managers facilitating rather than controlling the process.

The difficulty of realizing this fundamental perestroika in thinking cannot be overestimated. Reorienting public managers, for example, will require more than changing graduate schools' curricula; it also will require changing the context in which public managers act. The current context of multiple and highly constraining mandates and procedures described by Denise Scheberle and others in their chapters in this volume focuses managers' attention on control. These procedures will have to be redesigned to focus managers' attention on facilitation and problem solving in partnership with citizens. The conditions under which legislatures will be willing to loosen their control over public managers by relaxing strict mandates is, no doubt, dependent on circumstances. But try they must if the insights of common-pool resource theory are to be realized.

Granted, common-pool resource theory does not predict that appropriators always will be successful. Instead, success or failure is conditioned on the specific circumstances in which appropriators and policymakers find themselves. Moreover, as noted, significant organizational, political, and analytical obstacles exist to complicate success. Nevertheless, developing more complete explanations of cooperation and resource users' ability to coordinate and govern their behavior in pursuit of building a results-based sense of common purpose is a significant contribution to environmental governance in the twenty-first century. Given the relative infancy of the theory and its testing, this is no small accomplishment.

Whether policymakers choose to take advantage of these insights in order to help build common purpose when common-pool resources are at risk remains an unanswered yet important question as the twenty-first century unfolds. What is *not* in question, however, is the need for humanity to find ways to address collaboratively the risks to common-pool resources that are so vital to livelihoods worldwide. Nor is it debatable that developing the common understanding, trust, and reciprocity essential for collaboration to occur is often the product of regular interpersonal interactions and participation in decision-making processes. It is to the topic of reconnecting citizens and stakeholders with environmental governance that this volume turns next.

Notes

1. J. Tierney, "A Tale of Two Fisheries," *New York Times Magazine*, August 27, 2000, pp. 38–43.
2. *Ibid.*, p. 40.
3. *Ibid.*, p. 38.
4. Garrett Hardin, "The Tragedy of the Commons," *Science* 162 (1968): 1243–1248.
5. Tierney, "A Tale of Two Fisheries," p. 41.
6. *Ibid.*
7. *Ibid.*
8. *Ibid.*
9. For an excellent review of the emerging evidence from nonenvironmental areas concerning cooperation and the conditions under which prisoners' dilemma problems are addressed effectively, see Mark Van Vugt, Mark Snyder, Tom R. Tyler, and Anders Biel, eds., *Cooperation in Modern Society: Promoting the Welfare of Communities, Organizations, and States* (London: Routledge, 2000).
10. H. Scott Gordon, "The Economic Theory of a Common Property Resource: The Fishery," *Journal of Political Economy* 62 (1954): 124–142; Anthony Scott, "The Fishery: The Objectives of Sole Ownership," *Journal of Political Economy* 63 (1955): 116–124.
11. "By ignoring the negative impact of an individual's appropriation on others' returns, the appropriator creates a negative externality. The presence of the externality leads to overinvestment of resources into the appropriation process" (E. Ostrom, R. Gardner, and J. Walker, eds., *Rules, Games, and Common-Pool Resources* [Ann Arbor: University of Michigan Press, 1994], p. 11).
12. According to Davis and Holt, Tucker was the first to articulate the prisoners' dilemma (D. Davis and C. Holt, *Experimental Economics* [Princeton, N.J.: Princeton University Press, 1993]; See A. W. Tucker, "A Two Person Dilemma," working paper, Stanford University, 1950).
13. Mancur Olson, *The Logic of Collective Action: Public Goods and the Theory of Groups* (Cambridge, Mass.: Harvard University Press, 1965). See Russell Hardin, *Collective Action* (Baltimore, Md.: Johns Hopkins University Press, 1982), for a careful explication and examination of the conditions under which cooperation can emerge under Olson's theory.
14. Olson, *The Logic of Collective Action*, p. 2, italics in the original.
15. As late as the 1980s, the Canadian minister of fisheries publicly was comparing Atlantic fisheries to the tragedy of the commons (D. R. Matthews, *Controlling Common Property: Regulating Canada's East Coast Fishery* [Toronto: University of Toronto Press, 1993]).
16. Marc Landy, Marc Roberts, and Stephen Thomas, *The Environmental Protection Agency* (New York: Oxford University Press, 1994).
17. Consolidated Statutes and Regulations, Department of Fisheries and Oceans Act, Canada, 1978, <http://laws.justice.gc.ca/en/F-15/44268.html>.
18. National Research Council, *Proceedings of the Conference on Common Property Resource Management* (Washington, D.C.: National Academy Press, 1986); B. McCay and J. Acheson, *The Question of the Commons: The Culture and Ecology of Communal Resources* (Tucson: University of Arizona Press, 1987); F. Berkes, ed., *Common Property Resources: Ecology and Community-Based Sustainable Development* (London: Belhaven, 1989); F. Martin, *Common Pool Resources and Collective Action: A Bibliography*, vol. 1 (Bloomington: Indiana University, Workshop in Political Theory and Policy Analysis, 1989).
19. Such models are not incorrect; they simply have been used incorrectly—applied to many situations and circumstances whose essential features they fail to capture (Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action* [Cambridge: Cambridge University Press, 1990]).
20. The International Association for the Study of Common Property, www.indiana.edu/~iascp/.
21. The *Common Property Resource Digest*, published three to four times per year, www.indiana.edu/~iascp/aboutcpr/html.
22. For instance, the Center for the Study of Institutions, Population, and Environmental Change, www.indiana.edu/~cipecl/.
23. Ostrom, *Governing the Commons*; Elinor Ostrom, "Institutional Rational Choice: An Assessment of the Institutional Analysis and Development Framework," in Paul Sabatier, ed., *Theories of the Policy Process*, 35–71 (Boulder, Colo.: Westview, 1999); Elinor Ostrom, "The Danger of Self-Evident Truths," *PS: Political Science and Politics* 33(1) (2000): 33–44.
24. Ostrom, *Governing the Commons*.
25. *Ibid.*, p. 44.
26. *Ibid.*, p. 45.
27. Ostrom, Gardner, and Walker, *Rules, Games, and Common-Pool Resources*; F. Berkes, *Sacred Ecology: Traditional Ecological Knowledge and Resource Management* (Philadelphia, Pa.: Taylor and Francis, 1999); B. McCay, "Emergence of Institutions for the Commons: Contexts, Situations, and Events," in Elinor Ostrom, Thomas Dietz, Nives Dolsak, Paul C. Stern, Susan Stonich, and Elke U. Weber, eds., *The Drama of the Commons*, 361–402 (Washington, DC: National Academy Press, 2002).
28. Ostrom, "The Danger of Self-Evident Truths," p. 40.
29. *Ibid.*, p. 40.
30. *Ibid.*
31. Ostrom, *Governing the Commons*, p. 90.

32. Edella Schlager, "Model Specification and Policy Analysis: The Governance of Coastal Fisheries," Ph.D. diss., Indiana University, 1990; Edella Schlager, "Fishers' Institutional Responses to Common-Pool Resource Dilemmas," in E. Ostrom, R. Gardner, and J. Walker, eds., *Rules, Games, and Common-Pool Resources*, 247-266 (Ann Arbor: University of Michigan Press, 1994).
33. The fishery analysis focuses only on conflict over space and not on overharvesting. Accurately measuring overharvesting is difficult, and no such measures were reported in any of the case studies included in the analysis. See Schlager, "Fishers' Institutional Responses," p. 260, for a more extensive discussion.
34. Ibid.
35. F. T. Christy, *Territorial Use Rights in Marine Fisheries: Definitions and Conditions*, FAO Fisheries Technical Paper no. 227 (Rome: Food and Agricultural Organization of the United Nations, 1982).
36. K. O. Martin, "The Law in St. John's Says . . . : Space Division and Resource Allocation in the Newfoundland Fishing Community of Fermeuse," master's thesis, Memorial University of Newfoundland, 1973.
37. F. Berkes, "Local Level Management and the Commons Problem: A Comparative Study of Turkish Coastal Fisheries," *Marine Policy* 10 (July 1986): 215-229.
38. B. McCay, "Community Based and Cooperative Fisheries: Solutions to Fishermen's Problems," in J. Burger, E. Ostrom, R. Norgaard, D. Policansky, and B. Goldstein, eds., *Protecting the Commons* (Washington, D.C.: Island, 2001), p. 183.
39. Schlager, "Model Specification and Policy Analysis"; Edella Schlager and Elinor Ostrom, "Property Rights Regimes and Coastal Fisheries: An Empirical Analysis," in T. L. Anderson and R. T. Simmons, eds., *The Political Economy of Customs and Culture: Informal Solutions to the Commons Problem*, 13-42 (Lanham, Md.: Rowman and Littlefield, 1993).
40. Y. S. Tang, "Institutions and Collective Action in Irrigation Systems," Ph.D. diss., Indiana University, 1989; Y. S. Tang, *Institutions and Collective Action: Self-Governance in Irrigation* (San Francisco: ICS, 1992); Y. S. Tang, "Institutions and Performance in Irrigation Systems," in Ostrom, Gardner, and Walker, eds., *Rules, Games, and Common-Pool Resources*, 225-246; W. F. Lam, *Governing Irrigation Systems in Nepal: Institutions, Infrastructure and Collective Action* (San Francisco: ICS, 1998).
41. Tang, "Institutions and Collective Action"; Tang, "Institutions and Performance in Irrigation Systems."
42. Tang, "Institutions and Collective Action"; Tang, *Institutions and Collective Action*; Tang, "Institutions and Performance in Irrigation Systems."
43. The level of maintenance of an irrigation system is tied directly to how well farmers' contributions to construction and maintenance are elicited and coordinated. It measures the extent to which provision dilemmas have been mitigated.

The adequacy of water supply depends on the rules used to allocate water and the level of maintenance. Both water allocation and system maintenance depend on how well-crafted the rules governing each are and the extent to which irrigators follow those rules.

44. Tang, "Institutions and Performance in Irrigation Systems."
45. The type of water allocation rule found among poorly performing systems was a fixed-time-slot rule. The irrigator was allowed to take water for a fixed period of time at set intervals. Although fixed-time-slot rules are relatively easy to define and enforce (presumably irrigators will protect their time slots or risk losing their water), they are fraught with uncertainty. A fixed time slot only guarantees a farmer a certain amount of time, not a certain amount of water. If the fixed time slots are not carefully coordinated with water availability, or if water availability is unpredictable, a fixed time slot will have little value.
46. Tang, *Institutions and Collective Action*. W. F. Lam analyzes extensive data on 150 Nepalese irrigation systems in *Governing Irrigation Systems in Nepal*; see also W. F. Lam, M. Lee, and E. Ostrom, "An Institutional Analysis Approach: Findings from the NIIS on Irrigation Performance," in J. Sowerwine, G. Shivakoti, U. Pradhan, A. Shukla, and E. Ostrom, eds., *From Farmers' Fields to Data Fields and Back: A Synthesis of Participatory Information Systems for Irrigation and Other Resources*, pp. 69-93 (Colombo, Sri Lanka: International Irrigation Management Institute; and Rampur, Nepal: Institute of Agriculture and Animal Science, 1994). Like Tang (*Institutions and Collective Action*; "Institutions and Performance in Irrigation Systems"), Lam found that farmer-managed irrigation systems perform significantly better than do government-managed irrigation systems. Irrigators in farmer-managed systems exhibit significantly higher levels of entrepreneurial activities in attempting to coordinate irrigation activities, information and understanding of the irrigation system, and mutual trust (*Governing Irrigation Systems in Nepal*, pp. 26-133). Irrigators in farmer-managed systems also use more varied and complex sets of rules for governing their activities. In addition, irrigators in farmer-managed systems are significantly more likely to be monitored and sanctioned for rule violations than are irrigators in government-managed systems. Rule-following behavior is significantly higher in farmer-managed systems (Lam, *Governing Irrigation Systems in Nepal*, p. 131).
47. Among the farmer-owned systems examined by Tang ("Institutions and Performance in Irrigation Systems," p. 241), 41 percent did not use any guards.
48. Ibid., p. 241.
49. W. Blomquist, *Dividing the Waters: Governing Groundwater in Southern California* (San Francisco: ICS, 1992).
50. Ibid., p. 51.
51. Ibid., p. 32.
52. Ibid., p. 33.
53. Ibid.

54. Ibid., p. 102.
55. Ibid., pp. 104, 106, 76.
56. Ibid., pp. 106, 109.
57. Ibid., p. 116.
58. Ibid.; Tang, *Institutions and Collective Action*.
59. Schlager, "Model Specification and Policy Analysis."
60. Tang, "Institutions and Performance in Irrigation Systems."
61. Blomquist, *Dividing the Waters*.
62. R. Q. Grafton, D. Squires, and J. E. Kirkley, "Private Property Rights and Crises in World Fisheries: Turning the Tide?" *Contemporary Economic Policy* 14 (1996): 90-99.
63. Tang, *Institutions and Collective Action*; Lam, *Governing Irrigation Systems in Nepal*.
64. G. Varughese and E. Ostrom, *The Contested Role of Heterogeneity*, working paper no. 32 (Bloomington: Workshop in Political Theory and Policy Analysis, Indiana University, 1998).
65. A. Agrawal, "Group Size and Successful Collective Action: A Case Study of Forest Management Institutions in the Indian Himalayas," in G. Clark, M. McKean, and E. Ostrom, eds., *Forest Resources and Institutions*, 49-74, *Forests, Trees, and People: Programme Working Paper no. 3* (Rome: FAO, 1998).
66. Steven Hackett, Edella Schlager, and James Walker, "The Role of Communication in Resolving Commons Dilemmas: Experimental Evidence with Heterogeneous Appropriators," *Journal of Environmental Economics and Management* 27 (1994): 99-126; M. Taylor and S. Singleton, "The Communal Resource: Transaction Costs and the Solution of Collective Action Problems," *Politics and Society* 21(2) (1993): 195-214; Varughese and Ostrom, "The Contested Role of Heterogeneity."
67. Varughese and Ostrom, "The Contested Role of Heterogeneity," p. 29.
68. Ibid.
69. Lam, *Governing Irrigation Systems in Nepal*.
70. Grafton, Squires, and Kirkley, "Private Property Rights and Crises in World Fisheries."
71. B. Blomquist, T. Heikkila, and E. Schlager, "Institutions and Conjunctive Water Management among Three Western States," *Natural Resources Journal* 41(3) (2001): 653-683.
72. T. Heikkila, "Managing Common Pool Resources in a Public Service Industry: The Case of Conjunctive Water Management," Ph.D. diss., School of Public Administration and Policy, University of Arizona, 2001; Blomquist, Heikkila, and Schlager, "Institutions and Conjunctive Water Management."
73. J. Ensminger, "Culture and Property Rights," in S. Hanna, C. Folke, and K. Maler, eds., *Rights to Nature*, 179-204 (Washington, D.C.: Island, 1997);

- R. Meinzen-Dick and M. Zwarteveen, "Gender Dimensions of Community Resource Management: The Case of Water Users' Associations in South Asia," in A. Agrawal and C. Gibson, eds., *Communities and the Environment: Ethnicity, Gender, and the State in Community-Based Conservation*, 63-88 (New Brunswick, N.J.: Rutgers University Press, 2001).
74. M. H. McDermott, "Invoking Community: Indigenous People and Ancestral Domain in Palawan, the Philippines," in Agrawal and Gibson, eds., *Communities and the Environment*, 32-62, specifically pp. 46-50.
75. Ibid., p. 58.
76. Ibid.
77. A. Agrawal and C. Gibson, "The Role of Community in Natural Resource Conservation," in Agrawal and Gibson, *Communities and the Environment*, 1-31.
78. Ibid., pp. 12-13.
79. James Q. Wilson, *Bureaucracy* (New York: Free Press, 1989); R. Reich, *Public Management in a Democratic Society* (Englewood Cliffs, N.J.: Prentice-Hall, 1990); M. Moore, *Creating Public Value* (Cambridge, Mass.: Harvard University Press, 1995); F. Fischer, *Citizens, Experts, and the Environment* (Durham, N.C.: Duke University Press, 2000).
80. Wilson, *Bureaucracy*; Moore, *Creating Public Value*.
81. Moore, *Creating Public Value*, p. 17.
82. Reich, *Public Management in a Democratic Society*.
83. Moore, *Creating Public Value*, p. 20.