THE STRUGGLE TO GOVERN THE COMMONS

by

Thomas Dietz, Elinor Ostrom, and Paul C. Stern [order TBD]

In 1968, Garrett Hardin (1968) drew attention to two factors that drive environmental change. One is increased demands on natural environment (stemming from growth in human population and in consumption). The other is the ways in which humans organize themselves to extract resources from the environment and contribute effluent to it-what social scientists refer to as institutional arrangements. Hardin saw only two types of institutional arrangements as effective for the governance of natural resources-centralized government and private property. As Hardin expressed it 30 years later, managed commons are "either socialism or the privatism of free enterprise. Either one may work, either one may fail: 'The devil is in the details.' But with an unmanaged commons, you can forget about the devil: As overuse of resources reduces carrying capacity, ruin is inevitable" (Hardin, 1998: 633).

Hardin was correct about tragic overuse when a highly valued commons lacks institutions, but he made two fundamental errors. The first was his claim that *only* two institutional arrangements could sustain commons over the long run: private property and the centralized state. The second was his presumption that resource users themselves were *trapped* in a commons dilemma and could never change the structure of the situation they faced by creating or modifying institutions. He missed the fact that many social groups-including the herders on the English commons that provided the metaphor for his analysis-have successfully struggled against threats of resource degradation by

developing self-governing institutions that have sustained shared resources for centuries (see Netting, 1981; McCay and Acheson, 1987; Baland and Platteau, 1996; De Moor, 2002). While these institutions have not always succeeded, neither have Hardin's preferred alternatives of private or state ownership.

Natural resources and the environment remain under threat from increasing human population, growing consumption, and the rapid deployment of advanced resource-using technology when governance institutions are absent or maladapted. For example, Myers and Worm (2003) provide an extremely worrisome picture of the massive depletion of fish communities in the open ocean and continental shelves, based on a massive compilation of historical statistics, including data recorded prior to major industrialized exploitation. From their mathematical model of fishery exploitation they estimate that "the global ocean has lost more than 90% of large, predatory fishes" with 80% decline typically occurring within the first 15 years of industrialized fishing. The combination of new technologies for harvesting fish combined with inadequate property rights has created a major threat of massive ecosystem destruction. {Plan to cite other examples here from the papers for which we are the overview.}

The massive destruction of ocean fisheries is in marked contrast to the abundance of lobsters along the coast of Maine where local fishers have developed a sophisticated governance system over multiple decades, backed up with congruent state rules and policies, to achieve a sustainable and economically valuable fishery (see Acheson, 2003; Wilson et al., 1994). Where local and state officials and users have not had sufficient autonomy or understanding of how to design effective institutions to change the strong incentive to overuse a resource, however, inshore fisheries are over-fished (Finlayson, 1994; Hannah, 1998). On the other hand, even large-scale resources have been

successfully protected through appropriate governance systems such as the Montreal Protocol and the International Commission for the Protection of the Rhine Agreements (Weiner and Maxwell, 1993; Weber, 2000; Verweij, 2000; Dieperink, 2000).

Since Hardin's essay we have had striking successes in creating sustainable interactions with the environment, and striking failures. There is little new in human history, although the scale of anthropogenic impact of the twentieth century is unprecedented. What is new, and what offers hope, is that we have learned a great deal about the characteristics of institutions that enhance the likelihood of sustainable use of the environment and of those that tend to generate resource collapses (E. Ostrom et al., 1999). We have an emerging science of human ecology-what has been called the "second environmental science" (Stern, 1993)-that can provide ongoing guidance to the design of institutions for governing the environment. The emerging science teaches us, however, that there are no easy, general-purpose, quick fixes. Governing a commons is always a struggle.

Why a Struggle?

Devising ways to sustain the earth's ability to support diverse life, including a reasonable quality of life for humans, involves making tough decisions under uncertainty, complexity, and substantial biophysical constraints. The human capacity to aspire to ever greater well-being and to invent new ways of making demands on earth's resources grows over time as new knowledge is put to use. Devising effective governance systems is frequently like engaging in an "arms race." A set of rules crafted over a long period to fit one socio-ecological set of conditions can slowly erode, if not designed to adapt, as growing affluence and population coupled with powerful technology increase the potential for human damage to most ecosystems and even the biosphere itself. Further,

humans can also devise new ways of taking advantage of the available resource to the detriment of others.

Some Problems Are Easier

Of course, context can make it easier or more difficult to develop an arrangement that allows humans to adapt successfully. Effective governance of resources is easier to achieve when:

Resources can be monitored at relatively low cost (e.g., are stationary or storable: trees are easier to monitor than fish, and lakes than rivers);

Rates of change in resources and human communities are moderate;

Communities are characterized by frequent communication and dense social networks, both of which increase the potential for trust and lower the cost of monitoring resource users' behavior and enforcing rules;

Outsiders can be excluded at relatively low cost from using the resource; and

Users support effective monitoring and rule enforcement by officials (Schlager, Blomquist, and Tang, 1994; Burger et al., 2001; E. Ostrom, 1999).

Few settings in the world are characterized by all of these conditions. The challenge is to devise institutional arrangements that help to establish such conditions or, as we discuss below, provide the information, deal with conflict, enforce rules and provide required infrastructure in the absence of ideal conditions for governing commons.

Selective Pressures

In subsistence societies and communities that are heavily dependent on local natural resources, face-to-face interaction among members of the community and daily engagement with the critical aspects of the environment form a selective regime for

institutional arrangements, including institutions for environmental governance (Burns and Dietz, 1992; E. Ostrom, 1990). The opportunity to observe and discuss the state of the resource and the behavior of resource users provides a basis for making adaptive changes; norms are enforced by members of the group themselves as well as by officials. Hundreds of documented examples exist of sustainable resource use in such communities, although there are also many failures (NRC, 1986, 2002; Gibson et al., 2000; Krech, 1999; for relevant bibliographies, see Hess, 1999, 2003). Small scale, direct interaction with the environment and relative buffering from other social and environmental systems helps push institutional arrangements towards sustainability, though entry into new environments, technological change or rapid political or cultural change can swamp this tendency and lead to resource collapse.

As human communities have integrated beyond the local scale, the selective pressures on environmental governance institutions have increasingly come from extra-local influences. For example, technology and human desires have enabled commerce to become regional, national, and global. Institutions at all these levels have been created to enable and regulate trade, transportation, competition and conflict. These institutions shape environmental impact, even though they often are not designed with that intent. They also provide mechanisms for environmental governance (e.g., national laws) and part of the social context for local efforts at environmental governance. Larger-scale governance may authorize local control, help it, hinder it, or override it (Young, 1999, 2002; Keohane and Ostrom, 1994; Lansing, 1991; Wunsch and Olowu, 1995: Dolšak and Ostrom, 2003). We have moved from a world of multiple localities into a world with institutions at multiple levels, where every local place is strongly influenced by global dynamics.

The most important contemporary environmental challenges involve systems that are intrinsically global (e.g., climate change) or are tightly linked to global pressures (e.g., timber production for the world market), and yet require governance at levels from the global all the way down to the local (Clark and Munn, 1986; Young, 2002). Here, selective pressures may increase the likelihood of destruction rather than sustenance of resources.

Efforts to govern such commons can benefit from an understanding of the governance tools that human societies have devised, their strengths and weaknesses, and the conditions for their usefulness both separately and in combination. Research on global and national environmental policy sometimes pays little attention to community-based governance and to traditional tools such as informal communication and sanctioning, but these tools have their place and can add significant value (NRC, 2002b; Berkes et al., 2003). Regulatory policies can take advantage of informal influences when they demand that information be made available about releases of pollutants, and that information influences polluter behavior through public pressure, concerns about industry reputation, and other non-regulatory means (Herb et al., 2002). Information properly disseminated can induce interest in financial incentives that are otherwise ignored (Stern, 1999). Thus, the store of governance tools and ways to modify and combine then is far greater than policy analysts sometimes recognize (NRC, 2002a, 2002b; Auer, 2000). In contrast to Hardin's stark dichotomy of markets and governments, one needs a rich and growing tool kit of governance options. Research is beginning to clarify the opportunities this insight suggests.

Requirements of Adaptive Governance in Complex Systems

The problem of achieving sustainable resources in complex systems has been

described as one of adaptive management: making choices in response to changing environmental and human conditions that are understood only with great uncertainty (Gunderson and Holling, 2001; Lee, 1993). With due respect to the achievements of scholars in this tradition, we prefer the term adaptive *governance.* Governance connotes the polycentric forces associated with the idea of making rules at multiple levels, engaging in political and scientific debate about the processes affecting resources, learning from past decisions, and making new policies (V. Ostrom, 1997; McGinnis, 1999, 2000).

Management, for some readers, suggests the possibility of successful control from above. Management also connotes agreed upon goals and value consensus. For most contemporary environmental and resource problems, however, these conditions do not obtain. Rather, we must proceed in the face of substantial uncertainty as well as conflict based on differing values, interests, and beliefs (Dietz and Stern, 1998). Effective environmental governance requires attention to people and groups who differ in the values, interests, perspectives, and kinds of information they bring to situations. It must include an understanding of both environmental systems and of human-environment interactions, including institutional arrangements (Stern, 1993; Costanza et al., 2001).

What is required for effective environmental governance? A substantial body of research has addressed this question, examining governance structures ranging from local communities relatively well-buffered from global forces through national environmental policy systems to international agreements on the environment that are global in scope (NRC, 1999a, 2002a, 2002b) From this literature, several requisites of effective environmental governance are clear. They include: providing information about system functioning and monitoring resource stocks and resource users; dealing with conflict;

inducing rule compliance; and providing infrastructure. We will examine each in detail and discuss many of the tools that can help us meet these requirements.

Providing Information

Environmental governance depends on good information about the resource systems being governed, as well as about the human-environment interactions affecting those systems. The critical role of environmental science in providing this information is well understood. It can measure and monitor resource stocks and provide the theoretical knowledge needed to interpret this information. It can also measure and monitor human activities and provide the theoretical knowledge needed to understand how these activities affect resources and other valued states of the world.

Information must be congruent in scale with environmental events and decisions (Willis and Whittaker, 2002-correct cite?). For example, there are local problems with global causes (e.g., deforestation to meet global market demand) and global problems with local causes that may be concentrated (e.g., stratospheric ozone depletion traced to chlorofluorocarbons produced at only a handful of sites) or widespread (e.g., carbon dioxide emissions from fossil fuel consumption). Highly aggregated information may average out local variations that are important in identifying future problems and developing solutions. Information must also be congruent with decision makers' needs in terms of timing, content, and form of presentation (NRC, 1989, 1999c). Informational systems that simultaneously meet high scientific standards and serve ongoing needs of decision makers and users are particularly useful from the standpoint of support for long-term data collection.

Effective governance requires not only factual information about the state of the environment and human actions but also information about uncertainty and values.

Scientific understanding of coupled human-biophysical systems will always be uncertain because of inherent unpredictability in the systems and because the science is never complete (Wilson, 2002). Decision makers need information that characterizes the types and magnitudes of this uncertainty. And since every environmental decision requires tradeoffs, knowledge is needed about individual and social values and about the effects of decisions on various valued outcomes. Globalization adds a layer of complexity to the value problem because of the disjuncture between decision makers and those affected and, often, an uneven distribution of costs, benefits and risks. For many environmental systems, local and easily captured values (e.g., the market value of lumber) have to be balanced against global, diffuse and hard to capture values (e.g., biodiversity, capability of humans and ecosystems to adapt to unexpected events). Finding ways to measure and monitor the outcomes for such varied values is a major informational challenge for governance.

Identifying the needed information, developing useful indicators, characterizing uncertainties, and informing value tradeoffs requires ongoing dialogue among scientists, decision makers, and those affected by decisions (NRC, 1996; Dietz and Stern, 1998; Rosa, McWright, and Renn, 2001). This interaction, properly structured, can enhance our understanding of biophysical and social systems, help interested and affected parties develop trust in uncertain science, and help direct analysis towards the key issues for shaping decisions.

Dealing with Conflict

Social conflict is inherent in making environmental choices. This is one reason we speak of environmental governance, rather than management. Indeed, conflict resolution may be as important a motivation for designing resource institutions as is

concern with resources themselves (McCay, 2002). People bring varying perspectives, interests, and fundamental philosophies to problems of environmental governance (NRC, 1999a, 1999b), and their conflicts, if they do not escalate to the point of dysfunction, can spark learning and change (Stern, 1991; V. Ostrom, 1993).

In traditional societies, conflicts are normally addressed within face-to-face groups, but complex nation-states and global problems require other institutional forms. Representative governments that delegate authority to environmental ministries do not always resolve conflicts satisfactorily, so governments are experimenting with various governance approaches to complement managerial ones. They range from ballots and polls, where engagement is passive and there is little interaction between those participating, to various experiments with intense interaction and deliberation aimed at negotiating decisions or providing structured input to them via participatory processes (Renn, Webler, and Wiedemann, 1995; Gregory et al., 2001; O'Leary and Bingham, 2003), to the revitalization of thousand-year old institutions such as weekly tribunals to resolve disputes related to highly valued water (Maass and Anderson, 1986). A growing body of empirical research is beginning to yield insights on how to organize such processes effectively (Beierle and Cayford, 2002; Leach et al., 2002; O'Leary and Bingham, 2003; public participation website).

Inducing Rule Compliance

Effective governance requires that the rules of resource use are followed. In small communities, enforcement is nearly invisible because individuals who have participated in making rules are more likely to conform to them and subtle social sanctions remind those who stray that they are expected to conform. Whether enforcement is visible or not, however, responsible formal organizations or informal

community groups must be seen as effective and legitimate, or resistance and evasion will overwhelm the commons governance strategy. "Paper rules" that are ignored undermine the legitimacy of any regime. Enforcement can be thought of the task of providing individuals and groups with incentives that encourage sustainable behavior and discourage its opposite.

Much environmental regulation in complex societies has been "command and control"-governments require compliance, and the incentive for proper behavior is avoidance of jail terms or fines. Command-and-control regulation is effective at controlling easily monitored behaviors if the government is strong and non-corrupt and if sufficient resources are made available for monitoring and enforcement. It is much less effective in a wide variety of situations, such as when governments lack the will or resources to protect "protected areas" (Curran, 2003), when major environmental damage comes from hard-to-detect "non-point sources," and when the need is to encourage innovation in behaviors or technologies rather than to require or prohibit familiar ones. Command and control approaches have also been criticized as economically inefficient (Berkes and Folke, 1998; Heal, 1998; Colby, 1995).

Substantial attention has been given to the use of financial instruments to provide the incentives needed to enforce environmental rules, particularly, in recent years, to market-based systems of tradable environmental allowances (TEAs) that define a limit to environmental withdrawals or emissions and permit free trade of allocated allowances under those limits (Rose, 2002; Tietenberg, 2002; Yandle and Dewees, 2003). Economic theory suggests that these mechanisms have significant advantages over command and control; experience, however, points to some significant limitations. TEA regimes tend to leave unprotected those linked resources not covered by the trading regime (e.g., by-

catch of non-covered fish species) and to suffer when monitoring is difficult (e.g., the question of whether geologically sequestered carbon will remain sequestered). Problems can also occur with the initial allocation of allowances: it is most feasible politically to allocate to historic users, but the intent of the policy may be to shift resource use to other purposes (Rose, 2002; Tietenberg, 2002). TEAs and community-based resource management systems appear to have opposite strengths and weaknesses, suggesting that one governance system may work best in the situations that lead the other to fail, or that institutions that combine aspects of both systems may work better than either system alone (Yandle and Dewees, 2003 and Blomquist, 1992).

Voluntary approaches have only begun to receive careful scientific attention (NRC, 2002b). Tentative conclusions emphasize conditions of firms and industries that predispose some of them to "beyond-compliance" environmental policies (Prakash, 2001; Nash, 2002; Aragón-Correa and Sharma, 2003), the value of negotiated approaches to voluntary agreements, the need for low-cost monitoring, and the importance of command and control as a back-up, especially if success requires that everyone comply (Randall, 2002).

Enforcement depends on more than the properties of particular tools. The evidence clearly indicates that the effectiveness of enforcement strategies depends on other enforcement strategies that are being used, on the adequacy of monitoring of resources and their users, on systems of information and conflict management, and on the success of coordinating governance at different scales. Enforcement often depends on such coordination, as when national authorities allow or prohibit local authorities to enforce local rules or when they depend on locals to monitor and enforce national rules (e.g., poaching in protected areas). The complexities multiply with international

agreements because of the limits on the authority for formal enforcement at the international level (Hannah, Folke, and Mäler, 1996; Weiss and Jacobson, 1998; Underdal, 1998).

Providing Infrastructure

The importance of physical and technological infrastructure is often ignored in discussions of environmental governance institutions, though such infrastructure is essential. Infrastructure, including technology, determines the degree to which a commons can be exploited (e.g., water works, fishing technology), the extent to which waste can be reduced in resource use, and the degree to which resource conditions and the behavior of humans users can be effectively monitored. Indeed, the ability to choose institutional arrangements depends at least in part on infrastructure. In the absence of barbed wire, enforcing private property rights on grazing lands is very expensive, but with barbed wire it is relatively cheap. Barbed wire makes feasible an institutional arrangement-private land ownership-that is not feasible in the absence of such technology. Effective communication and transportation technologies are also of immense importance. Fishers who observe an unauthorized boat or harvesting technology while out at sea can use a citizen's band radio or a cell phone to alert others to illegal actions (Singleton, 1998). Infrastructure also affects the links between local commons and regional and global systems. Good roads can provide food in bad times but can also open local resources to global markets, creating demand for resources that cannot be used locally (Moran, 1990).

Institutional infrastructure is also important. This includes government support for environmental science research, public and private insurance systems that affect individuals' willingness to take environmental risks, and the informal social connections

that allow people to trust that others will live up to their commitments. The need to use multiple governance tools is underlined by the need for coordinated governance across scales. Many environmental outcomes are spatially displaced from their causes and hard to monitor. Economic incentives operating at larger scales may not be closely aligned with the condition of local ecosystems. Often, the costs of environmental change do not come to the same groups or even the same areas as the benefits. Thus, environmental governance must include coordination between local communities and larger levels of governance, between local resource users and outsiders whose behavior affects the resource base, and between environmental institutions and other institutions (trade, finance, etc.) (Young, 2002; Dietz and Rosa, 2002). These demands imply a need for substantial institutional innovation (Princen, 2003).

Lessons to Apply in Designing Adaptive Governance Systems

Sustainable environmental governance is highly context dependent and must change in character as the biophysical and social environment change. Despite Hardin's substantial insights, his original argument was flawed by not recognizing that global generalizations about the two best forms of commons governance are not possible. Some general lessons have been learned about the factors that always need attention, even though their instantiation must vary from situation to situation.

1. Ongoing dialogue among scientists, resources users, and the interested public is essential. Dialogue not only provides information, it provides the trust in information that is essential for information to be used effectively (NRC, 1996).

2. Institutional arrangements must be complex, redundant, and nested in many layers (Levin, 1999; Low et al., 2003; Janssen, 2003). Simple strategies for governing the world's resources that rely exclusively on imposed markets or centralized command

and control and that eliminate apparent redundancies in the name of efficiency have been tried and failed.

3. Institutional arrangements also need to use mixtures of institutional types (e.g., hierarchies, markets, community self-governance) that employ a variety of decision rules to change incentives, increase information, monitor use, and enforce sanctions. Innovative rule evaders can learn how to get around a single type of rule more effectively than a multiplicity of rules-in-use.

4. On-going change of the design must be an inherent part of the design. Adaptation is necessary because some current understanding is wrong, the required scale of organization can shift, and biophysical and social systems change. Strategies that attempt to optimize are likely to fail because they place too much confidence in the current state of knowledge, while suboptimal systems that guard against the low probability, high consequence possibilities may prove wiser in the long run. Some aspects of the overall institutional design are likely to fail, and noting that our flawed understanding is likely to improve, systems should be designed to adapt over time.

Conclusion

Research on environmental governance is robust in that it draws on nearly all the social science disciplines, has been closely integrated with parallel research on the dynamics of environmental systems, and has employed a wide variety of methods-from detailed ethnographic and historical accounts to controlled laboratory studies (E. Ostrom, Gardner, and Walker, 1994), that allow triangulation across methods. It has been useful in helping to reveal and explain the successes and failures of past efforts at environmental governance, suggest promising approaches to difficult governance problems, and anticipate the effects of new institutional forms and governance tools.

It has also raised important questions and identified key underappreciated issues that are essential for effective governance. How can the state of the resource and the behavior of users be monitored at reasonable cost? How can efficient governance mechanisms developed in small face-to-face communities be made useful in governing global commons? How can information from environmental science be integrated with "local knowledge" and with the informational needs of decision makers at various levels? In participatory processes of environmental assessment and management, how can the goals of accurate information, sound analysis, and fairness and legitimacy of the management strategy be reconciled when people's values and interests are in conflict? How can governance systems be designed that link different scales, especially when essential functions such as monitoring and enforcement are weak at some scales? How can the value of sustainable governance of large-scale commons flow to local users of small-scale commons?

It is critical to note that most common-pool resources and governance strategies are embedded in larger ecological and social systems. A strategy that is effective in the face of a slowly changing climate may collapse in the face of rapid climate change. So too, a strategy based on slowly changing commodity prices or stable local job opportunities may not be able to withstand large swings in the local economy induced by changes in the global economy. Thus, the design of commons management must attend to local and global issues and the links between the two, as well as to changes in social and environmental systems. These linkages can create opportunities as well as difficulties-resilience as well as vulnerability. Local instability can sometimes be offset by intervention from the large system-a local loss of jobs might lead to unemployment assistance, retraining and job development before economic pressures lead to

overexploitation of a local commons.

The 35 years since Hardin's essay have yielded new understandings of commons governance. Governance still frequently fails due to inadequate knowledge, inadequate application of the knowledge we have, narrow political and economic interests, or events outside the control of governance institutions. The record of the late twentieth century shows remarkable success where we have applied emerging knowledge of commons governance and remarkable failure where we have ignored those lessons or simply failed to address commons governance at all. The twenty-first century offers great promise for improvement in knowledge of environmental governance and in its application.

References

J. Acheson, *Capturing the Commons: Devising Institutions to Manage the Maine Lobster Industry* (Univ. Press of New England, Hanover, NH, 2003).

J. A. Aragón-Correa, S. Sharma, *Academy of Management Review* **28,** 71 (2003).

Association of American Geographers GCLP Research Group. *Global Change and Local Places: Estimating, Understanding, and Reducing Greenhouse Gases.* (Cambridge, Cambridge University Press, 2003).

M. Auer. *Policy Sciences*. **33**, 155 (2000).

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

A. Bebbington, *The Geographical Journal* **163**, 189 (1997).

T. C. Beierle and J. Cayforn, *Democracy in Practice: Public Participation in Environmental Decisions.* (Resources for the Future, 2002).

F. Berkes and C. Folke. *Linking Social and Ecological Systems. Management Practices and Social Mechanisms.* (Cambridge Univ. Press, 1998)

F. Berkes, J. Colding, C. Folke. *Navigating Social-Ecological Systems. Building Resilience for Complexity and Change.* Cambridge Univ Press, Cambridge, 2003)

W. Blomquist. *Dividing the Waters: Governing Groundwater in Southern California*.

(ICS Press, San Francisco, 1992)

J. Burger, et al., *Protecting the Commons: A Framework for Resource Management in the Americas.* (Island Press, Washington, D.C., 2001)

T. R. Burns, T. Dietz, *Intl. Soc.* **7**, 259 (1992).

W. Clark and R. Munn (eds.) *Sustainable Development of the Biosphere* (Cambridge Univ. Press, 1986).

B. G. Colby. in *The Handbook of Environmental Economics* (Blackwell Publishers, Oxford, 1995), pp. 475-502.

R. Costanza, et al., *Institutions, Ecosystems, and Sustainability*. (Lewis Publishers, New York, 2001)

C. Dahlman, *The Open Field System and Beyond. A Property Rights Analysis of an Economic Institution.* (Cambridge Univ. Press, 1980).

M. De Moor, L. Shaw-Taylor, P. Warde, *The Management of Common Land in North West Europe, c. 1500-1850* (Brepols, Turnhout, Belgium, 2002).

C. Dieperink, *Water International* **25**, 347 (2000).

T. Dietz, E. A Rosa, in *Handbook of Environmental Sociology*, R. E. Dunlap, W. Michelson, Eds. (Greenwood Press, Westport, CT, 2002), pp. 370-406.

T. Dietz, P. C. Stern, *BioScience* **48**, 441 (1998).

N. Dolšak, E. Ostrom, Eds., *The Commons in the New Millennium: Challenges and Adaptation* (MIT Press, Cambridge, MA, 2003).

A. C. Finlayson, *Fishing for Truth: A Sociological Analysis of Northern Code Stock Assessments from 1987 to 1990.* (Institute of Social and Economic Research, Memorial Univ. of Newfoundland, St. Johns, New Foundland, 1994).

C. Gibson, M. McKean, E. Ostrom, 2000. *People and Forests.* (MIT Press, 2000)

R. Gregory, T. McDaniels, D, Fields, *Journal of Policy Analysis and Management* **20,** 415 (2001).

L. H. Gunderson, C. S. Holling, *Panarchy: Understanding Transformation in Human and Natural Systems* (Island Press, Washington, DC, 2001).

S. Hannah, in *Northern Waters: Management Issues and Practice*. Ed,. By D. Symes. (Blackwell, London, 1998), pp. 25-25

S. Hannah, C. Folke, and K-G Mäler. *Rights to Nature*. (Island Press, Washington, D.C., 1996)

G. Hardin, *Science* **162**, 1243 (1968).

G. Hardin, *Science* **280**, 682 (1998).

G. M. Heal. *Valuing the Future: Economic Theory and Sustainability*. (Colombia Univ. Press, New York, 1998).

J. Herb, S. Helms, and M. J. Jensen in *New Tools for Environmental Protection: Education, Information, and Voluntary Measures.* T. Dietz and P. C. Stern, Eds. (National Academy Press, Washington, DC, 2002), pp. 253-262.

C. Hess, *A Comprehensive Bibliography of Common Pool Resources.* CD-ROM. (Workshop in Political Theory and Policy Analysis, Indiana University, Bloomington, 1999).

C. Hess, *The Comprehensive Bibliography of the Commons* http://www.indiana.edu/~iascp/Iforms/searchcpr.html (2003).

M. Janssen. *Complexity and Ecosystem Management.*. (Elgar Publishers, Cheltenham, UK, 2002)

R. Keohane, E. Ostrom. *Local Commons and Global Interdependence*. (Sage, London, 1995)

S. Krech III, *The Ecological Indian: Myth and History* (W.W. Norton, New York, 1999).

J.S. Lansing. *Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali.* (Princeton Univ. Press, 1991).

W. Leach, N. Pelkey, and P. Sabatier, *Journal of Policy Analysis and Management* **21,** 645 (2002).

K. Lee, *Compass and Gyroscope* (Island Press, Washington, DC, 1993).

S. Levin, *Fragile Dominion: Complexity and the Commons* (Perseus Books, Reading, MA, 1999).

J. Liu et al., *Science* **300**, 1240 (2003).

B. Low, E. Ostrom, C. Simon, J. Wilson, in *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change,* F. Berkes, J. Colding, C. Folke, Eds. (Cambridge University Press, New York, 2003), pp. 83-114.

A. Maass, R. L. Anderson, . . . *and the Desert Shall Rejoice: Conflict, Growth and*

Justice in Arid Environments (R. E. Krieger, Malabar, FL, 1986).

W. Makalowski, *Science* **300**, 1246 (2003).

B. J. McCay, in *The Drama of the Commons*, E. Ostrom *et al*., Eds. (National Academy Press, Washington, DC, 2002), pp. 361-402.

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

M. McGinnis. *Polycentric Games and Institution.* (Univ. of Michigan Press, 2000).

M. McGinnis. *Polycentric Governance and Development.* (Univ. of Michigan Press, 1999.

E. Moran. *The Ecosystem Approach in Anthropology.* Univ of Mich Press, Ann Arbor, 1990).

R. A. Myers, B. Worm, *Nature* **423**, 280 (2003).

J. Nash, in *New Tools for Environmental Protection: Education, Information and Voluntary Measures*, T. Dietz, P. C. Stern, Eds. (National Academy Press, Washington, DC, 2002), pp. 235-252.

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

National Research Council, *Improving Risk Communication*. (National Academy Press, Washington, DC, 1989.

National Research Council, *Understanding Risk: Informing Decisions in a Democratic Society* , P. C. Stern and H. V. Fineberg, Eds. (National Academy Press, Washington, DC, 1996).

National Research Council, *Our Common Journey: A Transition toward Sustainability* (National Academy Press, Washington, DC, 1999a).

National Research Council, *Perspectives on Biodiversity: Valuing Its Role in an Everchanging World* (National Academy Press, Washington, DC, 1999b).

National Research Council, *Making Climate Forecasts Matter*, Panel on Human Dimensions of Seasonal-to-Interannual Climate Variability, Committee on the Human Dimensions of Global Change. P. C. Stern and W. E. Easterling, Eds. Commission on Behavioral and Social Sciences and Education. (National Academy Press, Washington, DC, 1996).

National Research Council, *The Drama of the Commons.* Committee on the Human

Dimensions of Global Change. E. Ostrom et al., eds. Division of Behavioral and Social Sciences and Education. (National Academy Press, Washington, DC, 2002).

National Research Council, *New Tools for Environmental Protection: Education, Information, and Voluntary Measures.* Committee on the Human Dimensions of Global Change. T. Dietz and P. C. Stern, eds. Division of Behavioral and Social Sciences and Education. (National Academy Press, Washington, DC, 2002).

R. McC. Netting, *Balancing on an Alp: Ecological Change & Continuity in a Swiss Mountain Community* (Cambridge Univ. Press, 1981).

R. O'Leary and L. B. Bingham, eds. *The Promise and Performance of Environmental Conflict Resolution* (Resources for the Future, Washington DC, 2003).

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

E. Ostrom. *Annual Review of Political Science* **2**, 493 (1999)

E. Ostrom, et al., *Science* **284,** 278 (1999)

E. Ostrom, R. Gardner, and J. Walker, *Rules, Games, and Common-Pool Resources* (Univ. of Michigan Press, 1994)

V. Ostrom. *Public Choice* **77**, 163 (1993)

V. Ostrom, *The Meaning of Democracy and the Vulnerability of Democracies.* (Univ. of Michigan Press, 1997)

C. Pahl-Wostl, *The Dynamic Nature of Ecosystems: Chaos and Order Entwined* (Wiley, Chichester, England, 1995).

A. Prakash, *Business Strategy and the Environment* **10,** 286 (2001).

T. Princen, *Global Environmental Politics* **3**, 33 (2003).

A. Randall, in *New Tools for Environmental Protection: Education, Information and Voluntary Measures*, T. Dietz, P. C. Stern, Eds. (National Academy Press, Washington, DC, 2002), pp. 311-318.

O. Renn, T. Webler, P. Wiedemann, *Fairness and Competence in Citizen Participation: Evaluating Models for Environmental Discourse* (Kluwer Academic Publishers, Dordrecht, the Netherlands, 1995).

E. Rosa, A. M. McWright, O. Renn, "The risk society: Theoretical frames and state management challenges" (Washington State Univ., Dept. of Sociology, Pullman,

WA, 2001).

C. Rose, in *The Drama of the Commons*, E. Ostrom *et al*., Eds. (National Academy Press, Washington, DC, 2002), pp. 233-257.

E. Schlager, W. Blomquist and S. Y. Tang. *Land Economics* **70**, 294 (1994).

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

P. C. Stern, *Science* **260**, 1897 (1993).

P. C. Stern, *Policy Sciences* **24**, 99 (1991).

P.C. Stern, *Journal of Consumer Policy* **22**, 461 (1999).

P. C. Stern, T. Dietz, N. Dolsak, E. Ostrom, and S. Stonich in *The Drama of the Commons*, E. Ostrom *et al*., Eds. (National Academy Press, Washington, DC, 2002), pp. 445-490.

R. W. Sussman, G. M. Green, & L. K. Sussman. *Human Ecology*. **22**, 333 (1994)

T. Tietenberg, in *The Drama of the Commons*, E. Ostrom *et al*., Eds. (National Academy Press, Washington, DC, 2002), pp. 233-257.

B. L. Turner II *et al*., *Global Environmental Change* **1**, 14 (1991).

A. Underdal. *The Politics of International Environmental Management*. (Kluwer Academic Publishers, Dordrecht, 1998)

E. Weiss and H. Jacobson (eds.). *Engaging Countries: Strengthening Compliance with International Environmental Agreements*. (MIT Press, 1998)

T. J. Wilbanks and R. W. Kates, *Climatic Change* **43**, 601 (1999).

T. Yandle and C. M. Dewees, in *The Commons in the New Millennium. Challenges and Adaptation*. (MIT Press, Cambridge), pp.101-128.

M. Verweij, *Transboundary Environmental Problems and Cultural Theory: The Protection of the Rhine and the Great Lakes* (Palgrave, New York, 2000).

Wallerstein 1974

U. Weber, *UNESCO Courier* (June 2000, p. 9).

S. Weiner, J. Maxwell, in *Dimensions of Managing Chlorine in the Environment*. Report of the MIT/Norwegian Chlorine Policy Study (MIT, Cambridge, MA, 1993).

K. J. Willis, R. J. Whittaker, *Science* **295**, 1245 (2002).

J. A. Wilson, in *The Drama of the Commons*, E. Ostrom *et al*., Eds. (National Academy Press, Washington, DC, 2002), pp. 327-360.

J. A. Wilson et al., *Marine Policy* **8**, 291 (1994).

J. Wunsch and D. Olowu. Eds. *The Failure of the Centralized State.* (ICS Press, San Francisco, 1995).

R. York, E. Rosa, T. Dietz, *Social Science Quarterly* **83**, 18 (2002).

O. R. Young, *The Effectiveness of International Environmental Regimes* (MIT Press, Cambridge, MA, 1999).

O. R. Young. *The Institutional Dimensions of Environmental Change. Fit, Interplay, and Scale* (MIT Press, Cambridge, MA, 2002).

Notes