SUSTAINABILITY AND RESILIENCE IN NATURAL RESOURCE SYSTEMS: POLICY DIRECTIONS AND MANAGEMENT INSTITUTIONS

Anthony T. Charles
Management Science / Environmental Studies, Saint Mary's University, Canada

Keywords: Natural resource management, sustainability, resilience, sustainability indicators, resource systems, precautionary approach, adaptive management, robust management, illusion of certainty, fallacy of controllability, co-management, community-based management, livelihood diversification, traditional knowledge, efficiency, capacity, institutional arrangements, resource management boards, self-regulatory institutions

Contents

1. Introduction
2. Sustainability and Resilience
3. Policy Directions for Sustainable and Resilient Resource Systems
4. Institutions
5. Conclusions
Acknowledgments
Related Chapters
Bibliography

Summary

Natural resources that form the backbone of much of the worlds economic activity, underpin the livelihoods of much of the worlds population, and have considerable cultural significance in locations around the world. Natural resource systems are also ones that require clear, deliberate management, yet are, at the same time, highly complex and uncertain. This article focuses on the challenge of developing policy measures and underlying institutions to support the management of natural resources in fisheries, forestry, wildlife harvesting, agriculture, mining and the like. Specifically, the article explores how the implementation of suitable policies and institutions can contribute to sustainability and resilience of natural resource systems and their ecological, socio-economic, community and institutional components.

The policies discussed fall into three categories. First, those relating directly to natural resource management include (a) development of a management portfolio, (b) application of the precautionary approach, and (c) implementation of robust and adaptive management. Second, those relating to the structure of the resource system and its interaction with the broader society include (a) co-management and community-based management, (b) planning approaches that promote efficiency in resource systems, (c) management of resource sector capacity, and (d) the diversification of livelihoods. Third, those policies relating to research, information and monitoring aspects of the resource system involve (a) development and utilization of the knowledge base, and (b) approaches for monitoring sustainability in resource systems.

Anthony T. Charles, "Sustainability and Resilience in Natural Resource Systems: Policy Directions and Management Institutions" In: *Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK, [http://www.eolss.net]

In promoting sustainability and resilience in resource systems, equal attention must be paid to the functioning of resource management institutions the organizational structures within which people interact (such as a resource management agency, an association of resource users, or the marketplace) and the underlying sets of rules and constraints adopted by society to govern behavior in resource use and management. This article explores the characteristics of institutions that may contribute to their own sustainability and resilience, and also the institutional arrangements that may support sustainable, resilient resource systems more broadly. An example of an important attribute of sustainable, resilient institutions is the capability for self-regulation, in which resource users themselves are involved in resource management functions, thereby supporting the management institution in getting the incentives right, so that resource users choose to operate in accordance with regulations and to avoid anti-conservationist actions.

1. Introduction

The worlds natural resources represent a fundamental link between humans and their environment. Whether in fisheries, forestry, agriculture, wildlife harvesting, or mining, the resource base clearly contributes crucial natural ingredients to development. Looking more broadly, natural resources are critical to most global industrial production from processed foods to furniture manufacturing to the production of oil-based plastics. Nowhere is the challenge of sustainable development more obvious than in dealing with the human uses of these natural resources. Given their inherently limited quantities, interactions between resources and the humans using them are constantly confronted with the threat of over-exploitation. This leads to the clear recognition that natural resource industries require deliberate management efforts; a *laissez-faire* approach is not suitable where natural resources are involved.

Natural resource management has an extensive theoretical base, drawing on ecology, economics, and a variety of other disciplines, but in practice, management efforts have met with at best, mixed success. Indeed, a widespread dissatisfaction with failures of the past has led resource management into a state of transition, with frequent calls for new approaches. It can be argued that many problems with resource management have been due to a lack of understanding of the policy and institutional aspects involved in managing natural resource systems. This article focuses on such aspects, and the manner by which suitable policies and institutions can enhance sustainability and resilience in resource systems. We begin with a discussion of the sustainability and resilience concepts themselves, turning then to an examination of policy directions that may support sustainable and resilient resource systems, and finally examining the role of institutions in resource management.

2. Sustainability and Resilience

Historically, the management of natural resources specifically, renewable resources has had as a major theoretical underpinning, the idea of determining a *sustainable yield*: a harvest that can be taken today without causing a decline in the resource available in future years. Two shortcomings of this perspective have become apparent, however. First, a focus on sustainable yield has an intrinsic emphasis on physical *output*, and tends to neglect the underlying natural *processes*, health of the ecosystems, and integrity of ecological interactions. Second, traditional discussions of sustainable yield in resource use have tended to ignore the corresponding human system and its sustainability, an aspect now highlighted in the ideas of *sustainable development*, laid out originally by the World Commission on Environment and Development.

There is now wide recognition that sustainability must be viewed broadly, in an integrated manner that involves maintaining and enhancing ecological, socioeconomic, community and institutional well-being. The sustainable development approach has brought about an important evolution from a focus merely on sustaining the output to a more integrated view in which sustainability is multi-faceted, and emphasizes the process as much as the output.

Discussion of sustainability is increasingly linked with the concept of resilience, introduced by the ecologist C.S. Holling to describe the capability of ecosystems to absorb unexpected shocks and perturbations without collapsing, self-destructing or otherwise entering intrinsically undesirable states. Specifically, Holling wrote in his paper "Resilience and stability of ecological systems" (Annual Review of Ecology and Systematics, volume 4, p.17, 1973):

"Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables and parameters, and still persist. In this definition resilience is the property of the system and persistence or probability of extinction is the result."

Thus, a resilient system is one that can absorb and bounce back from perturbations (shocks) caused by natural or human actions. Holling drew a strong distinction between the concept of resilience and that of stability, which he defines as "the ability of a system to return to an equilibrium state after a temporary disturbance." He highlights the point that "a system can be very resilient and still fluctuate greatly, i.e. have low stability" and indeed notes examples that suggest that "the very fact of low stability seems to introduce high resilience."

Hollings work on resilience led to a key conclusion about management in ecological systems that management approaches focusing on the pursuit of stability could be detrimental to resilience. Specifically, Holling noted that pursuit of a stable sustained yield for a renewable resource could change the underlying forces operating on the system to such an extent that "a chance or rare event that previously could be absorbed can trigger a sudden dramatic change and loss of structural integrity of the system."

The idea of resilience, while first formulated with ecosystems in mind, is just as relevant throughout resource systems. For natural resource systems, resilience implies that not only the relevant ecosystem, but also the corresponding human and management systems, are able to absorb perturbations, such that the system as a whole remains able to sustain (on average) a reasonable flow of benefits over time. In a resource sector, then, we can envision resilient management institutions, resilient communities, a resilient economic structure in the resource sector, and a resilient ecosystem in which the resource is located. For example, in thinking of components of human-based systems, such as communities, resilience implies a capability to persist in a healthy state whatever the state of the natural system and the socioeconomic environment. The resource management system should be resilient as well: if something unexpected happens (as is bound to be the case from time to time), will management still perform adequately? Since we cannot predict the unexpected impacts on a resource system, or even know the set of such possibilities, the challenge lies in designing resource management systems with the flexibility to deal as well as possible, and as often as possible, with such surprises.

3. Policy Directions for Sustainable and Resilient Resource Systems

Management must play a key role in seeking to maintain and enhance the sustainability and resilience of natural resource systems. This section presents several policy directions that may help resource systems function successfully within an uncertain world, even in the face of unexpected changes in natures course, or a poor understanding of the inherent structure and functioning of the systems. The policy directions discussed here fall into three categories: (a) those relating directly to natural resource management, (b) those relating to the structure of the resource system and its interaction with the broader society, and (c) those relating to research, information and monitoring aspects of resource management. Specifically, the topics, to be addressed sequentially below, are as follows:

Natural resource management:

- Developing a management portfolio;
- Applying the precautionary approach;
- Robust and adaptive management.

Resource system structure and interactions:

- Co-management and community-based management;
- Planning for efficiency in natural resource systems;
- Managing resource sector capacity;
- Diversifying livelihoods.

Information and monitoring:

- Developing and utilizing the knowledge base;
- Monitoring sustainability.

3.1 Developing a Management Portfolio

A wide array of management instruments is available in natural resource systems, from use rights arrangements to technological controls. Each has its advantages and disadvantages, and an over-emphasis on any single management method is unlikely to optimize sustainability or resilience of the resource system. There will always be some situation in which any such method will fail: in other words, any single management measure cannot be considered safe. Risk will be reduced if a portfolio (multiplicity) of management measures is utilized within the resource system. The key goal is for the portfolio to be *mutually-reinforcing***,** in that the various tools each help to rectify the shortcomings of the others.

A *portfolio* of appropriate management tools can be selected on a case-by-case basis, taking into account (a) societys objectives, (b) physical and/or biological aspects of the resource, (c) human aspects such as tradition and experience, (d) the level of uncertainty and complexity in the resource sector, and (e) the predicted consequences of the various instruments.

Consider, for example, a management system with quantitative limits on resource extraction. This system might be made more robust by supplementing these controls with other measures such as protected areas and input controls. The latter, whether qualitative limits on the how, when and where of resource use , or quantitative limits on input variables such as the amount of equipment or time used, provides an extra degree of security that ensures conservation will be achieved.

It should be added, however, that while a diversified portfolio for resource management is superior to a more narrow approach, it remains crucial to choose the right components of the portfolio. Particular management measures must satisfy certain criteria, to which we now turn.

3.2 Applying the Precautionary Approach

Uncertainties are ubiquitous in natural resource systems. It is unclear, however, to what extent these uncertainties are reducible over time, and unlikely that most uncertainties can be resolved in a clear-cut manner. Instead, many uncertainties must be addressed primarily through changes to the practice of resource management. The design of a management framework within which uncertainty can be addressed is surely a key element of a strategy for sustainable resource use.

A principal aspect of such a framework is the implementation of a *precautionary approach* to management decision-making, to ensure that we properly allow for uncertainty in our decisions, and err on the side of conservation. The precautionary approach provides the ground rules of management decisions, to guide scientists and managers in better *erring on the side of caution* in the face of uncertainty. As the U.N.s Food and Agriculture Organization has noted ("Precautionary approach to fisheries. Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions." FAO Fisheries Technical Paper No. 350, Part 1. Page 6. Rome, Italy):

> "Management according to the precautionary approach exercises prudent foresight to avoid unacceptable or undesirable situations, taking into account that changes are only slowly reversible, difficult to control, not well understood, and subject to change in the environment and human values Precautionary management involves explicit consideration of undesirable and potentially unacceptable outcomes and provides contingency and other plans to avoid or mitigate such outcomes"

There are two approaches to implementing the precautionary approach. One, requiring the re-design of management structures and methods, is discussed in the following section. The second approach is applicable to different forms of uncertainty that can be addressed through the use of quantitative decision rules to govern management actions. A precautionary risk-averse decision rule would typically be structured so that, other things being equal, a lower level of resource use will be chosen the greater the uncertainty in key variables, such as resource status. Not only does this imply that uncertainty is less likely to produce damaging outcomes, it also helps create incentives for scientists to ensure that uncertainty is fully incorporated in their analyses, and for resource users to help to reduce uncertainty.

3.3 Robust and Adaptive Management

Many uncertainties present in resource systems are of a *structural* nature; structural uncertainty reflects basic ignorance about the nature of the resource system, its components, its dynamics, and its inherent internal interactions. Structural uncertainty can have a major impact on the outcome of management, manifesting itself in such aspects as resource dynamics and resource-environment interactions, spatial complexity, technological change and the societal/management objectives being pursued. Such uncertainties inherent in natural resource systems make it risky to rely on management methods that are sensitive to highly uncertain variables or which depend on high levels of controllability.

To deal with structural uncertainty requires substantial changes (redesign) to the *practice* of resource management, so that its structure and methods are *robust* and *adaptive*. Specifically, *robust management* is such that it is possible to achieve a reasonable level of performance (i.e., an acceptable level of success) even if (a) we have a faulty understanding of the resource system (notably the status of the resources), its environment and the processes of change over time, or (b) the actual capability to control resource exploitation is highly imperfect. Such a policy move must overcome two counter-tendencies in many resource management systems:

- *Illusion of Certainty*. Some resource management systems suffer from an illusion of certainty, a perception arising in policy, management and/or operating practices that the world is certain and predictable, or at least that major elements of uncertainty can be safely ignored. Far from recognizing and working within the bounds of the uncertainty, the illusion of certainty leads to the opposite result.
- *Fallacy of Controllability*. Natural resource management is intrinsically an imperfect endeavour, with resource systems at best partially controlled. Unfortunately, this is by no means universally recognized: a *fallacy of controllability* is often in place, reflecting a perception that in resource systems more can be known, and more controlled, than can be realistically expected.

The move to robust management requires a re-thinking of these tendencies, and of the very philosophy of management. There is a need to focus on the challenge of developing management measures that optimize the overall sustainability of inherently uncontrollable resource systems. While clearly a desirable attribute for management of any highly uncertain system, robustness is not easily achieved. New structural and decision-making tools, notably the Precautionary Approach and the Ecosystem Approach, will help in this direction.

Furthermore, no matter how successful a management system is in lessening the overall sensitivity to uncertainty, such uncertainties will not disappear. Thus it remains important to institutionalize *adaptive management*, which has two principal implications. First, there is a need to account systematically for uncertainty by properly using available information, and seeking out new information, through continuous monitoring of the natural resource system. Second, adaptive management involves maintaining a capability and willingness to make appropriate adjustments, over both short and long time scales, adapting in a timely manner to unexpected circumstances, so that management goals are not compromised.

Adaptive management requires that resource use plans, and individual ‘business plans’ for resource industries, must be flexible, to allow for the uncertain nature of the natural resource. This requires a more flexible approach in which new information is integrated with existing data on a regular basis, with management actions reassessed accordingly. This does not imply the need to respond drastically to even the smallest apparent change in the resource, but there must be the *capability* to adapt to change over long time frames and in the short-term. In particular, while ideally it would be desirable from a resource users perspective to adopt fixed annual production plans, the apparent *stability* so obtained may be at the expense of ecological (and long-term economic) well-being.

3.4 Co-management and Community-Based Management

In a co-management system, a suitable combination of government agencies, resource users, communities and the public is involved in resource management specifically developing, implementing and enforcing management measures based on the sharing of decision-making power and taking responsibility to ensure the resource sectors sustainability. Co-management is rapidly expanding and evolving in natural resource systems, in many cases replacing a top-down governmental management style that dominated in the recent past, and that tended to create conflict between resource users and managers something that is reduced with successful co-management. The matter of who should participate in co-management is complex. For example, participation in some *operational* management decisions may be restricted to only those directly involved among resource users and government, while *strategic* management decisions (over policy that affects the overall direction of resource use) may require co-management arrangements in which the public can also play a major role. It should be noted as well that while participation is important to management, it is equally relevant to resource sector *research*, where resource industries and non-governmental organizations are increasingly playing an important role.

Community-based management can be seen as a form of co-management, in which much of the management authority rests at a local level, held within a suitable management body comprising resource users, organizations and community representatives. This 'CBM' approach can be effective in combining two key features of sustainable resource management. First, it can provide the means to make use of local resource knowledge and indigenous methods of resource management (discussed below). Second, such local control can provide more efficient, effective resource management, by bringing the community's moral pressure to bear on the actions of resource users. In other words, resource users not only have a greater incentive to support the management measures, they are under pressure to do so from their own community, which had itself developed the management measures and is dependent on a sustainable resource system.

3.5 Planning for Efficiency in Natural Resource Systems

The concept of *efficiency* is frequently misinterpreted, although its objective is straightforward: to obtain the greatest benefits with the least cost. Within resource sectors, this is often reduced simplistically to the goal of extracting the largest quantity (or value) of the resource, as quickly as possible, at the least cost. However, there is no reason to believe that this short-term and narrow view of efficiency captures what is desirable for the natural resource system or for communities and society more broadly.

A broader view of efficiency takes a longer term perspective. Given a conservation-based constraint on the resource available annually, it makes sense to view an efficient resource sector as one maximizing the long-term net benefits obtained *per resource unit extracted*, with the net benefits measured broadly, to incorporate all that is valued in society likely including a combination of profits and rents, employment, community well-being, ecological resilience, and so on. This is the case whether we are dealing with a simple resource system involving just one natural resource, or a multi-resource system (such as a forest or coastal zone), in which we seek to balance the use of various resources to optimize the overall use and health of the system.

Thus natural resource policy needs to pursue a *vision* of the future providing the greatest net benefits for a given available resource base, within agreed-upon system boundaries that are satisfactory from natural and societal perspectives. This implies determining a preferred *resource sector configuration* i.e., what the resource sector should look like in human terms, balancing among multiple user groups, technological methods, and scales of operation (notably small-scale versus large-scale). Next, within any single user group, there is a need to decide on the balance among a variety of inputs - including labour, capital, technology, management and enforcement activity. These decisions all depend on the blend of societal objectives pursued and the capability of the various resource sector players to meet those objectives.

Consider, for example, the dichotomy between small-scale and large-scale resource users. In recent decades, while the small-scale has often received verbal support from decision-makers, the focus in many jurisdictions has been in the opposite direction toward industrialization, technological advances, market mechanisms, and a view of natural resources as commodities within an industry. As a result of this industrial view of resource use, it is often *assumed* that small-scale resource users are inefficient. But a proper analysis would take the perspective described above, comparing small- and large-scale resource use with efficiency viewed from a wider perspective - integrating resource use itself with related activities and the regional economy as a whole (of which the resource sector is often the engine), and considering aspects of resilience and sustainability. That such points often fail to be addressed highlights the current dominance of a simplistic view of efficiency, and the strong need for integrated analysis to support the intelligent design of natural resource policy.

3.6 Managing Resource Sector Capacity

A key element in natural resource planning lies in determining a suitable magnitude of interaction between the human system and the natural system, one that optimizes the performance of the natural resource system. Over-capacity (or over-capitalization) arises when there is a mismatch between the level of inputs *needed* to extract or harvest the available resource, and the level of inputs *currently present* in the resource system. The latter is referred to as 'capacity', and reflects the capability of the resource users to harvest or extract the resource. A situation of over-capacity is one in which this capacity to utilise the resource exceeds that needed for the given resource level.

Over-capacity is often considered a major concern in resource industries. Two major reasons are cited for this. First, it may be seen as a waste of physical capital if, for example, the capital exceeds that required to harvest the available resource. There may be an excessive level of labour as well, but only if the surplus resource users have other employment options, i.e. productive activities in which they could be engaged elsewhere in the economy. Second, over-capacity could produce negative conservation impacts. A resource sector with over-capacity has abundant inputs, and thus a *potential* to over-exploit the resource. This potential need not be realized if the various inputs are properly controlled, but problems could arise if over-capacity arises in conjunction with ineffective natural resource management. In such a case, conservation may be affected through an inability to control the use of the resource. In the end, then, the key is to effectively limit resource use through proper management as well as capacity planning.

Suppose, however, that capacity has grown excessive, and some form of reduction is desired. Such a move needs to be part of a planning process that moves the natural resource system toward a desired configuration, in a manner compatible with the balance of objectives being pursued through natural resource policy. Three major classes of capacity reduction can be envisioned. First, *market-based* approaches imply that the marketplace determines the eventual configuration of the resource sector, which is likely to be based on a combination of individual efficiency and access to financial capital. It may be that resource sector participants are assigned or acquire rights to take specified quantities of the resource. If these rights can be bought and sold, markets become established to facilitate the trading of rights, and in theory those who are less efficient from an individual perspective sell off their rights to others and exit the resource sector. Second, *planning* approaches lead to targeted capacity reduction aiming to achieve a desired overall resource sector configuration, which may take into account such factors as the differential capacity of the various users, and the impacts of the resource use technologies. Third, local-level *community-based* approaches to capacity reduction produce a resource sector configuration that is planned explicitly to meet local objectives. Under suitable circumstances, this can be efficient both at the resource sector level (reducing costs by coordinating activity among community participants) and at the regulatory level (e.g., by reducing conflict, increasing self-enforcement and decentralizing management).

3.7 Diversifying Livelihoods

No amount of research or management is likely to produce a resilient natural resource system if humans are completely reliant on such resources for their livelihoods, and are unable to survive without over-exploiting them. In particular, the natural ups and downs of resource availability produce a consequent need for resource users to vary their level of usage over time, with alternative livelihood sources being needed for times when the resource is less available. There is thus a need to diversify employment in otherwise resource-dependent areas, providing multiple sources of livelihood, and enabling available resources to be used to their best advantage. Clearly, it is not enough to focus only within the resource sector inherent linkages between the sector and non-resource aspects reinforce the need for an understanding of interactions beyond the natural resource system, as well as the need for integrated and multidisciplinary approaches to achieve sustainability.

Solving the problem of a lack of *livelihood diversity*, through economic diversification, is by no means simple if it were, resource-based economies would already have become diversified by now, in response to past resource downturns. Yet efforts in this direction seem critical in most cases to the success of programs for sustainable natural resource systems.

First, there is a need to encourage *occupational pluralism* resource users holding other jobs during times when the resource is not available. This diversification is sometimes discouraged by governments, but is indeed common as a traditional practice in many seasonal resource sectors. Such practices reduce the pressure that resource users would otherwise face to obtain a livelihood entirely from within the resource sector, and thus also reduce the pressure on the resource stocks. Encouraging such practices, and by implication, discouraging excessive specialization, boosts the resiliency of the natural resource system.

Second, there is a need to diversify (broaden the base) of the resource-dependent economy, by creating new, sustainable economic activity outside the resource sector. From the perspective of the individual, this enhances the range of available livelihood choices, both for current resource users and for young people looking for a job. The process is also likely to increase income levels outside the resource sector. All this will tend to make it more attractive for so-inclined participants to leave the resource sector, and reduce incentives for others to enter the sector (increasing the *opportunity cost* of remaining in the resource sector, as the economist puts it). This leads to an overall reduction in pressure on resources. Thus economic diversification, combined with conservation-oriented management restrictions within the resource sector, can increase resilience, as well as community and socioeconomic sustainability.

Economic diversification may, in many cases, be the single most important need in the pursuit of sustainable, resilient resource sectors, but it is also the most challenging of tasks. As noted above, if it were a simple matter, such economic diversification would have been accomplished long ago. Yet there is hope that progress might be made through more *integrated* approaches which might involve (i) a focus on indigenously-created employment alternatives within the local region or community, taking advantage of comparative advantages, (ii) attention to constraints on local development that may be due to factors at the macroeconomic or macro-political level, and (iii) attention to the need for institutional arrangements that promote effective governance at the local level.

3.8 Developing and Utilizing the Knowledge Base

Building or maintaining sustainability and resilience in natural resource systems requires a suitable knowledge base. It is notable that there are major gaps in our understanding of the various ecosystems within which natural resources lie, and of the interactions between humans and those systems. It is also clear that in many cases of resource use, there has been a failure to use all the *available* sources of information and knowledge. In particular, the information that already exists but has been under-utilized in natural resource management typically lies beyond the standard scientific apparatus, in the realm of what is called Traditional Ecological Knowledge (TEK) or in some cases, "local knowledge".

This knowledge base incorporates the accumulated information and wisdom concerning the natural world that has been built up over time by resource users and communities, through regular interaction with their environment and the natural resources in them. TEK is defined by Fikret Berkes, in his book "Sacred Ecology: Traditional Ecological Knowledge and Resource Management" (Taylor and Francis, Philadelphia, U.S.A., 1999) as follows:

"a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment."

It is important to note that while knowledge about nature *per se* is a crucial part of TEK, it is not the only part. For example, resource users and their communities can have important knowledge about what resource management arrangements function best within their cultural systems, about workable approaches to improving compliance among resource users, and about which harvesting techniques are most effective, or most conservationist, within the local context. Furthermore, the relevant knowledge is not just that developed over long time periods, but also information acquired in recent years, notably in the course of resource use. For example, this may include information about distributions of the resource over time and space within a given year, which can be valuable input for scientists and managers, even if it does not necessarily translate into a comprehensive estimate of overall abundance. Local residents may also have important information on environmental conditions within the ecosystem.

Valuable ecological and resource management knowledge is likely to exist wherever resource users and local residents interact with local resources and their environment, and such TEK needs to be incorporated in, and nurtured by, practitioners of resource science and management. This is certainly a challenge, since modern resource science and resource management have developed largely without this recognition. There is a need to develop both the sense of trust and the means of communications between scientists and managers on the one hand, and those holding the knowledge on the other. This calls for policies promoting systems of community-based management and co-management, which encourage participation in decision-making (and in research) by those most familiar with, and most attached to, the resources and their environment. The latter group typically are those living in communities adjacent to the resource which implies the additional need for policy measures to maintain the knowledge base by providing such people with secure permanent access to the local resource sector.

3.9 Monitoring Sustainability

Clearly, it is important to be able to assess the extent to which a given natural resource system is in fact sustainable, or making progress towards sustainability. An integrated process of *sustainability assessment* can provide a mechanism for accomplishing this, by developing a set of indicators relating to the four components of sustainability ecological, socioeconomic, community and institutional sustainability. One can begin this process by formulating a checklist that lists precisely what sustainability criteria are required in order to assess a natural resource system, incorporating aspects of the ecosystem, the socioeconomic structure, the well-being of local communities, and the institutional integrity of the system. Table 1 depicts an example of a possible checklist, providing a framework to highlight trouble spots, relating both to the system directly impacted and to related support activities. The next step in sustainability assessment is to build on the set of criteria to develop a *quantitative* set of indicators, the *measuring* tools of sustainability within a natural resource system. Each relevant sustainability criterion needs to be quantified appropriately, whether through an *objective* variable (one that is in some sense observable or measurable, such as a human population or a level of resource abundance), or through a *subjective* measure amenable to evaluation (perhaps on a scale from 1 to 10). Some examples of possible ecological, socioeconomic, community and institutional sustainability indicators are shown in Table 2.

Table 1: Sustainability Checklist

Table 2: Examples of Possible Sustainability Indicators

The development of quantitative sustainability indicators has been substantial, especially in agricultural systems, forests, rangelands and wildlife. Analysis ranges from the local (micro) to the regional or industry levels. For example, this might involve indicators of sustainability for forestry operations in a specific location, or for wildlife management in a specific park. Also relevant are sets of quantitative sustainability indicators developed at the international or national levels relating to alternative national accounts (natural resource accounting, or ‘green accounting’), and alternative indicators of human progress and well-being, to augment Gross Domestic Product (GDP) measures.

4. Institutions

While the appropriate choice of policy directions in resource management, as discussed above, is important in moving resource systems toward sustainability and resilience, equally critical from this perspective is adequate attention to resource management *institutions*. Indeed, however well-crafted may be the policy statements, successful resource management is unlikely in the absence of due attention to institutional arrangements. This implies the need for both (1) suitable organizational structures within which people interact, pursue societys goals and manage themselves such as governmental resource management agencies, associations of resource users, or relevant markets, and (2) appropriate underlying sets of rules and constraints, adopted by society to govern the behavior of resource users and the management of the natural resource. In seeking to create and nurture suitable management institutions, certain attributes of such institutions will be desirable, including (a) sustainability and resilience of the institution itself, and (b) effectiveness of the institution in managing the resource system for sustainability and resilience.

4.1 Sustainable and Resilient Institutions

Consider first the matter of determining the ingredients of a sustainable and resilient institution, and conditions favorable to the development of such an institution. Researchers Folke and Berkes suggest that with respect to enhancing resilience, "(t)he task is to make institutional arrangements more diverse, not less so; to make natural system social system interactions more responsive to feedbacks; and to make management systems more flexible and accommodating of environmental perturbations." ("Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience", Cambridge University Press, Cambridge, U.K., 1998.) They highlight the importance of social/institutional memory, notably within traditional knowledge, in meeting this objective.

With respect to long-term institutional sustainability, the specific conditions required of a local institution of natural resource users have been explored by well-known institutional analyst Elinor Ostrom. These conditions may be paraphrased as follows. First, access and use are regulated based on a small number of agreed-upon rules. Second, enforcement of these rules is shared by all users, with support from external observers and enforcers. Third, the relevant management organization operates adaptively. Fourth, natural resource users also have legal claims as owners of the resource. Fifth, the relevant organization is nested within larger entities, which view the organization as legitimate. Sixth, processes of change external to the institution are not excessively rapid. Presumably, the more of these conditions that are met, the more likely the institution is sustainable. Some of the conditions are within the control of those designing the institution, while others are not. In particular, the sixth condition recognizes that if dynamic change in the external world such as population, technology and politics is too great, impacts on a local institution may occur to such an extent that it is unable to adapt to change.

4.2 Institutional Effectiveness in Achieving Sustainability and Resilience

Following from the above, Ostrom explores the question of institutional effectiveness in meeting specified management goals which in the present case focuses on resource system sustainability and resilience. Her approach is to characterize the determinants of institutional effectiveness through eight ‘design principles’ which, in a natural resource context, can be stated as follows. First, the boundaries of the resource itself and of the set of resource users must be clearly defined. Second, resource use rules must be in keeping with local conditions. Third, those affected by use rules must be able to participate in modifying those rules. Fourth, there must be effective monitoring of the resource and resource use, which should be done by, or accountable to, the resource users. Fifth, sanctions for violations of use rules must be graduated, based on the seriousness and context of the offence, and issued collectively by the resource users or by officials accountable to the users. Sixth, mechanisms for rapid, low-cost local-level conflict resolution must be available. Seventh, the institutions right to exist and operate must be accepted by government authorities. Eighth, appropriate management rules must be established at each spatial and/or organizational scale of the system. Taken together, these principles help to define the nature of a management institution most likely to succeed in producing a sustainable, resilient resource system.

The work of Folke and Berkes, discussed above, provides another perspective on the matter of institutional effectiveness in achieving sustainability and resilience. A series of case studies depict situations in which "adaptiveness and resilience have been built into institutions so they are capable of responding to and managing processes, functions, dynamics and changes in a fashion that contributes to ecosystem resilience." In other words, such case studies show how institutions that are themselves resilient can help to maintain and promote resilient ecosystems, in the face of intensive resource exploitation. Folke and Berkes suggest that resilience can be enhanced through traditional ecological approaches to management, such as the (a) embracing of small-scale disturbances to avoid major catastrophes, (b) use of reserves and habitat protection measures, and (c) avoiding a reliance on exploitation of a single species in the ecosystem, by encouraging multiple occupations and sources of livelihood (as discussed earlier).

A key attribute of an effective resource management institution appears to be a *self-regulatory* capability. *Self-regulatory institutions* are those that not only involve resource users in management functions, but also help to get the incentives right, so resource users and others are induced through those incentives to operate in accordance with the regulations and to avoid anti-conservationist actions. Strong self-regulatory institutions help to enhance the resilience of the resource system, in part by providing a feedback loop between harvesting and management, reinforcing desirable incentives and thereby reinforcing management goals. For example, effective community-based institutions may be important in (a) creating social incentives for the sharing of natural resources and for more responsible behaviour in resource use and (b) providing a suitable system of rights that helps to clarify the roles and responsibilities of the various players in the resource sector. The set of use rights over natural resources is a crucial ingredient, since an *appropriate* rights system enhances the resource sector and its sustainability, while conversely, an inappropriate rights systems can lead to undesired consequences, such as a loss of resilience in communities.

The idea of self-regulatory institutions has clear practical manifestations. In particular, the many steps needed towards community-based management and co-management involve the creation or reinforcement of such institutions. Resource users as a group commit to a management plan, and may also develop the means for self-policing. While this is not a simple panacea, since there remain many incentives to thwart regulations through illegal or anti-conservationist actions, the focus is on discouraging such actions through social mechanisms and moral suasion - pressure from the community to do the right thing. There are also many examples emerging in which self-regulatory institutions have led to conservation actions beyond what a central authority could have achieved alone.

More generally, a desired characteristic of any resource management institution, relating to its capability to promote a sustainable and resilient resource system, is its ability to develop a *conservation ethic*, a fundamental embracing of conservation as part of the ‘belief system’, among resource sector participants. This requirement reflects the reality that underlying many problems with excessive natural resource use lies the matter of *attitude*: how resource sector players users, scientists, managers and policymakers view the system in which they operate. The right institutions can help create an atmosphere in which old attitudes change, and a conservation ethic emerges.

4.3 Institutional Choices

So far in this discussion of institutions, we have focused on characteristics of institutional design, and of the institutions themselves, that may be conducive to sustainability and resilience. But of the specific institutional choices available, which are to be preferred, with respect to the resource systems sustainability and resilience as well as to the magnitude of benefits produced? In reality, there is no single answer to this question; instead, the specific choice of institutions is a context-sensitive question, dependent on (1) society’s objectives with respect to the resource system, (2) the structure, history and traditions of the resource system, and (3) the relevant social, cultural and economic environment. Thus, there is a need for a careful assessment of the institutional choices in any given situation. What management institutions work for specific combinations of resources, industry structure and political jurisdictions? What factors determine a desirable balance between resource owners and resource users whether central government control, co-management or self-regulation? Progress is being made in addressing these matters, by examining real-world case studies to better understand the ingredients of sustainable, resilient, self-regulatory resource management institutions. Such an understanding is of great importance given that, in the past, poor institutional arrangements in many resource sectors led to major conservation failures.

However, it is worth reiterating the point made earlier that no single institutional arrangement can possibly be desirable in every situation. Given this, the appropriate role for resource managers must be to seek out an agreed-upon institutional structure that will work in practice, based on an understanding of the nature of the resource, the history of the resource system, and the philosophy of those involved in it. Clearly, this reflects not a one-size-fits-all but rather a case-by-case approach, which nevertheless might be guided by a meta-assessment of overall tendencies in institutional appropriateness based on the range of past experiences with natural resource systems.

Consider, for example, two oft-discussed options for determining access to resource systems one based on markets as the key decision-making institutions, and the other on resource management boards and other similar organizational structures (e.g., resource users cooperatives, and councils in native/indigenous societies). In the first of these models, decisions on who participates in the resource system and to what extent are made implicitly through the actions of resource sector participants, buying and selling rights to resource access in the marketplace. In contrast, the management board approach assigns resource access in a more deliberate manner through a decision-making process carried out by community-based, regional or national institutions, typically based on the recognition of multiple societal goals.

A variety of considerations arise in examining these institutional choices. For example, a key aspect in evaluating the market model is the matter of who actually buys and sells access rights, since this determines the future appearance of the resource system. Is it the more efficient players who buy out the less efficient ones (thereby increasing efficiency) or is it those with better access to financial capital who buy out others (raising particular concerns about equity)? How, in any particular situation, do markets rate in terms of ease of implementation and cost-efficiency in handling transactions between resource users? To what extent does a market-based institution, with its essentially irreversible process of distributing and monetizing access rights, constrain the process of policy development? Turning to resource management boards and related institutions, how can these best combine legislation and governmental decisions, on the one hand, with tradition and informal arrangements on the other? Under what circumstances can such institutions effectively incorporate the participation of resource users and resource-based communities in the management process? Under what circumstances can such an institutional environment effectively create a collective incentive to promote conservation, efficient resource allocation and increased management efficiency?

Between these institutional choices, there seems to be a tendency to prefer the resource management board model where there is a clear need to balance multiple objectives, within a relatively small-scale system, and/or in situations with a coherent social structure, in which users have clear ties to their communities. On the other hand, a market-based arrangement may be suitable when the resource sector has a predominantly industrial orientation, and when the profit motive dominates over community and socioeconomic goals. However, it must be reiterated again that any such tendencies are by no means absolute. The preferred institutional arrangement will certainly vary with the context, dependent not only on natural and human realities, but also on society's objectives and the varying priorities attached to each.

5. Conclusions

This article has explored the concepts of sustainability and resilience as they apply to the human use of natural resources, and the management of resource uses. Emphasis has been placed on exploring policy directions and institutional arrangements that promote sustainable and resilient natural resource systems. Specific topics of discussion were as follows:

Policy directions relating to natural resource management:

- Developing a management portfolio;
- Applying the precautionary approach;
- Robust and adaptive management.

Policy directions relating to resource sector structure and interactions:

- Co-management and community-based management;
- Planning for efficiency in natural resource systems;
- Managing resource sector capacity;
- Diversifying livelihoods.

Policy directions relating to information and monitoring:

- Developing and utilizing the knowledge base;
- Monitoring sustainability.

Institutional arrangements:

- Sustainable and resilient institutions;
- Institutional effectiveness in achieving sustainability and resilience;
- Institutional choices.

Three major philosophical considerations guide the discussion in this article:

- First, the pursuit of sustainable development requires a multi-dimensional view, incorporating ecological sustainability, as well as socioeconomic, community and institutional components of sustainability. This broad perspective applies as well to resilience; specifically, natural resource strategies must enhance resilience in the ecosystem, the economy, human communities, and relevant institutions.

- Second, since uncertainty is a dominant and permanent feature in natural resource systems, there is a need to *live with uncertainty*. This requires the sort of measures outlined earlier, such as (a) adopting the Precautionary Approach to guide managers on appropriate choices for resource use, erring on the side of conservation, (b) reducing risks through adoption of a broad management portfolio, (c) developing management measures that are robust in the face of uncertainty, and (d) adopting adaptive management approaches.

- Third, the move toward sustainability and resilience in natural resource sectors requires an appreciation of the importance of *natural capital* the natural resources themselves, and the underlying ecosystems, providing a range of ecological services such as maintenance of the water cycle, biological diversity and scenic beauty. This broadens the old view of natural resource industries, with a focus exclusively on extracting a resource, and highlights the role of natural capital alongside the more traditionally discussed forms of human capital and physical capital.

While human interaction with the environment involves many aspects beyond natural resource use, certainly the wise use of resources not only lies at the foundation of a sustainable economy, but is also indicative of our capability as a society to live in harmony with nature. While the various policy and institutional measures proposed in this article do not represent an exhaustive coverage of the potential paths toward sustainable and resilient natural resource systems, it is hoped they may provide useful guidance to resource managers and policymakers, as well as those seeking to develop resource management institutions.

Acknowledgements

The support provided by a Pew Fellowship in Marine Conservation and by the Natural Sciences and Engineering Research Council of Canada, operating grant 6745, is gratefully acknowledged.

Bibliography

Berkes F. and Folke C. (1998). *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. 459 pp. Cambridge, U.K.: Cambridge University Press.

Berkes F. (1999). *Sacred Ecology: Traditional Ecological Knowledge and Resource Management*. 209 pp. Philadelphia, U.S.A.: Taylor and Francis. [This book provides a comprehensive exploration of traditional knowledge, particularly that of native peoples, and the use of that knowledge within natural resource management.]

Bromley D.W., Feeny D., McKean M.A., Peters P., Gilles J.L., Oakerson R.J., Runge C.F. and Thomson J.T. (Editors) (1992). *Making the Commons Work: Theory, Practice and Policy*. 339 pp. San Francisco, U.S.A.: Institute for Contemporary Studies.

Charles A.T. (2001). *Sustainable Fishery Systems*, 370 pp. Oxford U.K.: Blackwell Science. [This book provides an integrated, multidisciplinary perspective on fisheries and fishery management, with an emphasis on sustainability and resilience.]

Folke C. and Berkes F. (1998). *Understanding Dynamics of Ecosystem-Institution Linkages for Building Resilience*. Beijer Discussion Paper Series No.112. Beijer International Institute of Ecological Economics, The Royal Swedish Academy of Sciences. Stockholm, Sweden.

Food and Agriculture Organization (1995). *Precautionary approach to fisheries. Part 1: Guidelines on the precautionary approach to capture fisheries and species introductions*. FAO Fisheries Technical Paper No. 350, Part 1. FAO, Rome, Italy. [This is an oft-referenced report describing the precautionary approach as applied to fisheries.]

Holling C.S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, Vol.4, pp.1-23. [This is Hollings seminal paper on the concept of resilience, and its implications for ecosystems.]

Holling C.S. (Editor) (1978). *Adaptive Environmental Assessment and Management*. 377 pp. New York, U.S.A.: Wiley. [This follows up on the preceding reference, developing an adaptive approach to environmental management.]

Jansson A., Hammer M., Folke C. and Costanza R. (Editors) (1994). *Investing in Natural Capital: The Ecological Economics Approach to Sustainability*. 504 pp. Washington, U.S.A.: Island Press. [This collection of papers describes a range of ideas and approaches relating to the sustainability and resilience of resource systems.]

Ostrom E. (1990). *Governing the Commons*. 280 pp. Cambridge, U.K.: Cambridge University Press. [This book and the following two references describe Ostroms seminal thinking on the formation and sustainability of institutions for natural resource management.]

Ostrom E. (1992). The rudiments of a theory of the origins, survival, and performance of common-property institutions. *Making the Commons Work: Theory, Practice and Policy*. (ed. D.W. Bromley, D. Feeny, M.A. McKean, P. Peters, J.L. Gilles, R.J. Oakerson, C.F. Runge and J.T. Thomson), pp.293-318. Institute for Contemporary Studies. San Francisco, U.S.A. [See above.]

Ostrom E. (1995). Designing complexity to govern complexity. In: *Property Rights and the Environment: Social and Ecological Issues*. (Ed. by S. Hanna and M. Munasinghe), pp.33-45. Beijer International Institute of Ecological Economics and the World Bank. Washington, U.S.A. [See above.]

World Commission on Environment and Development (1987). *Our Common Future*, Oxford, U.K.: Oxford University Press. [This is the classic reference on sustainable development, by the Brundtland Commission.]

To cite this chapter:
Anthony T. Charles, “Sustainability and Resilience in Natural Resource Systems: Policy Directions and Management Institutions”, In: *Encyclopedia of Life Support Systems (EOLSS)*, Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford ,UK, [http://www.eolss.net]

Table 1. Sustainability Checklist

Ecological Sustainability:
1. Are exploitation levels on directly impacted resources such that ecosystem sustainability and resilience are maintained (or at least not reduced excessively)? 2. Are indirect impacts reasonably understood to the extent required to ensure sustainability? 3. Are impacts on the ecosystem as a whole reasonably understood to the extent required to maintain overall resilience? 4. Are alternative systems of management and/or utilization available so that pressures from any increased demands placed on the system do not increase beyond management capabilities? 5. Are imposed stresses and rates of change likely to be within the bounds of ecosystem resilience?
Socioeconomic Sustainability:
1. Will the activity increase the aggregate long-term rate of employment? 2. Will the project enhance economic viability in the local and regional systems? 3. Are possible impacts on input and output prices understood? 4. Are changes in natural capital incorporated into national accounting practices? 5. Are current and projected levels of distributional equity in the system sufficient? 6. Will long-term livelihood security be maintained or increased?
Community Sustainability:
1. Is the project likely to maintain or increase the long-term stability of affected communities? 2. Does the local population have access to the resource base? 3. Is the local population integrated into resource management and development practices? 4. Are traditional value systems of importance to the community maintained? 5. Are traditional resource and environmental management methods utilized to the extent possible? 6. Are there adverse impacts that unduly affect particular components of the community, such as youth or particular religious groups?
Institutional Sustainability:
1. Will the long-term capabilities of corresponding institutions be increased? 2. Is financial viability likely in the long term, or does the intrinsic importance of the resource system justify ongoing support from society regardless?

Table 2. Examples of Possible Sustainability Indicators

Sustainability Criteria:	***Indicator:***
Biomass	Biomass (relative to historical average)
Environmental Quality	Quality (relative to historical average) + (% Rate of Change)
Diversity (Ecosystem)	(# Species)/(Historical Average) + (Diversity)/(Historical Average)
Protected Areas	Area Protected as % of Total Area
Ecosystem Understanding	Level of understanding, relative to ‘full’ knowledge
Community Resiliency	Index of Diversity in Employment
Environmental Carrying Capacity	Natural Absorptive Capacity / Waste Production
Equity	Ratio of Historical to Current Gini Coefficients of Income Distribution
Management Effectiveness	Level of Success of Stated Management and Regulatory Policies
Incorporating Local Input	Extent of Incorporation
Institutional Viability	Level of Financial and Organizational Viability