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Introduction

Over the last half-century, human activities have eroded Earth's life-support system (Likens, 1991; Vitousek et al., 1997; Steffen et al., 2004; Foley et al., 2005; Haberl et al., 2007). This has occurred through changes in climate, biogeochemical cycles, and land-cover; through loss of biodiversity; and through pollution of the global environment (Rockström et al., 2009). This has caused an overall global decline in many of Earth's most important ecosystem services, the benefits that people derive from ecosystems (Daily, 1997; MEA, 2005). Ecosystem services that have declined in the last half-century include the capacities of land, freshwaters, and oceans to sustain renewable supplies of natural resources that are harvested from ecosystems; to regulate processes such as climate, water delivery, and the spread of disturbance and disease that link ecosystems across landscapes; and to provide the cultural, aesthetic and recreational benefits that cause people to value particular places.

In the last decade or so it has become increasingly evident that these trends are interdependent and in most cases are accelerating (Steffen et al., 2004; IPCC, 2007). This has reduced many aspects of human well-being, especially of vulnerable people and places, (MEA, 2005; UN, 2010). At the global scale, many of these changes appear to be approaching or may have exceeded the safe operating limits for the long-term well-being of humanity (Rockström et al., 2009). This unsustainable trajectory demands a dramatic change in society's relationship with the environment to avoid irreparable damage to Earth's life-support systems.

Although the serious degradation of the Earth's system is widely recognized by the scientific community, governments are frequently reluctant to adopt policies that would radically reduce the rates of change and degradation, for fear of the economic costs. Aggressive actions that are taken now, however, are likely to be much less costly than the costs of failing to act (Stern, 2007; NRC, 2010). Institutional inertia and cultural habits are additional impediments to action.

Given the pace of environmental deterioration and the increased recognition that this path is untenable, society should seize the opportunity to reorient its relationship to the biosphere. In this article we outline Earth Stewardship as one approach to achieve this goal. We describe the strategy that has been initiated by the Ecological Society of America (ESA) in collaboration with many other disciplines and segments of society.

Defining Earth Stewardship as an Approach for Action

Earth Stewardship is the active shaping of trajectories of change in coupled social-ecological systems at local-to-global scales to enhance ecosystem resilience and promote human well-being. The concept of Earth Stewardship is rooted in religious thought (Conradie, 2006; Kearns and Keller, 2007) and is similar to the principles underlying U.S. environmental policy[1], sustainable development in developing nations (WCED, 1987; UN, 2010), and the emerging science of ecosystem management (Szaro et al., 1999; Chapin et al., 2009). The concept of stewardship is familiar to the general public and has essentially the same meaning in lay terms as we intend in its scientific usage. Its goals are thus widely accepted by scientists, policy makers, and society, although their application often raises contentious issues regarding tradeoffs (Clark and Levin, 2010).

In 1991 ESA launched the Sustainable Biosphere Initiative (SBI) to "define the role of ecological science in the wise management of Earth's resources and the management of Earth's life support system" (Lubchenco et al., 1991). The SBI identified three research priorities requiring particular attention in addressing global environmental problems: global change, biodiversity loss, and sustainable ecological systems. An important contribution of the SBI was the recognition of tight coupling between human activities and ecological processes on an increasingly human-dominated planet, although its emphasis was on the application of ecological science to address these issues. The SBI was one of several threads leading to the development of sustainability science (NRC, 1999; Kates et al., 2001; Clark and Dickson, 2003; Matson, 2009), whose goal is to "promote human well-being while conserving the life support systems of the planet" (Clark and Levin, 2010). Sustainability science recognizes the coupling of human and natural systems at multiple scales (Berkes et al., 2003; Turner et al., 2003).

Earth Stewardship is an action-oriented initiative that uses the principles of sustainability science to shape societal and environmental pathways. The U.N. Millenium Development goals are one example of such a pathway for "living in a world where environmental sustainability is a priority, and women and men live in equality…with freedom from extreme poverty and hunger" (UN, 2010). Examples of the application of science to promote Earth Stewardship include (1)

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[1] U.S. National Environmental Policy Act of 1969: The purpose of the act is "to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation…"

understanding the causes of polar ozone holes and reducing the production of ozone-destroying chemicals that caused them (global scale) (Graedel and Crutzen, 1995); (2) transforming management of the Great Barrier Reef in Australia to protect marine biodiversity and livelihoods (regional scale) (Olsson et al., 2008); and (3) minimizing the impacts of climate change in New York City through assessment, mitigation, and adaptation (local scale) (http://www.nyc.gov/html/planyc2030/html/plan/plan.shtml).

ESA, in partnership with other academic societies, agencies, non-governmental groups, the private sector, and other stakeholders seeks to foster Earth Stewardship by (1) clarifying the science needs for understanding and shaping trajectories of change at local-to-global scales; (2) communicating the basis for Earth Stewardship to a broad range of audiences, including natural and social scientists, students, the general public, policy makers, and other practitioners; and (3) formulating pragmatic strategies that foster a more sustainable trajectory of planetary change by enhancing ecosystem resilience and promoting human well-being.

Identifying the Science Needs for Earth Stewardship

Planetary interactions, feedbacks, and thresholds

Social-ecological interactions are ubiquitous on Earth. Indeed, human impacts on the biophysical system and the resulting changes in ecosystem services are among the interactions and feedbacks that have changed most rapidly (MEA, 2005; IPCC, 2007; Rockström et al., 2009). What is needed is a new science that identifies these key interactions and feedbacks and explores ways to stabilize them, reducing rates of change or amplifying feedbacks that foster more favorable trajectories (ICSU, 2010) (http://www.icsu-visioning.org/).

Managing the global commons

The idea of a global commons is a powerful one. A commons is a type of property regime, i.e., an institutional arrangement for managing shared resources. A community manages a commons to secure resources and other environmental benefits. This approach contrasts with an open-access property regime, in which there is in effect no shared management. Users simply take what they wish from the area in question. It was in fact an open-access property regime property regime that Garrett Hardin (1968) described in “Tragedy of the Commons.” A true commons characterized by effective management by an informed and interactive community should avoid tragedy. It is this ideal that forms part of the foundation of Earth Stewardship. International agreement to stop producing ozone-destroying chlorofluorocarbons has led to the successful management of the atmosphere as a commons, whereas failure to agree on CO_2 emissions has treated the atmosphere as an open-access resource to be exploited by each country to its own benefit. Understanding the lessons of successful ozone management, and the key differences between reducing ozone and CO_2 emissions, will make action on climate change more likely to succeed.

A key element of the Earth Stewardship challenge is that, historically, social-ecological coupling occurred primarily at local scales, with the environmental consequences of human actions affecting resources and people at that scale. Tight local feedbacks allowed learning to occur and enabled people to adjust behavior so as to modify their impacts and to continue to meet their needs. This cycle of learning and adjustment is the foundation of both long-standing traditional resource management regimes (Dietz et al., 2003; Ostrom, 2009) and recent efforts at adaptive co-management (Armitage et al., 2007; Kofinas, 2009). As human-environment interactions have expanded in scale, many of the key environmental impacts have become more distant or diffuse, making it increasingly difficult for those who cause impacts to perceive, experience, and learn from the consequences of their actions (Moser, 2010). Eutrophication from midwestern U.S. farming, for example, has greater impact on fishermen in the Gulf of Mexico than on the farmers who over-fertilize their crops. Developed nations that emit the most carbon dioxide are often less affected by climate change than are marginal developing-nation economies that are more directly tied to local food harvest. This change in scale of the human enterprise requires careful analysis and conceptualization of the linkages that couple people and nature in world that is increasingly interconnected through a globalized economy, trade networks, and biotic exchanges. In addition to the challenges of distant and diffuse impacts that result from globalization, there are opportunities associated with greater information exchange, visualization, and communication. This leads to a central research question: **What linkages between environment, human perceptions and actions, and institutional dynamics govern the sustainability of society and the biosphere in a globally coupled social-ecological system?** In practical terms, this leads to the following question: **How can society transform a trajectory of environmental degradation and disparity in human well-being to a more sustainable trajectory that provides greater opportunity for present and future generations to meet their needs?**

Designing a proactive science for stewardship

Science for stewardship will be sensitive to traditional ecological knowledge, anticipatory of environmental and social changes, and engaged in dialogue with social actors and institutions. It must be proactive, in the sense of "creating or controlling a situation by causing something to happen rather than responding to it after it has happened".

Proactive Earth stewardship requires a large departure from our past policies and current responses to environmental change. Some (eminent) scientists who deal with real-world environmental problems have commented, ironically, that they feel themselves to be "environmental janitors"--called in to clean up messes after the fact, as best they can. This leads to blind stumbling from crisis to crisis as the environment degrades. This is analogous to a flawed medical care that ignores preventative measures and minor symptoms and allows people to suffer until symptoms are critical, then throws them onto difficult, expensive life support.

If we are to develop a proactive science of stewardship, we must grow the science of stewardship (*sensu lato*) in two fundamental ways. First, we must become better at holistic environmental understanding and prediction. How will social-ecological systems respond to shocks (hurricanes, earthquakes, plagues) or steady, directional changes (e.g. in population densities, resource levels, or environmental conditions)? What elements and processes confer or undermine resilience in particular systems? As these systems change, how can we nimbly adjust or reassess management approaches and focused interventions that seemed beneficial in the past? How can we foster resilience to the inevitable surprises (Schneider et al., 1998; Carpenter et al., 2009)?

As challenging as it will be to grow and improve this understanding and predictive capacity, the second challenge may prove even greater: developing a basis for societal dialogue and decision-making about what elements and processes in particular social-ecological systems need to be protected or managed. These decisions are made not by scientists but by diverse stakeholders, e.g., constituencies who want to maintain current ecosystems and others interested in land conversion (or "restoration"). A proactive science of stewardship, however, could help decision-makers "upscale" predictive knowledge of local social-ecological systems to understand the likely outcomes of alternative local decisions for larger regional, and ultimately global systems. What will be the future of large regions, or the Earth, with this much rangeland or rain forest, or that much agricultural land or urban development, or if this or that energy source fuels endeavors across such systems?

Both sets of issues are grand challenges (ICSU, 2010). There are, however, many sources of knowledge and wisdom on which society can draw (Power and Chapin, 2009). The traditional ecological knowledge community and many environmental researchers share a deep interest in the natural history of organisms and landscapes. This provides an opportunity for sharing understanding of the knowledge and practices that have created a "sense of place" that, together with scientific information and approaches, may inform continued adaptive stewardship during times of rapid change. Similarly, farmers, ranchers, fishers, reserve managers, wilderness advocates, urban community organizers, and religious leaders bring perspectives and understanding (often forged over generations) of how society might protect and benefit from the services that sustainable healthy ecosystems and thriving communities provide. The second challenge of developing broader societal support for alternative stewardship paths will engage local and non-local constituencies. Within the next 20 years, it is projected that 80% of the world's population will be living in cities; as a result, there are critical challenges in maintaining a sense of place and of planetary responsibility in our children – to connect one's neighborhood or city block to the planet (Grove, 2009). This will require mixing local and personal communications with worldwide scales of dialogue, knowledge sharing, innovation, and education. In addition, scientific data on the structure and function of urban areas, including suburbs and the hinterlands affected by urban areas, must increase if decision-making and planning of these growing areas is to have the soundest scientific basis.

A proactive science of stewardship requires that we pool our collective knowledge to understand better how social-ecological dynamics and Earth dynamics are linked, so that we can guide our homelands and our planet to a different, better future. Scientific communication must grow to include the capacity to engage in dialogue involving diverse human values in diverse places.

Engaging key stakeholders

Fostering interdisciplinarity

Interdisciplinary science is promoted by developing common frameworks across disciplines, identifying joint research questions, establishing lasting networks of communication, and often, by exploiting common spatial arenas of research (Pickett et al., 1999). Furthermore, the "habits of mind" that promote synthesis can also support integrative, interdisciplinary research (Pickett, 1999). Although discussion of interdisciplinary research often emphasizes the development of a common language, Bohm (1996) notes that establishment of common meaning is the deeper and more important task. Earth Stewardship provides and requires broad interdisciplinary research, education, and engagement with society to identify and communicate those common meanings.

The science of Earth Stewardship requires interdisciplinary collaboration among many natural and social sciences, including climate, earth, and ocean science, environmental sciences, ecology, psychology, sociology, political science, and anthropology. We must work together to comprehend causal relationships among human behavior, institutional dynamics, and environmental, ecological, and earth-system stability and change. At least three communities must be engaged: 1) earth and biophysical sciences; 2) social and economic sciences; and 3) planning, resource management, and restoration practitioners.

Earth, atmospheric, and ocean sciences have critical knowledge concerning the physical processes of the planetary system. Their scale of research and their contributions to the civil discourse concerning global and regional changes are particularly germane to Earth Stewardship. ESA has initiated a dialogue with earth scientists about the goals and actions required for Earth Stewardship. ESA and the American Geophysical Union, for example, developed joint symposia at annual meetings of the two societies on topics such as coupled biogeochemical cycles, earth-system stewardship, and geo-engineering. Each of these topics requires collaboration among diverse types of ecologists and geophysical scientists. Steve Schneider, to whom this special issue is dedicated, bridged this gap between ecological and geophysical sciences and was a key advocate for interdisciplinary approaches (Schneider et al., 2002). Several of the geophysical sciences have developed summaries of the fundamental principles that connect their science to the functioning of the Earth System. These “literacies” provide the building blocks for the science of Earth Stewardship. Each disciplinary literacy invokes the importance of the scientific process and recognizes interactions with physical, ecological and human dimensions of the Earth as a basis for sustainability of a changing planet (Table 1). The similarity in structure among these literacies should facilitate their integration into a comprehensive earth-stewardship literacy that defines the key principles of Earth as a social-ecological-geophysical system.

The second realm to be addressed is the social and economic sciences. Social sciences bring not only their understanding of human institutions, behavior, and population changes but also a keen understanding of policy and political realities and the nature of the civil dialogue that must be pursued for the sake of Earth Stewardship. A meeting in 2010 between representatives of ESA and some of these disciplines identified several lines of inquiry and activities that different academic societies are independently pursuing but that have potential to contribute to an integrated program in Earth Stewardship. Most organizations have targeted initiatives on climate change and many address the contribution of their discipline to sustainability (Table 2). As with the geophysical sciences, a logical step in collaboration between the natural and social sciences is the organization of interdisciplinary symposia at national meetings, such as those planned by ESA and by the American Association of Geographers in 2011.

Academic societies that represent the individual disciplines could play an important new role in developing the interdisciplinary science needed for Earth Stewardship. Academic societies associated with a discipline (e.g., ESA as a society representing ecologists) have traditionally looked inward to meet the disciplinary needs of their members. In the context of the critical role of interdisciplinarity in defining and implementing Earth Stewardship, these societies could play an important new role by facilitating the communication and collaboration across disciplines needed to meet the broader goals of Earth Stewardship. The Association for Environmental Studies and Sciences, which founded this journal, specifically addresses the intersection among these communities and is therefore particularly well poised to play a leadership role in fostering interdisciplinarity for Earth Stewardship.

Engaging practitioners

Earth Stewardship will require mitigation of damage done, as well as creative planning for the future. Built, designed, and managed systems are becoming the predominant land covers of the Earth (Vitousek et al., 1997; Ellis and Ramankutty, 2008). Hence design in the broadest sense is integral to Earth Stewardship (Palmer et al., 2004). The third realm to be engaged is the design and planning professions, resource managers, and ecological restorationists. Interaction with designers, planners, engineers, and managers presents significant challenges. These professions have a project orientation, and it may be difficult to elicit the underlying theory that can promote connections with ecological research. Furthermore, these professions have different cultures from that of science, in which creativity and novelty, practicality and feasibility play particularly important roles. Open and lasting dialogue will be required to bridge these contrasts. Still, opportunities for interaction exist. For example, any design or plan is a hypothesis that can be tested for its contribution to Earth Stewardship (Felson and Pickett, 2005). This will require not only interaction of designers and developers as projects are prepared, but also measurement of social and ecological consequences in, near, and downstream of the project. Design, broadly conceived, is a crucial link in any framework linking ecosystem services with decision-making (Daily et al., 2009). Indeed, collaboration on design and assessment of projects as an adaptive process (Pickett and Cadenasso, 2008) is an exciting opportunity to promote Earth Stewardship.

During 2011-2012, ESA officers and sections will explore connections with professional societies of landscape ecology, urban and regional planning, policy planning, and ecological restoration. This collaboration will place the insights and recommendations emerging from interaction with the geophysical sciences and with the social sciences into a practical frame. This will promote awareness of Earth Stewardship across the professions that are tasked with envisioning the future and will build bridges based on sound ecological knowledge.

Many people with a hand on the practical levers of policy and action that can advance Earth Stewardship are members of legislative bodies or executive agencies. Their roles include both practical environmental management and the implementation of an ethic of responsibility for planetary life support systems. Stewardship-friendly ideas that practitioners in government can advance include management across traditional departmental divisions rather than management within silos, managing comprehensive social-ecological systems rather than managing separate functions, and institutionalizing adaptive approaches to policy and management (Nelson et al., 2007; Chapin et al., 2010). In so doing, legislators and executive officials have an opportunity to bridge the gap between those focused on science-based environmental policy and others who may be skeptical of science but accepting of a philosophical or religious obligation to care for Earth systems. Further, decision makers and those who craft documents that support decisions already know how to cross disciplinary boundaries. They are routinely compelled to do so by the practical world they inhabit. The National Environmental Policy Act (NEPA) and its implementing regulations, for example, compel federal agencies to analyze the environmental and socioeconomic consequences of major federal actions. A typical environmental impact statement prepared under NEPA may address issues as wide ranging as impacts on threatened and endangered species, geological resources, air quality, employment, and Native American access to traditional cultural resources. Similar breadth can be found in the implementation of laws and regulations relating to the cleanup of hazardous waste sites, protection of air and water quality, and in state laws similar to NEPA, such as those in California and New York.

In parallel with our efforts to reach out to the design and planning professions, ESA officers and staff will seek opportunities to introduce the concept of Earth Stewardship in briefings to federal managers and legislative staff, and will encourage ESA chapters to do so at local governmental levels.

Strategic engagement of the public

Earth Stewardship can be successful in its goal of reorienting the relationship between society and the biosphere only if it engages broad segments of society to develop a new ethic of environmental citizenship. This is most likely to be successful by partnering with individuals, businesses, and governments that are already committed to these goals. ESA has initiated or discussed collaborations with three specific groups that are promising in this regard: (1) communities of faith, (2) businesses, and (3) students. Each of these groups is already engaged in promoting important aspects of stewardship and is receptive to collaboration with the scientific community to jointly foster these common goals.

A meeting in 2010 between ESA and various religious groups concerned about environmental degradation identified Earth Stewardship as a common goal (Table 3). About 75% of Americans associate themselves with some religious group, and about half of the American public attends religious services fairly regularly. These people span a broad spectrum of political opinion and professional activities. Academic professionals can meet the needs of communities of faith by objectively providing information about the scientific basis of Earth Stewardship. Two approaches seem particularly promising: (1) providing scientific materials related to specific issues that are of concern to religious communities (e.g., influence of environmental degradation on poverty) and (2) organization of a speakers' bureau prepared to speak at local or national meetings of religious about the scientific basis of issues related to Earth Stewardship. Speakers for such an effort will require training to communicate effectively in both a scientific and religious context.

Many transnational corporations and other businesses are quite aware of the implications for sustainability of alternative approaches to meeting their business goals. They also recognize the economic implications of environmentally motivated consumer choices. Natural and social scientists can work with interested companies to indentify the ecological and societal implications of alternative business choices for the sustainability of the planet. This represents a fertile arena for collaboration for science-practitioner dialogue and collaboration.

Students are a critical component of society to engage in Earth Stewardship. They not only have the most to gain or lose from the outcome of Earth Stewardship efforts but many students also have the passion to make a difference in shaping Earth's future trajectory. The ESA student section is the society's most rapidly growing section and one of the sections most engaged in developing the Earth Stewardship initiative. The SEEDS (Strategies for Ecology Education, Diversity, and Sustainability) program in ESA has been particularly proactive in *learning* about sustainability and Earth Stewardship through workshops and fieldtrips, *communicating* it through the establishment of 66 campus chapters (as of January 2011), and *implementing* it by organizing local sustainability projects such as BioBlitz, which engages communities in local biodiversity assessments to promote community ecological awareness (http://www.goearthtrek.com/BioBlitz/BioBlitz.html).

Communicating Effectively

Scientists are accustomed to thinking about communication as the *delivery* of scientific information to interested audiences. The questions and issues thus addressed are those important to the scientific community. However, true communication is a dialogue. In addressing Earth Stewardship a dialogue must include scientific information about the functioning of social-ecological systems at various scales, but it must also be sensitive to the concerns of citizens of various demographic and economic groups, the mandates of managers, and the interests of business, for example. Thus, all parties can be seen as stakeholders, and all have a voice in the dialogue that will promote Earth Stewardship. Scientists have a responsibility to respectfully engage in this dialogue, being clear and cogent in sharing their insights, but also welcoming of co-definition of questions and willing to conduct research in the context of design and development. Focusing on real world problems can facilitate building the trust and respect required for this complex dialogue.

Communication strategies designed to catalyze behavior change toward greater Earth Stewardship must address the importance of social norms in guiding behavior. Studies have shown that social normative behavior influences desired behavior change perhaps more than any other factor (Schultz et al., 2007). The social nature of humans presupposes the importance of peer pressure, particularly at the local scale. Moreover, technologies now exist that allow social circles to be scaled well beyond the local (e.g., via internet social-networking sites) and may provide communication platforms that allow social normative behaviors to influence people at much broader scales than is possible through traditional community-based social marketing programs. For example, several recently developed websites designed to inspire greater Earth Stewardship are using social norm messaging to encourage participation at a global scale (e.g. http://www.onehundredmouths.org/, http://www.1010global.org/).

Understanding the psychology of communication about Earth Stewardship is critical to its effectiveness. Abundant negative messages have successfully increased awareness about the dangers of environmental degradation. This negative messaging summons up a host of negative emotions, such as fear, anger, and shame, that trigger the deep evolutionary pathways associated with short-term fight-or-flight responses (Baumeister et al., 2001). The resultant natural avoidance behaviors do little to inspire the integration of long-term solutions into lifestyle choices. On the other hand, stimuli that summon up positive emotions activate thinking and acting that incorporate our creative abilities and allow for coherent long-term strategies to develop (Fredrickson and Branigan, 2005). There are tremendous opportunities to incorporate positive messaging into our communication protocols regarding climate change and other environmental issues, thereby increasing their effectiveness.

Key to the success of any practical efforts to instill Earth Stewardship behaviors within the larger community of society, particularly people living in developed countries, is the explicit communication of the inherent linkage between greater Earth Stewardship and greater well-being. Scientific findings from the psychology community continue to highlight increases in psychopathology related to modernity, particularly depression and anxiety (Seligman, In Press). More importantly, however, scientific findings continue to demonstrate how behaviors consonant with greater care and respect for natural systems can stabilize and improve well-being indicators (Brown and Kasser, 2005).

The promising new discipline of positive psychology, for example, has matured to the point that it is now possible to establish a comprehensive theoretical model, based on hard scientific evidence, effectively elaborating the building blocks on which human flourishing is based (Diener and Biswas-Diener, 2008; Seligman, In Press). Of particular note is the high correlation between an Earth Stewardship orientation and well-being indicators such as positive emotions, community engagement, intimate relationships, meaning, and resilience. Conversely, those values, and associated behaviors, most identified as harmful to ecosystem health (e.g. narcissism, materialism, hyper-individualism) contribute to the erosion of human well-being (Kasser, 2002)).

Perhaps because of the ubiquitous belief that unrestrained economic growth leads to the highest levels of human well-being, dominant communication frameworks (e.g. commercial advertising) perpetuate this belief in spite of the mounting evidence against it. What is sorely needed are comprehensive communication frameworks that clearly inform audiences of the benefits to individual and collective well-being resulting from value frames, identities, and behaviors more aligned with Earth Stewardship. The associated positive messages of these well-being-focused communication frameworks can be integrated into the initiatives of the three stakeholder communities explicitly identified here: (1) earth and biophysical sciences; (2) social and economic sciences; and (3) design, restoration, and planning practitioners. Furthermore, the strategic engagement of the public through communities of faith, businesses, and students must include positive messages that clearly communicate the linkages between Earth Stewardship and human flourishing. Likewise, where appropriate, messages can be elaborated that warn audiences of the psychological dangers of those value orientations and behaviors most dissonant to ecosystem health and sustainability.

Implementing Change

A social movement is needed if Earth Stewardship is to be implemented at a scale required to make a difference for the future relationship between society and the biosphere. However, the role of academic societies in social movements requires careful thought. Science will be most effective if it remains objective and avoids an advocacy role. Collaboration with other groups (e.g., communities of faith, business interests, policy makers) that make a commitment to action may facilitate the provision of action-relevant information within the context of objective science.

Conclusions

We already know enough about the causes of recent planetary change to begin formulating paths towards more sustainable trajectories at local-to-global scales. Such strategies should enhance ecosystem resilience and human well-being but maintain flexibility to learn and adapt to the inevitable surprises. Earth Stewardship provides a strategy for developing a new ethic of environmental citizenship on the part of individuals, businesses, and governments. This must be based on a clear understanding of the consequences, tradeoffs, and opportunities associated with action choices that influence the trajectory of our planet. This, in turn, requires effective communication of issues and opportunities and improved alignment of incentives with those social norms that foster sustainable human behavior.

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Table 1. Sets of literacy principles developed in the natural sciences to represent the fundamental principles that K-12 students should understand about the discipline.

Theme	Earth Literacy [a]	Ocean Literacy [b]	Climate Literacy [c]	Atmospheric Science Literacy [d]
System driver	--	--	Sun	Sun
Internal Interactions	Rock, water air, life	Ocean basin interactions	--	Atmospheric circulation
Time	Age of earth Continual change	--	Natural & human-induced climate variability	Atmospheric change
System interactions				
Physical	Water planet	Ocean shapes earth & weather	Interacts with earth system	Interacts with earth system
Ecological	Interacts with life	Ocean supports life	Interacts with life	Sustains life
Social	Natural hazards Provides resources People affect earth	Ocean and people interact	People impact climate Climate affects people	Atmosphere & people interact
Science processes	Observations to explain	Ocean is unexplored	Observations, theory, modeling	Observations for prediction

[a] http://www.earthscienceliteracy.org/
[b] http://oceanliteracy.wp.coexploration.org/

[c] http://cleanet.org/cln/
[d] http://eo.ucar.edu/asl/

Table 2. Selected initiatives of social-science societies that met with ESA on Nov. 3, 2010 to discuss joint contributions to an initiative in Earth Stewardship

Society	Representative initiatives
Am. Anthropological Assn.	Transnational and global anthropology Anthropology of psychology and of consciousness
Am. Psychological Assn.	Task force on psychology and climate change Environmental psychology section Psychology of social issues section
Assoc. of Am. Geographers	Several climate change initiatives Understanding the changing planet: Strategic directions Sustainable development (My Community, Our Earth) Sustainable urban development
Assn. for Psychological Science	Psychological principles of climate change communication Behavior, energy and climate change
Am. Sociological Assn.	Task force on sociology and global climate change Environment and technology section
Consortium of Soc. Sci. Assns.	Promotes roles for social and behavioral sciences Promotes collaboration with other groups to achieve common goals
Internat. Soc. Ecol. Economics	Ecologically and economically sustainable future Integration of economic, social and ecological systems
Resources for the Future	Energy and climate Health and the environment

	Regulating risks
Ecological Soc. Am	Earth Stewardship Initiative Sustainable Biosphere Initiative SEEDS (education, diversity, and sustainability)

Table 3. Selected recommendations for action by environmentally oriented religious groups that met with ESA on Nov. 3, 2010 to discuss collaborations for an initiative in Earth Stewardship. This list also includes groups that participated in follow-up discussions.

Group	Suggestions for action
Catholic Coalition on Climate Change	Provide good intelligible information on science
	Focus on collective health and well-being
Coalition on the Environment and Jewish Life	Increase energy efficiency and security
	Addressing environmental issues and human welfare
Evangelical Environment Network	ESA members of faith as ambassadors to their religious communities
	Coach speakers in communicating with communities of faith
Interfaith Power and Light	Collaborate with ESA in developing a speakers' bureau
	Provide credentialed sources of information
National Religious Partnership for the Environ.	Collaborate in testimony before congress
	Open letter from scientists and religious leaders
Religious Action Center of Reform Judaism	Tight linkage of environmental with faith issues
	Clergy as bridge between scientists and the religious community
Society of Conservation Biology	Recycling
	Focus discussions on common concerns of stewardship
United Methodist Church	Focus on human aspects of environmental degradation
	Bring science to seminary training
Yale Forum on Religion and the Environment	Earth Charter to provide a common voice for all religions