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Carpenter is taking a leadership role in designing the global grand challenges for international science planning and was a key player in the Millennium Ecosystem Assessment, which was probably the best practical science effort in Earth Stewardship

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## **Earth Stewardship: A Strategy for Social-Ecological Transformation to Reverse Planetary Degradation**

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## Abstract

A century ago, stewards were responsible for managing estates or for keeping order at public events. Today, the Earth is one global estate, and improved stewardship is vital for maintaining social order and for preserving life on Earth. In this paper, we describe Earth Stewardship, a social-ecological framework for sustaining life in a rapidly changing world. The paper defines the components of Earth Stewardship, characterizes the scientific needs for its agenda, and discusses initial efforts to engage multiple disciplines and segments of society in its application. As a beginning, new knowledge for global stewardship must be generated by teams of physical, biological, and social scientists. However, other stakeholders are needed for generating and applying such knowledge, including people in communities of faith, professions involved in design, planning and restoration, and policy makers and managers. Communicating environmental problems and solutions must take into account the psychology of how people perceive problems, promoting positive stances toward the actions needed for an adaptive approach to Earth Stewardship. Successful long-term stewardship of the Earth will require a global partnership linking researchers, managers, policy makers, and citizens.

## 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

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4 reduce the rates of change and degradation, for fear of the economic costs. Aggressive actions  
5 that are taken now, however, are likely to be much less costly than the costs of failing to act  
6 (Stern, 2007; NRC, 2010). Institutional inertia and cultural habits are additional impediments to  
7 action.  
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9 Given the pace of environmental deterioration and the increased recognition that this path  
10 is untenable, society should seize the opportunity to reorient its relationship to the biosphere. In  
11 this article we outline Earth Stewardship as one approach to achieve this goal. We describe the  
12 strategy that has been initiated by the Ecological Society of America (ESA) in collaboration with  
13 many other disciplines and segments of society.  
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## 15 **Defining Earth Stewardship as an Approach for Action**

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19 *Earth Stewardship is the active shaping of trajectories of change in coupled social-ecological*  
20 *systems at local-to-global scales to enhance ecosystem resilience and promote human well-*  
21 *being.* The concept of Earth Stewardship is rooted in religious thought (Conradie, 2006; Kearns  
22 and Keller, 2007) and is similar to the principles underlying U.S. environmental policy<sup>1</sup>,  
23 sustainable development in developing nations (WCED, 1987; UN, 2010), and the emerging  
24 science of ecosystem management (Szaro et al., 1999; Chapin et al., 2009). The concept of  
25 stewardship is familiar to the general public and has essentially the same meaning in lay terms as  
26 we intend in its scientific usage. Its goals are thus widely accepted by scientists, policy makers,  
27 and society, although their application often raises contentious issues regarding tradeoffs (Clark  
28 and Levin, 2010).  
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31 In 1991 ESA launched the Sustainable Biosphere Initiative (SBI) to “define the role of  
32 ecological science in the wise management of Earth’s resources and the management of Earth’s  
33 life support system” (Lubchenco et al., 1991). The SBI identified three research priorities  
34 requiring particular attention in addressing global environmental problems: global change,  
35 biodiversity loss, and sustainable ecological systems. An important contribution of the SBI was  
36 the recognition of tight coupling between human activities and ecological processes on an  
37 increasingly human-dominated planet, although its emphasis was on the application of ecological  
38 science to address these issues. The SBI was one of several threads leading to the development  
39 of sustainability science (NRC, 1999; Kates et al., 2001; Clark and Dickson, 2003; Matson,  
40 2009), whose goal is to “promote human well-being while conserving the life support systems of  
41 the planet” (Clark and Levin, 2010). Sustainability science recognizes the coupling of human and  
42 natural systems at multiple scales (Berkes et al., 2003; Turner et al., 2003).  
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46 Earth Stewardship is an action-oriented initiative that uses the principles of sustainability  
47 science to shape societal and environmental pathways. The U.N. Millenium Development goals  
48 are one example of such a pathway for “living in a world where environmental sustainability is a  
49 priority, and women and men live in equality...with freedom from extreme poverty and hunger”  
50 (UN, 2010). Examples of the application of science to promote Earth Stewardship include (1)  
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54 <sup>1</sup> U.S. National Environmental Policy Act of 1969: The purpose of the act is “to  
55 declare a national policy which will encourage productive and enjoyable harmony  
56 between man and his environment; to promote efforts which will prevent or  
57 eliminate damage to the environment and biosphere and stimulate the health and  
58 welfare of man; to enrich the understanding of the ecological systems and natural  
59 resources important to the Nation...”  
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4 understanding the causes of polar ozone holes and reducing the production of ozone-destroying  
5 chemicals that caused them (global scale) (Graedel and Crutzen, 1995); (2) transforming  
6 management of the Great Barrier Reef in Australia to protect marine biodiversity and livelihoods  
7 (regional scale) (Olsson et al., 2008); and (3) minimizing the impacts of climate change in New  
8 York City through assessment, mitigation, and adaptation (local scale)  
9 (<http://www.nyc.gov/html/planyc2030/html/plan/plan.shtml>).

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

### 22 *Planetary interactions, feedbacks, and thresholds*

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

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37 The idea of a global commons is a powerful one. A commons is a type of property regime, i.e.,  
38 an institutional arrangement for managing shared resources. A community manages a commons  
39 to secure resources and other environmental benefits. This approach contrasts with an open-  
40 access property regime, in which there is in effect no shared management. Users simply take  
41 what they wish from the area in question. It was in fact an open-access property regime property  
42 regime that Garrett Hardin (1968) described in “Tragedy of the Commons.” A true commons  
43 characterized by effective management by an informed and interactive community should avoid  
44 tragedy. It is this ideal that forms part of the foundation of Earth Stewardship. International  
45 agreement to stop producing ozone-destroying chlorofluorocarbons has led to the successful  
46 management of the atmosphere as a commons, whereas failure to agree on CO<sub>2</sub> emissions has  
47 treated the atmosphere as an open-access resource to be exploited by each country to its own  
48 benefit. Understanding the lessons of successful ozone management, and the key differences  
49 between reducing ozone and CO<sub>2</sub> emissions, will make action on climate change more likely to  
50 succeed.  
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54 A key element of the Earth Stewardship challenge is that, historically, social-ecological  
55 coupling occurred primarily at local scales, with the environmental consequences of human  
56 actions affecting resources and people at that scale. Tight local feedbacks allowed learning to  
57 occur and enabled people to adjust behavior so as to modify their impacts and to continue to  
58 meet their needs. This cycle of learning and adjustment is the foundation of both long-standing  
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4 traditional resource management regimes (Dietz et al., 2003; Ostrom, 2009) and recent efforts at  
5 adaptive co-management (Armitage et al., 2007; Kofinas, 2009). As human-environment  
6 interactions have expanded in scale, many of the key environmental impacts have become more  
7 distant or diffuse, making it increasingly difficult for those who cause impacts to perceive,  
8 experience, and learn from the consequences of their actions (Moser, 2010). Eutrophication from  
9 midwestern U.S. farming, for example, has greater impact on fishermen in the Gulf of Mexico  
10 than on the farmers who over-fertilize their crops. Developed nations that emit the most carbon  
11 dioxide are often less affected by climate change than are marginal developing-nation economies  
12 that are more directly tied to local food harvest. This change in scale of the human enterprise  
13 requires careful analysis and conceptualization of the linkages that couple people and nature in  
14 world that is increasingly interconnected through a globalized economy, trade networks, and  
15 biotic exchanges. In addition to the challenges of distant and diffuse impacts that result from  
16 globalization, there are opportunities associated with greater information exchange, visualization,  
17 and communication. This leads to a central research question: **What linkages between**  
18 **environment, human perceptions and actions, and institutional dynamics govern the**  
19 **sustainability of society and the biosphere in a globally coupled social-ecological system?** In  
20 practical terms, this leads to the following question: **How can society transform a trajectory of**  
21 **environmental degradation and disparity in human well-being to a more sustainable**  
22 **trajectory that provides greater opportunity for present and future generations to meet**  
23 **their needs?**  
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### 29 *Designing a proactive science for stewardship*

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

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

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45 If we are to develop a proactive science of stewardship, we must grow the science of  
46 stewardship (*sensu lato*) in two fundamental ways. First, we must become better at holistic  
47 environmental understanding and prediction. How will social-ecological systems respond to  
48 shocks (hurricanes, earthquakes, plagues) or steady, directional changes (e.g. in population  
49 densities, resource levels, or environmental conditions)? What elements and processes confer or  
50 undermine resilience in particular systems? As these systems change, how can we nimbly adjust  
51 or reassess management approaches and focused interventions that seemed beneficial in the past?  
52 How can we foster resilience to the inevitable surprises (Schneider et al., 1998; Carpenter et al.,  
53 2009)?

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55 As challenging as it will be to grow and improve this understanding and predictive  
56 capacity, the second challenge may prove even greater: developing a basis for societal dialogue  
57 and decision-making about what elements and processes in particular social-ecological systems  
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4 need to be protected or managed. These decisions are made not by scientists but by diverse  
5 stakeholders, e.g., constituencies who want to maintain current ecosystems and others interested  
6 in land conversion (or “restoration”). A proactive science of stewardship, however, could help  
7 decision-makers “upscale” predictive knowledge of local social-ecological systems to understand  
8 the likely outcomes of alternative local decisions for larger regional, and ultimately global  
9 systems. What will be the future of large regions, or the Earth, with this much rangeland or rain  
10 forest, or that much agricultural land or urban development, or if this or that energy source fuels  
11 endeavors across such systems?  
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14 Both sets of issues are grand challenges (ICSU, 2010). There are, however, many sources  
15 of knowledge and wisdom on which society can draw (Power and Chapin, 2009). The traditional  
16 ecological knowledge community and many environmental researchers share a deep interest in  
17 the natural history of organisms and landscapes. This provides an opportunity for sharing  
18 understanding of the knowledge and practices that have created a “sense of place” that, together  
19 with scientific information and approaches, may inform continued adaptive stewardship during  
20 times of rapid change. Similarly, farmers, ranchers, fishers, reserve managers, wilderness  
21 advocates, urban community organizers, and religious leaders bring perspectives and  
22 understanding (often forged over generations) of how society might protect and benefit from the  
23 services that sustainable healthy ecosystems and thriving communities provide. The second  
24 challenge of developing broader societal support for alternative stewardship paths will engage  
25 local and non-local constituencies. Within the next 20 years, it is projected that 80% of the  
26 world’s population will be living in cities; as a result, there are critical challenges in maintaining  
27 a sense of place and of planetary responsibility in our children – to connect one’s neighborhood  
28 or city block to the planet (Grove, 2009). This will require mixing local and personal  
29 communications with worldwide scales of dialogue, knowledge sharing, innovation, and  
30 education. In addition, scientific data on the structure and function of urban areas, including  
31 suburbs and the hinterlands affected by urban areas, must increase if decision-making and  
32 planning of these growing areas is to have the soundest scientific basis.  
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37 A proactive science of stewardship requires that we pool our collective knowledge to  
38 understand better how social-ecological dynamics and Earth dynamics are linked, so that we can  
39 guide our homelands and our planet to a different, better future. Scientific communication must  
40 grow to include the capacity to engage in dialogue involving diverse human values in diverse  
41 places.  
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## 44 **Engaging key stakeholders**

### 45 *Fostering interdisciplinarity*

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49 Interdisciplinary science is promoted by developing common frameworks across disciplines,  
50 identifying joint research questions, establishing lasting networks of communication, and often,  
51 by exploiting common spatial arenas of research (Pickett et al., 1999). Furthermore, the “habits  
52 of mind” that promote synthesis can also support integrative, interdisciplinary research (Pickett,  
53 1999). Although discussion of interdisciplinary research often emphasizes the development of a  
54 common language, Bohm (1996) notes that establishment of common meaning is the deeper and  
55 more important task. Earth Stewardship provides and requires broad interdisciplinary research,  
56 education, and engagement with society to identify and communicate those common meanings.  
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4 The science of Earth Stewardship requires interdisciplinary collaboration among many  
5 natural and social sciences, including climate, earth, and ocean science, environmental sciences,  
6 ecology, psychology, sociology, political science, and anthropology. We must work together to  
7 comprehend causal relationships among human behavior, institutional dynamics, and  
8 environmental, ecological, and earth-system stability and change. At least three communities  
9 must be engaged: 1) earth and biophysical sciences; 2) social and economic sciences; and 3)  
10 planning, resource management, and restoration practitioners.  
11

12 Earth, atmospheric, and ocean sciences have critical knowledge concerning the physical  
13 processes of the planetary system. Their scale of research and their contributions to the civil  
14 discourse concerning global and regional changes are particularly germane to Earth Stewardship.  
15 ESA has initiated a dialogue with earth scientists about the goals and actions required for Earth  
16 Stewardship. ESA and the American Geophysical Union, for example, developed joint symposia  
17 at annual meetings of the two societies on topics such as coupled biogeochemical cycles, earth-  
18 system stewardship, and geo-engineering. Each of these topics requires collaboration among  
19 diverse types of ecologists and geophysical scientists. Steve Schneider, to whom this special  
20 issue is dedicated, bridged this gap between ecological and geophysical sciences and was a key  
21 advocate for interdisciplinary approaches (Schneider et al., 2002). Several of the geophysical  
22 sciences have developed summaries of the fundamental principles that connect their science to  
23 the functioning of the Earth System. These “literacies” provide the building blocks for the  
24 science of Earth Stewardship. Each disciplinary literacy invokes the importance of the scientific  
25 process and recognizes interactions with physical, ecological and human dimensions of the Earth  
26 as a basis for sustainability of a changing planet (Table 1). The similarity in structure among  
27 these literacies should facilitate their integration into a comprehensive earth-stewardship literacy  
28 that defines the key principles of Earth as a social-ecological-geophysical system.  
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30 The second realm to be addressed is the social and economic sciences. Social sciences  
31 bring not only their understanding of human institutions, behavior, and population changes but  
32 also a keen understanding of policy and political realities and the nature of the civil dialogue that  
33 must be pursued for the sake of Earth Stewardship. A meeting in 2010 between representatives  
34 of ESA and some of these disciplines identified several lines of inquiry and activities that  
35 different academic societies are independently pursuing but that have potential to contribute to  
36 an integrated program in Earth Stewardship. Most organizations have targeted initiatives on  
37 climate change and many address the contribution of their discipline to sustainability (Table 2).  
38 As with the geophysical sciences, a logical step in collaboration between the natural and social  
39 sciences is the organization of interdisciplinary symposia at national meetings, such as those  
40 planned by ESA and by the American Association of Geographers in 2011.  
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42 Academic societies that represent the individual disciplines could play an important new  
43 role in developing the interdisciplinary science needed for Earth Stewardship. Academic  
44 societies associated with a discipline (e.g., ESA as a society representing ecologists) have  
45 traditionally looked inward to meet the disciplinary needs of their members. In the context of the  
46 critical role of interdisciplinarity in defining and implementing Earth Stewardship, these societies  
47 could play an important new role by facilitating the communication and collaboration across  
48 disciplines needed to meet the broader goals of Earth Stewardship. The Association for  
49 Environmental Studies and Sciences, which founded this journal, specifically addresses the  
50 intersection among these communities and is therefore particularly well poised to play a  
51 leadership role in fostering interdisciplinarity for Earth Stewardship.  
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4 *Engaging practitioners*  
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7 Earth Stewardship will require mitigation of damage done, as well as creative planning for the  
8 future. Built, designed, and managed systems are becoming the predominant land covers of the  
9 Earth (Vitousek et al., 1997; Ellis and Ramankutty, 2008). Hence design in the broadest sense is  
10 integral to Earth Stewardship (Palmer et al., 2004). The third realm to be engaged is the design  
11 and planning professions, resource managers, and ecological restorationists. Interaction with  
12 designers, planners, engineers, and managers presents significant challenges. These professions  
13 have a project orientation, and it may be difficult to elicit the underlying theory that can promote  
14 connections with ecological research. Furthermore, these professions have different cultures  
15 from that of science, in which creativity and novelty, practicality and feasibility play particularly  
16 important roles. Open and lasting dialogue will be required to bridge these contrasts. Still,  
17 opportunities for interaction exist. For example, any design or plan is a hypothesis that can be  
18 tested for its contribution to Earth Stewardship (Felson and Pickett, 2005). This will require not  
19 only interaction of designers and developers as projects are prepared, but also measurement of  
20 social and ecological consequences in, near, and downstream of the project. Design, broadly  
21 conceived, is a crucial link in any framework linking ecosystem services with decision-making  
22 (Daily et al., 2009). Indeed, collaboration on design and assessment of projects as an adaptive  
23 process (Pickett and Cadenasso, 2008) is an exciting opportunity to promote Earth Stewardship.  
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26 During 2011-2012, ESA officers and sections will explore connections with professional  
27 societies of landscape ecology, urban and regional planning, policy planning, and ecological  
28 restoration. This collaboration will place the insights and recommendations emerging from  
29 interaction with the geophysical sciences and with the social sciences into a practical frame. This  
30 will promote awareness of Earth Stewardship across the professions that are tasked with  
31 envisioning the future and will build bridges based on sound ecological knowledge.  
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34 Many people with a hand on the practical levers of policy and action that can advance  
35 Earth Stewardship are members of legislative bodies or executive agencies. Their roles include  
36 both practical environmental management and the implementation of an ethic of responsibility  
37 for planetary life support systems. Stewardship-friendly ideas that practitioners in government  
38 can advance include management across traditional departmental divisions rather than  
39 management within silos, managing comprehensive social-ecological systems rather than  
40 managing separate functions, and institutionalizing adaptive approaches to policy and  
41 management (Nelson et al., 2007; Chapin et al., 2010). In so doing, legislators and executive  
42 officials have an opportunity to bridge the gap between those focused on science-based  
43 environmental policy and others who may be skeptical of science but accepting of a  
44 philosophical or religious obligation to care for Earth systems. Further, decision makers and  
45 those who craft documents that support decisions already know how to cross disciplinary  
46 boundaries. They are routinely compelled to do so by the practical world they inhabit. The  
47 National Environmental Policy Act (NEPA) and its implementing regulations, for example,  
48 compel federal agencies to analyze the environmental and socioeconomic consequences of major  
49 federal actions. A typical environmental impact statement prepared under NEPA may address  
50 issues as wide ranging as impacts on threatened and endangered species, geological resources,  
51 air quality, employment, and Native American access to traditional cultural resources. Similar  
52 breadth can be found in the implementation of laws and regulations relating to the cleanup of  
53 hazardous waste sites, protection of air and water quality, and in state laws similar to NEPA,  
54 such as those in California and New York.  
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4 In parallel with our efforts to reach out to the design and planning professions, ESA  
5 officers and staff will seek opportunities to introduce the concept of Earth Stewardship in  
6 briefings to federal managers and legislative staff, and will encourage ESA chapters to do so at  
7 local governmental levels.  
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### 10 *Strategic engagement of the public*

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12 Earth Stewardship can be successful in its goal of reorienting the relationship between society  
13 and the biosphere only if it engages broad segments of society to develop a new ethic of  
14 environmental citizenship. This is most likely to be successful by partnering with individuals,  
15 businesses, and governments that are already committed to these goals. ESA has initiated or  
16 discussed collaborations with three specific groups that are promising in this regard: (1)  
17 communities of faith, (2) businesses, and (3) students. Each of these groups is already engaged in  
18 promoting important aspects of stewardship and is receptive to collaboration with the scientific  
19 community to jointly foster these common goals.  
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22 A meeting in 2010 between ESA and various religious groups concerned about  
23 environmental degradation identified Earth Stewardship as a common goal (Table 3). About 75%  
24 of Americans associate themselves with some religious group, and about half of the American  
25 public attends religious services fairly regularly. These people span a broad spectrum of political  
26 opinion and professional activities. Academic professionals can meet the needs of communities  
27 of faith by objectively providing information about the scientific basis of Earth Stewardship.  
28 Two approaches seem particularly promising: (1) providing scientific materials related to  
29 specific issues that are of concern to religious communities (e.g., influence of environmental  
30 degradation on poverty) and (2) organization of a speakers' bureau prepared to speak at local or  
31 national meetings of religious about the scientific basis of issues related to Earth Stewardship.  
32 Speakers for such an effort will require training to communicate effectively in both a scientific  
33 and religious context.  
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36 Many transnational corporations and other businesses are quite aware of the implications  
37 for sustainability of alternative approaches to meeting their business goals. They also recognize  
38 the economic implications of environmentally motivated consumer choices. Natural and social  
39 scientists can work with interested companies to indentify the ecological and societal  
40 implications of alternative business choices for the sustainability of the planet. This represents a  
41 fertile arena for collaboration for science-practitioner dialogue and collaboration.  
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44 Students are a critical component of society to engage in Earth Stewardship. They not  
45 only have the most to gain or lose from the outcome of Earth Stewardship efforts but many  
46 students also have the passion to make a difference in shaping Earth's future trajectory. The ESA  
47 student section is the society's most rapidly growing section and one of the sections most  
48 engaged in developing the Earth Stewardship initiative. The SEEDS (Strategies for Ecology  
49 Education, Diversity, and Sustainability) program in ESA has been particularly proactive in  
50 *learning* about sustainability and Earth Stewardship through workshops and fieldtrips,  
51 *communicating* it through the establishment of 66 campus chapters (as of January 2011), and  
52 *implementing* it by organizing local sustainability projects such as BioBlitz, which engages  
53 communities in local biodiversity assessments to promote community ecological awareness  
54 (<http://www.goearthtrek.com/BioBlitz/BioBlitz.html>).  
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### 59 **Communicating Effectively**

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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

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4 based (Diener and Biswas-Diener, 2008; Seligman, In Press). Of particular note is the high  
5 correlation between an Earth Stewardship orientation and well-being indicators such as positive  
6 emotions, community engagement, intimate relationships, meaning, and resilience. Conversely,  
7 those values, and associated behaviors, most identified as harmful to ecosystem health (e.g.  
8 narcissism, materialism, hyper-individualism) contribute to the erosion of human well-being  
9 (Kasser, 2002)).

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

## 25 26 27 28 29 30 **Implementing Change**

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

## 39 40 41 **Conclusions**

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

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55 **Acknowledgments.** We thank representatives of the multiple academic disciplines and citizen  
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57 appreciate the vision and courage of Steve Schneider who spoke so forcefully about the need for  
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4 such an initiative and the Association for Environmental Studies and Sciences for providing a  
5 venue to explore these ideas.  
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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 <sup>a</sup>	Ocean Literacy <sup>b</sup>	Climate Literacy <sup>c</sup>	Atmospheric Science Literacy <sup>d</sup>
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 people interact	Atmosphere & people interact Climate affects people
Science processes	Observations to explain	Ocean is unexplored	Observations, theory, modeling	Observations for prediction

<sup>a</sup> <http://www.earthscienceliteracy.org/>

<sup>b</sup> <http://oceanliteracy.wp.coexploration.org/>

<sup>c</sup> <http://cleanet.org/cln/>

<sup>d</sup> <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

Ecological Soc. Am

Regulating risks

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
Evangelical Environment Network	Addressing environmental issues and human welfare 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