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FEATURE ARTICLE

Promoting a coupled human and natural systems approach to addressing conservation in complex mountainous landscapes of Central Asia

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Abstract Global climate change, nonpoint source pollution, watershed and wildlife habitat destruction, and unsustainable development are damaging the natural world, threatening the socio-cultural integrity of communities, and jeopardizing the livelihood security of peoples worldwide. Despite the past 50 years of progress in addressing environmental damage in the United States and elsewhere, intractable problems have arisen that to date have eluded successful technological or policy responses. Solutions have been sought by recognizing that these problems are very complex and demand interdisciplinary approaches that require building effective partnerships among relevant academic institutions, governmental agencies, nongovernmental organizations, and private business, as well as levering various disciplines and traditional knowledge systems. Such thinking has evolved to now consider humans to be an integral part of nature, which is captured in the idea of the 'human ecosystem' , where biophysical, socioeconomic, and cultural systems interact via a complex set of organizational, spatial, and temporal 'couplings'. Within such a context, environmental problems can be viewed as coupled human and natural systems, which afford unique and novel approaches to their solutions. This paper discusses the development of the coupled systems approach as a scientific methodology, reviews its key characteristics and principles, provides an example of how it has been applied to assess conservation issues in alpine areas of Northwest Yunnan Province, China, and recommends how this scientific approach might be further developed for use in mountainous landscape regions of Central Asia and elsewhere.

Keywords coupled systems, alpine ecosystems, Central Asia

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1 Introduction

Academe, nongovernmental organizations, and government agencies have long acknowledged that sound policy formulations and management decisions about the environment and natural resources necessitate effective collaboration among social and biophysical scientists and management practitioners, as well as a better understanding of the influence of differing scales of biological organization. Although numerous examples of effective collaborations at small scales exist (e.g., populations and communities), efforts to address complex, environmental issues at the local, national, and global levels, such as climate and social change, biodiversity loss, rural poverty, and watershed management, have proven to be much more challenging (Shellenberger and Nordhaus, 2007). Often falling under the reorganizing principle of sustainable development, it is now widely understood that this situation must change and that human processes must be considered as integral components of natural systems (Machlis et al., 1997; Folke et al., 2002; Berkes et al., 2003; Young et al., 2006; Liu et al., 2007a, c; Chapin et al., 2009).

Mountainous regions represent critical intersections where human and natural forces interact to determine the fate of biodiversity and environmental integrity and the quality of life for those who seek viable livelihoods in such locations (Messerli and Ives, 1997). Climatic extremes characterizing high elevations pose a difficult context for human survival, especially when faced with the unpredictable effects of climate change. In addition, globalization is rapidly finding its way into remote areas worldwide often upsetting cultural norms and socioeconomic systems that have been in place for centuries. Hence, research institutions, development organizations, and government agencies are seeking sustainable solutions to resolving conservation and development conflicts in mountainous landscapes across the planet.

The vast expanse of Central Asia is characterized by the highest mountain landscapes and some of the largest river basins on Earth. Best defined by the region served by the International Centre for Integrated Mountain Development[1], it includes the Hindu Kush-Himalayas, Karakoram, and Pamirs and extends 3500 km across eight countries (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan). This mountain system is the source of ten large river systems (Amu Darya, Indus, Ganges, Brahmaputra [Yarlungtsanpo], Irrawaddy, Salween [Nu], Mekong [Lancang], Yangtse [Jinsha]), Yellow River, and Tarim [Dayan]) that provide water, ecosystem services, livelihoods for a population of over 210 million people in the region, and water for about 1.3 billion people across Central Asia.

This paper argues that a new approach is needed for addressing environmental issues in complex mountainous landscapes of Central Asia, especially in the face of climatic and socioeconomic changes that are progressing rapidly across the region. Such an approach must transcend traditional interdisciplinary thinking and consider elements of scale and the close couplings of human and natural systems. Humans and their biological, physical, socioeconomic, and cultural systems must be seen as functional components of ecosystems and the biosphere. In turn, nature's processes must be understood as they control human systems as well as how they are impacted by human activity. These ideas are best captured by current thinking coming from the United States with respect to a better understanding of Coupled Human and Natural Systems (CHANS) (McPeak et al., 2006; Liu et al., 2007a; Walsh and McGinnis, 2007).

In pursuing this argument, we will first trace the evolution of CHANS as a scientific approach to addressing environmental issues in the United States. This will be followed by two examples illustrating the importance of the CHANS approach and then by a detailed case where it has been applied to address conservation issues in alpine areas of Northwest Yunnan, China. Last, we will recommend that interdisciplinary research teams collaborate more closely together and with governmental agencies and nongovernmental organizations to seek sustainable solutions to the complex environmental and social issues facing communities in mountainous areas of Central Asia and elsewhere.

2 Historical perspective from the United States

The United States is widely acknowledged for pioneering nature conservation and environmental protection (Schlosberg and Dryzek, 2002). For example, Yellowstone National Park, established by an act of the U.S. Congress in 1872, was the world's first nationally authorized park set aside for public enjoyment and the protection of nature, and the decade beginning in the mid-1960s marked the passing of landmark federal legislation oriented to addressing the nation's environmental problems. Quite clearly, these monumental actions by the U.S. Government represented an evolution in national policies in response to public demands to correct past environmental transgressions rather than an ecological epiphany arising from Washington, D C. The fact that the United States has just recently agreed to address global warming in a significant manner[2] reinforces the cyclical and sometimes recalcitrant nature of environmental politics. In addition, the evolution of environmental policies also reflects how science has evolved to enhance our understanding of the complexity of the natural world. Since the concept of Coupled Human and Natural Systems arose from such a context, a brief historical perspective of environmental conservation and the science that supported it is warranted.

North America has a rich history of human habitation possibly dating back 14000 years (Gilbert et al., 2008). Native Americans not only used natural resources (Cronon, 1983) but also likely manipulated their environment primarily through the use of fire (Patterson and Sassaman, 1988) and agriculture (Lewandowski, 1987). However, First Contact by European settlers in the late 15th Century initiated a chain of events leading to the social, cultural, economic, and environmental fabric that characterizes the United States today (Whitney, 1996). Environmentally, this 500-year period can be delineated into five periods marked by an evolving understanding of the complexity of the natural world relative to the expanding socioeconomic stature of the United States.

The Pioneer Period defines the two centuries following the First Contact, where European settlers first eked out a subsistence life style likely similar to their Native American neighbors but under a land-use system stressing permanency and ownership (Cronon, 1983). A Colonial America slowly took form across the northeastern seaboard, as natural resources, such as timber and wildlife, were exploited to develop agriculturally based communities and export valuable resources back to England. Political and economic independence from England following the Revolutionary War (1776) saw the establishment a 'United States' of America based on the original 13 colonies. A scientific understanding of the natural world during this period likely involved what is now termed 'traditional knowledge,' where understanding evolved through practice and qualitative observations (Kuzmiak, 1991). More systematically applied, this approach informed the study of natural history focused on identifying, classifying, and collecting plants and animals unique

1) http://www.icimod.org
2) http://www.state.gov/g/oes/climate/, http://www.epa.gov/climatechange/policy/index.html

to the New World, often to assess their potential utilitarian uses (Bartholomew, 1986).

Systematic and comprehensive nature studies expanded greatly during the Exploitation Period that characterized the 1800s (Kuzmiak, 1991). This century in U.S. history was marked by a rapid expansion of settlements westward, often at the expense of Native American sovereignty and survival (Thornton, 1990), which was driven by increased efficiencies at converting land to agriculture, harvesting timber, killing wildlife, and mining minerals (Whitney, 1996).

Roots for the Conservation Period began during the latter part of the 19th Century as key voices for the natural world began issuing warnings that natural resources were not limitless and that vast portions of the developing country should be protected from human exploitation (Kuzmiak, 1991). As mentioned earlier, the world's first national park, Yellowstone, was established in 1872, which was followed by three more in California in 1890 and another in Washington nine years later. The Division of Forestry was established in 1881 in the U.S. Department of Agriculture to oversee the nation's federally owned forestlands. The establishment of major nongovernmental conservation organization, such as the American Forestry Association in 1875 and the Sierra Club in 1892 illustrated growing public concern over the plight of the nation's dwindling natural resource base. Our understanding of the natural world also was being influenced by the newly emerging science of ecology that tightly linked biological organisms to the environment (Odum, 1977). The nation's first college dedicated to 'scientific forestry' was established in 1898 at the Cornell University campus in Ithaca, New York (Lassoie et al., 1998).

Ecologically oriented forestry programs expanded rapidly across the United States during the early 20th Century as the need for maintaining a sustained yield of forest products became evident (Hays, 2006). The Division of Forestry was elevated administratively to the U.S. Forest Service in 1905 to help bring such knowledge to the nation's forestlands. Similarly, the National Park Service was established 1917 as a separate bureau in the U.S. Department of the Interior to coordinate the nation's protected areas. Federal agencies and professional academic programs focused on the nation's fish and wildlife resources saw similar development and expansion during the first half of the 20th Century. In all cases, however, biological resources were studied and managed as distinct populations typically for enhancing their utilitarian values, and our understanding of these resources was deeply formulated through the disciplinary-based sciences, often leading to their over-exploitation (Ludwig et al., 1993; Slocombe, 1993). The discipline of ecology, however, was beginning to provide a systems' context for connecting organisms and their environment (Odum, 1953, 1977; Hagen, 1992).

The conservation of biological resources including their sustainable use and protection remains a national priority, but by the mid-1950s, there were growing concerns about the pollution of our planet, which ushered in the Environmental Period in the United States. Rachel Carson's book, A *Silent Spring* first published in 1963 is often touted as a landmark in public environmental consciousness, which eventually lead to expansive legislation focused on protecting the nation's waters, air, and land from toxic substances, including the establishment of the U.S. Environmental Protection Agency in 1970 (Kuzmiak, 1991). The nation first celebrated the environment with Earth Day One on April 22, 1970.

Building on the pioneering work of E. P. Odum in systems ecology during the 1950s (e.g., Odum, 1953), the International Biological Program (1964–1974) brought multinational attention to the biomes of the world to better understand their functioning and how humans influence them (Worthington, 1975; Hagen, 1992). Specifically, the U.S. program focused on the following: 1) investigating the nation's ecological problems with a new approach involving multidisciplinary teams of scientists coordinating their efforts to learn how total ecosystems, including humans, were interrelated, and 2) understanding and predicting natural and human-caused impacts on biological processes to better manage natural resources in five ecosystems that characterized the country (grassland, desert, deciduous, coniferous, and tundra). This decade established the ecological sub-discipline of ecosystem ecology defined by models of mass and energy flows of complex ecological systems (Blair, 1977; Hagen, 1992). This integrated scientific approach demand interdisciplinary collaboration and provided a means for quantitatively assessing the impacts of human and natural perturbations of ecosystem functions (e.g., Brown et al., 1980; Risser et al., 1981; and Edmonds, 1982).

Unfortunately, the approach to environmental problem solving established during the past 50 years is not yielding quick answers to the complex problems of the 21st Century (Shellenberger and Nordhaus, 2007). The forces promoting global climate change, deforestation, biodiversity loss, and nonpoint pollution simply do not lend themselves simple solutions. The two past decades have established the Sustainability Period where environmental conservation issues must be examined from an inter-related perspective involving environmental (ecological), social (cultural), and economic (livelihoods) components (Daly, 1990; Costanza, 1991; Brebbia and Tiezzi, 2009). The systems approach to understanding these problems and seeking their solutions is still viable, but human socio-economic systems must be integrated tightly into ecosystem functioning as the two are now seen as being inseparably linked and interdependent. Such issues not only demand collaborative work among social and biophysical scientists but also must involve the meaningful involvement of practitioners (e.g., farmers, herders, villagers, etc.), governmental agencies, the

nongovernmental community, and policy makers. In addition, the past decade has seen a growing consideration of the critical importance of noncommodity resources, which is now termed as 'ecosystem or environmental services' in supporting human systems (Daily et al., 1997; MEA, 2005; Boyd and Banzhaf, 2007).

These ideas can best be captured by the notion of the 'human ecosystem' as articulated by Gary Machlis and colleagues in 1997 (Force and Machlis, 1997; Machlis et al., 1997) (discussed later) and later refined as Coupled Human and Natural Systems (CHANS) by Jianguo Liu and his colleagues ten years later (Liu et al., 2007a, c). CHANS's operational specifics will be discussed later in this paper, but it is important to understand that this scientific approach to addressing complex environmental problems is being adopted across the U.S. helping to define not only research and education programs but also academic position descriptions. Central to this evolving methodology has been the availability of research funding.

The U.S. National Science Foundation (NSF) initiated a special competition in 1999 to support research that examined the interrelationships between biological and social systems, which became the Biocomplexity in the Environment Program in 2001. It served as the administrative umbrella for various integrative competitions until 2006 when the competitions were moved to different organizations within NSF. One such competition was added in 2001, NSF's Dynamics of Coupled Natural and Human Systems Program, which recognized the need to enhance our understanding of complex systems. This program was established to promote and financially support "…quantitative and interdisciplinary analyses of relevant human and natural system processes and complex interactions among human and natural systems at diverse scales"[1)]. The availability of such a competitive funding has stimulated major changes concerning how the scientific community now addresses interdisciplinary and applied environmental problems (Table 1).

3 Examples of CHANS

Most all of the critical environmental issues currently facing society could serve to illustrate the importance of better understanding Coupled Human and Natural Systems, for example, global climate change, deforestation, unsustainable agriculture, and the loss of biodiversity and other ecosystem services. These problems exhibit not only interdisciplinary and multiscale characteristics but also a complexity that often leads to unforeseen and unpredictable consequences (Morell, 2005; Abel et al., 2006). Two brief examples of such 'coupled complexities' will suffice to illustrate our point.

The first involves the Wolong Nature Reserve in Sichuan Province, China (Liu et al., 2001). Established in 1975, this highly valued 200000 ha reserve protects about ten percent of China's Giant Panda (*Ailuropoda melanoleuca*) population and over 6000 other species of plants and animals. Hence, the Chinese Government and the World Wildlife Fund have extensively supported it, and it has become a popular ecotourism destination. Despite such attention, however, an assessment in 1999 reported continued rapid habitat destruction of the bamboo forests critical to panda survival. It appears that the increased tourism associated with the development and marketing of this nature reserve increased the local economy stimulating a concurrent increase in demand for forest products. Confounding the problem was the fact that a major proportion of the economic benefits by-passed the local communities making the connection between the reserve and local livelihoods vague and ineffective. To counter this problem, the government established a subsidy program in 2001 paying local people to monitor illegal cutting in the reserve. Payments were made to households rather than individuals positively affecting 20%–25% of the households in the region. Unexpectedly, this stimulated an increase in the number of households stemming from immigration and the fragmentation of existing households, which increased the demand for forest products intensifying habitat destruction. These findings have encouraged the adoption of a more comprehensive strategy for addressing the relationships between humans and nature in the Wolong Nature Reserve (Viña et al., 2007).

The second example illustrates the complexities and uncertainties of global climate change. One outcome of warming temperatures worldwide is that mountain and continental glaciers are receding at unprecedented rates and that many coastlines worldwide are facing eventual inundation and concurrent massive ecological, economic, and social disasters as oceans rise (Solomon et al., 2007). However, a recent report from Juneau, Alaska (Kelly et al., 2007), while verifying the rapid melting of the nearby Mendenhall Glacier and Glacier Bay ice fields, also predicted a continued increase in local land area arising from glacio-isostatic rebound where the land rises when it is no longer depressed by a mass of ice. This has accounted for a total uplift of about 3.2 m since the late 18th century. This phenomenon is well understood by geologists (e.g., Walcott, 1973), but it gained wide public attention recently (e.g., Dean, 2009), which included a landowner reporting to have opened a nine-hole golf course at the mouth of Glacier Bay in 1998 on land that was underwater 50 years ago. Although avoiding the threat of flooding, rising land and decreasing sea level in the Juneau area pose their own environmental and socioeconomic challenges, such as falling water tables, loss of wetlands, shifting property boundaries, changing land uses, and sedimentation of waterways affecting navigation and salmon habitat (Kelly

1) http://www.nsf.gov/funding/pgm_summ.jsp?pims_id = 13681

et al., 2007). As a coupled system more oceanic water from melting glaciers does not uniformly and directly translate to the same level of flooding and associated socioeconomic impacts in coastal areas worldwide.

4 CHANS as an approach to environmental problem solving

The Coupled Human and Natural Systems (CHANS) methodology has been applied to a wide range of subjects, each with a slightly different attention to elements of scale and disciplinary mix (see Table 1). As a result, recent journal series have either focused quite specifically on one particular perspective, such as economic modeling for policy formulation (e.g., McPeak et al., 2006) or more broadly by emphasizing biocomplexity (e.g., Walsh and McGinnis, 2007). A common attribute among all these studies, however, has been that they moved beyond using traditional nature-society concepts and approaches where nature and its functioning are isolated from human socioeconomic systems (An et al., 2005; Walsh and McGinnis, 2007). Likely, the clearest and most comprehensive discussion of the concept and principles of CHANS comes from Jianguo Liu's group at Michigan State University (Liu et al., 2007a, b, c). It is not by coincidence that he has also led a major research effort examining the complexities of managing the Wolong Nature Reserve, which was highlighted in the preceding section.

4.1 Principles

The concept of coupled systems is based on a Human Ecosystem Model developed by Machlis and others (Force and Machlis, 1997; Machlis et al., 1997), which has been used to organize a Study Group at the University of Idaho since 2006[1)]. This group defines the human ecosystem as "a coherent system of biophysical and social factors capable of adaptation and sustainability over time". Their conceptual model illustrates the feed-forward, feedback relationships among critical biophysical, socioeconomic resources, and a social system defined by institutions, cycles, and social order determinants that together define

Table 1 A selection of research projects supported by the U.S. National Science Foundation's Dynamics of Coupled Natural and Human Systems Program (modified from NSF, 2008)

date	organization	title
2009	Columbia Univ.	Paleoclimate shocks: Environmental variability, human vulnerability, and societal adaptation during the last millennium in the Greater Mekong Basin.
2009	Univ. of Wisconsin	Social-ecological dynamics of aquatic species invasions on a lake-rich landscape.
2009	Univ. of Minnesota Univ. of California at Santa Barbara	Coupling human choice and biogeochemical cycling in urban ecosystems.
2009	Rutgers Univ. Univ. of Massachusetts Old Dominion Univ.	Climate change and responses in a coupled marine system.
2008	Oregon State Univ.	Interactions of climate change, land-management policies, and forest succession on fire hazard and ecosystem trajectories in the wild-land-urban interface.
2008	Michigan State Univ.	Globalization and the connection of remote communities: Environmental implications.
2008	Univ. of Colorado Arizona State Univ. Univ. of Montana	Determinants of grassland dynamics in Tibetan Highlands: livestock, wildlife, and the culture and political economy of pastoralism.
2008	Univ. of California at Riverside	Urban vulnerability to climate change: a system dynamics analysis.
2007	Bowdoin College Univ. of Southern Maine Univ. of Maine	Direct and indirect coupling of fisheries through economic, regulatory, environmental, and ecological linkages.
2007	SUNY College of Environmental Science and Forestry	Biodiversity dynamics and land-use changes in the Amazon: multiscale interactions between ecological systems and resource-use decisions by indigenous peoples.
2007	Michigan State Univ.	Effects of cross-boundary processes on human-nature dynamics in Wolong Nature Reserve for giant pandas.
2007	Univ. of Miami Columbia Univ.	Interactions between changing climate and technological innovations in agricultural decision making: implications for land use and sustainability.

1) http://www.webpages.uidaho.edu/~gmachlis/principal.html

the human ecosystem (Fig. 1). Relationships are established and maintained by the flow of individuals, energy, nutrients, materials, information, and capital. It is not a determinant model but would be "…primarily useful for predicting and evaluating cascading and nonlinear first-, second-, and third-order effects and is capable of synthesizing a large range of theory, method, and evidence" [1]. Hence, it is ideally suited to helping frame a CHANS and identifying key research needs and appropriate collaborators.

Liu and colleagues' comprehensive examination of six diverse CHANS case studies identified key features that set this approach apart from more common interdisciplinary examinations of human-nature interactions (Liu et al., 2007a, b). Most critical was that they all examined particular issues within a human ecosystem context as just discussed, which included measurements of ecological and human variables and the links between them. As a result, another common characteristic was the need to develop an interdisciplinary team that identified and pursued a common set of critical questions that focused on understanding interacting processes. This opened the opportunity to use research tools and techniques from many different disciplines for collecting, managing, analyzing, modeling, and integrating data. These studies were also context-specific and longitudinal over long time periods so that spatial patterns and temporal dynamics were discernable. Because of the CHANS approach, each study yielded insightful understandings of complex issues that would have evaded a disciplinary approach.

Liu and colleagues also have defined the types of linkages that connect natural and human systems providing further insights into the functioning of coupled systems (Liu et al., 2007c). Identified as 'couplings' these included linkages among organizational levels, across space, and over time, which further define the 'flows' identified in Machlis' human ecosystem model (see Fig. 1). These authors also provided numerous examples for each based on a very comprehensive review of the literature, which also illustrated the extensive involvement of others in the development of CHANS thinking (e.g., Costanza, 1991;

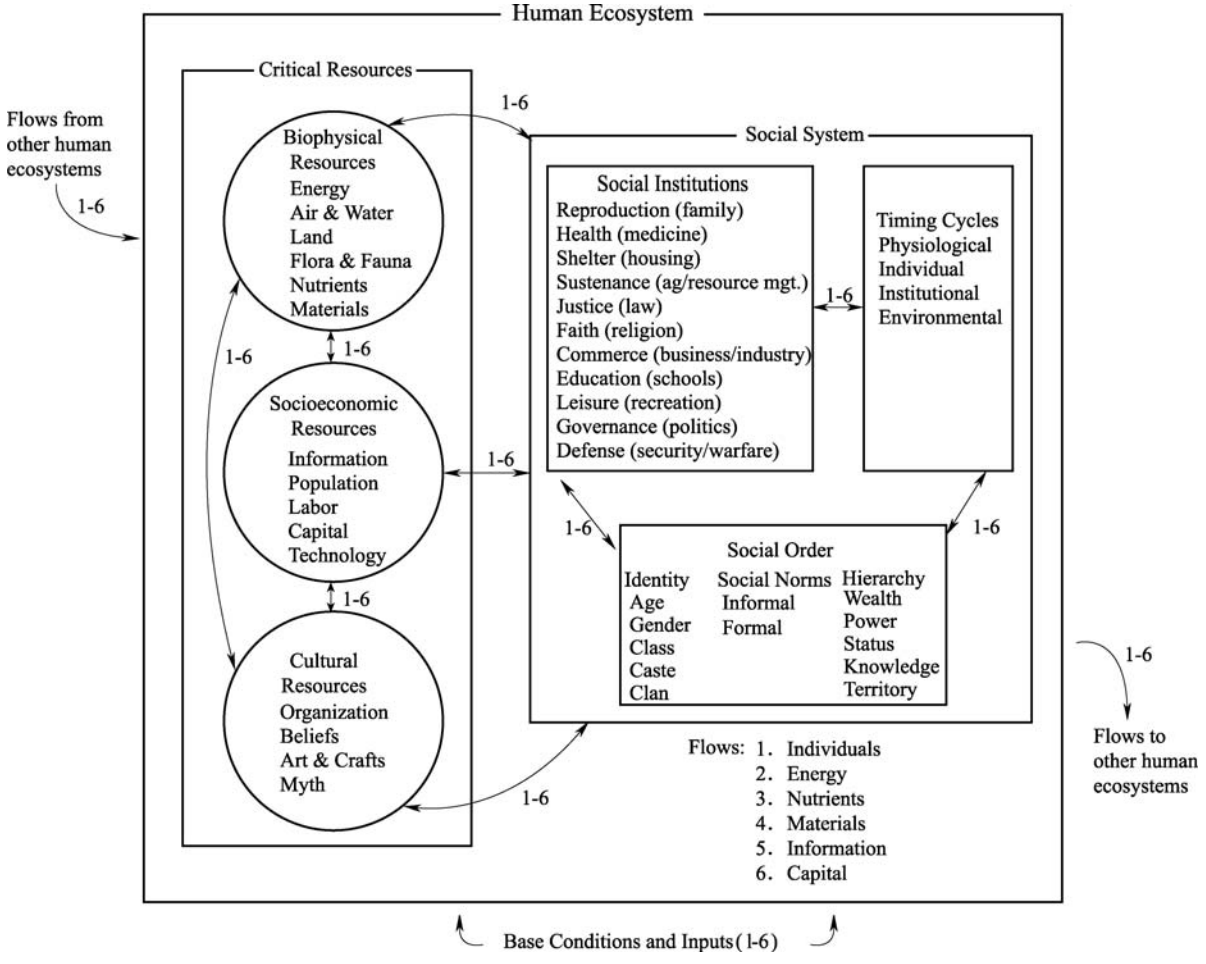

Fig. 1 Human ecosystem model[1]

1) http://www.uiweb.uidaho.edu/hesg/model.html

Stern 1993; Berkes and Folke, 1998; Folke et al., 2002; Pickett et al., 2005; and Chapin et al., 2006).

Organizational couplings define the characteristics of the complex interrelationships that go on between human and natural systems. Liu et al. (2007c) discussed five types of such couplings, which have their bases in systems ecology (Hagen, 1992).

4.1.1 Reciprocal effects and feedbacks

Human activities driven by socioeconomic development cause major changes in natural systems through habitat destruction, pollution, and the unsustainable utilization of natural resources (Whitney, 1996). In turn, human-caused environmental degradation and natural disasters, such as earthquakes, floods, and wild fires can have disastrous effects on social systems (Pachauri and Reisinger, 2007). Such reciprocity occurs at diverse social and ecological organizational levels, from local to global, forming complex webs of interactions (Pickett et al., 2005). Feedback, and feed-forward, relationships exist between human and natural processes that can have positive as well as negative effects on CHANS (e.g., coal-fired energy generation vs. global climate change), again impacting diverse levels of organization.

4.1.2 Indirect effects

The complexity of CHANS makes predictability difficult, and the interactions often lead to indirect outcomes that are often unexpected. Hence, manufactured and synthesized products, such as computers, cars, pesticides, and antibiotics, commonly are found to have unforeseen and unintended effects on social and ecological systems at many organizational levels. For example, recycling is widely considered to be environmentally beneficial, but the recycling of computers, televisions, cell phones, and other electronic products (e-waste) worldwide has been found to cause environmental and health problems in China despite the economic benefits accruing to the local communities involved (Hicks et al., 2005; Leung et al., 2006). In a similar fashion, worldwide concern over continued biodiversity loss is triggered by knowledge that certain species can have a disproportionate impact on the structure of food webs and total ecosystem functioning (Mills et al., 1993).

4.1.3 Emergent properties

CHANS have unique properties that are inherent to the interactions that characterize them, ones that are not evident when human and natural systems are examined separately. For example, wildlife habitat is determined by the interaction between human activities (e.g., timber harvesting and reforestation) and natural processes (e.g., wild fire and natural succession), with a net effect of either decreasing or increasing the populations of certain species (Morrison et al., 2006). In turn, this can have a major effect on the mix of species and on ecosystem functioning.

4.1.4 Vulnerability

For species, threatened or endangered status conveys the potential for population collapse in the face of new and/or continuing internal (e.g., disease) and external (e.g., habitat loss) perturbations (Smith et al., 2009). In similar fashion, natural ecosystems and human communities possess a degree of susceptibility to change depending on how well they function (Adger et al., 2005; MEA, 2005). For CHANS, the notion of vulnerability is extended to the entire system reinforcing the interdependency between human and natural systems.

4.1.5 Thresholds and resilience

The response of natural ecosystems to anthropocentric perturbations may not be linear or even observable but might eventually reach a critical ‘tipping point’ followed by rapid ecosystem collapse (Skei et al., 2000; Scheffer et al., 2001; Abel et al., 2006). The recent worldwide economic collapse and the social and environmental impacts that followed might represent such a threshold for human systems (Chan, 2009; Orr, 2009). The ability for ecosystems or societies to respond and maintain or return to stability determines their resilience. As a CHANS, some believe that global climate change is nearing a threshold point that will surpass our ability to respond effectively thereby leading to irreversible changes to the human ecosystem (e.g., Jordan et al., n.d.).

As mentioned, the analysis of organizational couplings by Liu et al. (2007c) was from a systems ecology perspective and they provided insights into the functioning of CHANS. It is interesting to consider similar couplings that might arise purely from social systems, which are how humans organize and how these might influence CHANS. Such considerations fall within the rapidly developing field of political ecology (Greenberg and Park, 1994; Biersack and Greenberg, 2006). Although specific principles are difficult in this complex field compared to systems ecology, one example will illustrate the need to further clarify political ecological couplings that influence CHANS.

The human ecosystem model clearly identifies the importance of cultural beliefs and practices in affecting the interdependent functioning of human and social systems (see Fig. 1). Hence, the tenets of organized religion should provide organizational couplings for CHANS—ones that are purely human in their origin. Liu et al. (2007c) allude to this coupling when they call for a paradigm shift in how humans view their

interconnectedness to nature (discussed later). In Bhutan, no such shift is required. As the national religion, Mahayana Buddhism places people in nature with a clear reverence for all living organisms. This provides social norms dictating the behavior of individuals and government agencies in their dealings with nature, making protection paramount. As a result, Bhutan is widely recognized for its conservation of nature and its use of a Gross National Happiness Index to assess development (Zurick, 2006). However, adherence to Buddhism causes problems that likely would not occur from other religious perspectives. For example, the killing of animals is considered a sin and a social taboo, which greatly complicates the ability to address human-wildlife conflicts in and around protected areas (GoB, 2008). Similar social couplings most certainly can also be identified within an economic context (McPeak et al., 2006).

Liu et al. (2007c) also noted that CHANS operated across multiple and nested spatial scales that influence one another. Such couplings, from local to global, transcend political, managerial, and ecosystem boundaries and are greatly influenced by globalization and today's ability to rapidly move of people, products, and materials, and information over long distances. This couples cities with rural areas, developed countries with developing, rich with poor leading to social and environmental costs and benefits that are quite heterogeneous and often disproportionately distributed. This can be easily illustrated by considering that developing countries lack the ability to develop benefits arising from the generation of greenhouse gases, and although they contribute little to global warming, it is these countries that will suffer the most from its effects (Mendelsohn et al., 2006). At a smaller scale, but no less potentially disrupting at a local level, mountainous communities in Northwest Yunnan, China, commonly supplement a subsistence lifestyle by participating in a potentially volatile international market that efficiently moves valuable matsutake mushrooms (*Tricholoma matsutake*) (Yeh, 2000; Yang et al., 2008). Market-motivated overharvesting of matsutakes and other nontimber forest products, including medicinal plants, also has prompted concern about biodiversity loss and ecosystem changes in these remote areas (Xu and Wilkes, 2004; Melick et al., 2005).

One key feature of CHANS discussed earlier was that they operated over long enough time periods that unique trends and outcomes can be identified (Liu et al., 2007a, b). This recognizes temporal couplings that such systems exhibit (Liu et al., 2007c). It is well recognized that the past 50 years have witnessed exponential increases in human populations, and in rapidly developing countries, like China and India, production and consumption indicators of development have grown faster than population (Arrow et al., 2003). This period also has experienced unprecedented human-induced changes in natural systems (MEA, 2005), which in turn have negatively impacted social systems and is jeopardizing human health and welfare in many parts of the world (Collier, 2007). Most certainly, human impacts on natural systems are occurring more rapidly and at larger scales with more indirect effects than in the past, illustrating the escalating influence of human development (Liu et al., 2007c), and likely our increasing ability to understand and measure the complexities of such impacts.

Organizational couplings of reciprocal and feedback effects discussed earlier also suggest that the effects of human and natural system interactions are cumulative and often present conditions that are greatly conditioned by past activities. Past land use practices (e.g., urban development leading to sprawl and timber harvesting leading to compositional and structural changes in forests) illustrate such 'legacy effects.'

Similarly, thresholds and resilience couplings lead to time lags between causes and effects in CHANS, whether they occur between policy decisions and effects on nature or between environmental consequences and impacts on human systems. For example, the massive financial losses and costs in human lives and livelihoods due to the flooding of the Yangtze River in 1998 (Zong and Chen, 2000), likely illustrates the impact of past policy decisions to clear-cut large portions of the upper watershed, and to promote development along its entire length. Incremental policy decisions, even when made with sound intentions, can lead to unintended consequences in CHANS.

4.2 Challenges and opportunities

Our growing understanding of CHANS is reflected in a growing acceptance that traditional environmental management policies and practices are inadequate in the long-term (MEA, 2005), as even ecosystem-based approaches lack assessments that are comprehensive enough to capture the complexities of today's management challenges (Liu et al., 2007c). The need for effective interdisciplinary research and development has long been recognized (e.g., Klein, 1991; Pickett et al., 1999), but Liu et al. (2007c) and many others (e.g., Berkes et al., 2003; Sayer and Campbell, 2004; and Chapin et al., 2009) also have called for a significant shift in the context within which management policies are formulated and practiced. First, as introduced earlier, humans and their activities must be accepted as being an integral part of nature as illustrated by the human ecosystem model (see Fig. 1), and the idea that humans can subdue and control nature must be set aside with humility. Furthermore, a longer term perspective is required as is an acceptance that the complexities of CHANS demand decision making under uncertainty (Perrings, 1991). This will require developing an adaptive approach to management based on the precautionary principle (Raffensperger and Tickner, 1999). Second, issues of scale and the impacts of globalization on local conditions and decision-making processes must be

considered. This will demand new and improved collaborations among nations as well as within and between sectors of government, civil society, and business. Last, environmental management approaches must be dynamic and adaptive to the constantly changing nature of CHANS, instead of reflecting static social, political, and economic conditions that may be outdated, ineffective, or both (Gunderson et al., 1995).

The need for new scientific approaches for quantifying CHANS in order to better understand the linkages between human and natural processes and to reflect this understanding in new management strategies is clearly warranted (Liu et al., 2007c). This will require new approaches that emphasize hierarchical and nested couplings across organizational, spatial, and temporal scales. This will call for the use of many tools and methodologies from a wide variety of biophysical and socioeconomic disciplines, and the integration of resulting data using sophisticated multidisciplinary models capable of statistical analysis. For example, the use of geographic information systems to assess policy-driven land-use changes in order to understand biophysical and socioeconomic processes occurring across a landscape in response to specific policy decisions (Parker et al., 2003; An et al., 2005).

As it has been recognized for understanding ecosystem functioning in response to natural and anthropogenic changes (Hobbie et al., 2003), CHANS must be investigated over long time periods in order to better understand temporal couplings. In addition, a complement of different CHANS study sites must be developed that capture spatial diversity and allow for cross-site comparisons. These must move beyond projects currently offered by the U.S. NSF (e.g., Table 1) to include larger efforts that involve global and collaborative investigations involving multiple countries and sites (Liu et al., 2007c). An excellent example of such a program is the Global Observation Research Initiative in Alpine Environments (GLORIA) that has established a worldwide collaborative research network to examine the long-term effects of climate change on alpine biodiversity[1)] (Grabherr et al., 2000).

There have been many calls for developing applied, interdisciplinary approaches to environmental and natural resource management problem solving, which would require changing institutional and funding systems that encourage and reward the individual accomplishments of teachers, researchers, and practitioners and the academic, governmental agencies, and nongovernmental organizations they represent (e.g., Liu et al., 2007c; Lassoie et al., 2009). It is clear that new approaches are needed for pursuing research questions, educating future practitioners and policy makers, and building communication networks among a diverse body of stakeholders with regard to CHANS.

The diversity and extent of the U.S. NSF CHANS Program suggests that such changes are underway in the United States (see Table 1), which has lead to the establishing the International Network of Research on Coupled Human and Natural Systems[2)]. Although a similar national-level funding program specifically for CHANS research currently is not available directly from China's NSF, the National Basic Research Program (i.e., 973 Program) organized and implemented by the Chinese Ministry of Science and Technology does offer support for strategic research related to all aspects of sustainable development[3)]. In order to illustrate an example of how a research group could develop a CHANS, we next highlight a study of alpine areas in Northwest Yunnan, China.

5 CHANS in practice: a case from Northwest Yunnan

We present a case study on the conservation of alpine ecosystems in Northwest Yunnan, China (NWY), as an example of an integrated research approach for understanding complex human and natural systems within a conservation context. The alpine ecosystems of these mountains have exceptionally high levels of biodiversity but also have a long history of human use that sustains local livelihoods. The largely Tibetan population of NWY has grazed livestock, primarily yak, in alpine meadows for millennia and nomadic pastoralism continues to be their most important livelihood today. However, there are concerns that these alpine systems are becoming fragmented and degraded (Xu and Wilkes, 2004). Strong conservation interests in the region stemming from its relatively recent recognition as a global biodiversity hotspot (Myers et al., 2000; CI, 2007) combined with concerns over the impacts of rapid economic development has created a sense of urgency among conservation managers to implement action plans to protect species and the alpine habitat (Ma et al., 2007).

The purpose of this study was to gain a clearer understanding of the relationships among alpine plant diversity, alpine land use practices, and environmental change as the first step in identifying critical issues and prioritizing sites for conservation action. It was recognized that any successful conservation strategies would require knowledge on the biophysical environment as well as how local communities use and manage this resource. To this end, ecologists, sociologists, climate change scientists, and conservation practitioners worked together to identify research goals, develop research questions, and design and implement the study as a means to fully integrate environmental, ecological, and socioeconomic data. In this section, we emphasize the process by which we

1) http://www.gloria.ac.at/
2) http://www.CHANS-NET.org
3) http://www.973.gov.cn/English/Index.aspx

developed and designed a CHANS research approach and provide a brief summary of the results, as detailed research papers on each topic have been published elsewhere (Baker and Moseley, 2007; Buntaine et al., 2007; Sherman et al., 2007, 2008).

5.1 Background

The mountains of South-central China have been identified as a global hotspot of biodiversity (Myers et al., 2000; CI, 2007) and more recently designated a World Natural Heritage Site[1]. The region is recognized for both its high biological diversity and rich cultural diversity. Within this hotspot lie the southern Hengduan Mountains, the site of the Yunnan Great Rivers Project, a joint conservation project initiated in 1999 between the Yunnan Provincial Government and The Nature Conservancy (TNC) to conserve critical habitats and species.

Due to the paucity of biodiversity data from this area and the need for quick action due to the rapid pace of development in China, experts were asked to identify priorities for conservation investment (Ma et al., 2007). The alpine ecosystems of Northwest Yunnan (NWY) were identified as a conservation priority within the Yunnan Great Rivers Project because of their high species richness, high levels of endemic species, economic, and cultural value to local communities, and threat of species losses due to increasing land use pressures and climate change (Xu and Wilkes, 2004; Baker and Moseley, 2007; Buntaine et al., 2007; Ma et al., 2007; Sherman et al., 2007). However, because the alpine zone, covering roughly 12% (8200 km^2) of the project area, is such a large and widely distributed habitat type and our knowledge of these systems limited, it was clear that decisions to invest in on-the-ground conservation action would require additional information.

To address these needs, TNC-China initiated the Alpine Ecosystem Project in 2003, a collaborative effort among community, government, and research institutions with the long-term goal of protecting and promoting the sustainable use of the alpine (TNC, 2006). It was recognized that effective conservation strategies would require an understanding of the ecology of the alpine, how local people use and manage this resource, and how the broader and more ubiquitous threat of climate change might impact these relationships. A unique integrated research approach was used whereby sociologists (Buntaine et al., 2007), climate change experts (Baker and Moseley, 2007), and plant ecologists (Sherman et al., 2007, 2008) visited alpine sites together to gather complementary data on a suite of alpine ecosystems across a broad geographic range. The cumulative results provide the basis for selecting critical alpine habitats across NWY and for designing and implementing collaborative conservation strategies at the site level and broader regional scale.

5.2 Methodological approach

An important aspect of the project that contributed to its success is that all scientists and practitioners involved in the study worked together from the start to identify goals, develop research questions, and design the study. This collaborative approach ensured that the research was truly interdisciplinary with all team members focusing their efforts toward a common goal and result. We argue that many interdisciplinary studies merely bring together separate disciplines that engage in individual studies that run parallel to each other without any direct integration. By engaging all participants at the onset of the project, all team members developed a shared vision and individual research questions were framed in a way so as to enrich the data collection and research efforts of all team members.

Because the project was initiated and funded by TNC, an international conservation nongovernmental organization (NGO), to address specific conservation concerns, it had a very applied focus. Practitioners from the NGO helped to maintain the project focus so that the results would be useful and directly applicable to conservation concerns in the region, as well keep researchers within time and fiscal constraints. Most of the work was completed within a two-year period with a limited budget. The study was intended to provide a rapid regional-level assessment of local and regional conservation issues while at the same time maintaining scientific rigor and producing quantitative results to provide an understanding of regional trends and lay a foundation for more detailed studies in the future at specific geographic locations of these widely dispersed habitats.

The research team first developed a set of general research questions:

- How does plant diversity and composition vary across the mountains of northwest Yunnan?
- What is the general ecological health and integrity of the alpine?
- Has the ecological condition of the alpine changed over the past 10–20 years?
- How do local communities use and manage alpine resources?
- Has the use and management of alpine resources changed over the past 10–20 years?
- How are livelihood activities, socioeconomic conditions, and alpine ecosystem integrity interconnected?
- Have environmental changes, i.e., climate change, had a measurable or perceptible (by local herders) affect on the ecology or human land use of the alpine?

Several field sites were selected randomly across the different mountain ranges to represent a broad geographic range of environmental/ecological conditions and land use practices in alpine habitats at local and regional scales

1) http://www.worldheritagesite.org/sites/parallelriversyunnan.html

(Sherman et al., 2007, 2008). Plant ecology surveys were conducted at 21 widely distributed sites. Interviews were conducted at a subset of three livestock herding sites where plant surveys were conducted, each within a different alpine subregion. Climate change scientists worked more broadly across the region to understand historical climate patterns and land use patterns. Specific methodologies were developed by each discipline that were rigorous and scientifically sound to meet the stated goals and objectives.

The plant ecology group used standard survey techniques to answer the following questions:

- How does alpine plant species richness and composition vary across the mountains?
- How is plant species richness and composition related to environmental and biophysical conditions?
- What is the general ecological health of the alpine?

The sociology group developed a survey and used open-ended interviews and maximum variation sampling to understand how local livelihood strategies affect the condition of the alpine resources and local herders' perceptions of changes in the alpine environment. Interview questions focused on topics of conservation, culture, and local economic development such as:

- Yak herding practices
- Medicinal plant collection and use
- Tourism
- Wildlife
- Income
- Spirituality
- Desires for the future
- Perceived environmental changes

The climate change group documented regional temperature trends in NWY using historic climate data and assessed changes in alpine tree line and glacier recession using historic repeat photographs over a 90-year period.

5.3 Summary of results

In each of the three studies outlined above, researchers asked common questions allowing us to triangulate information from three disciplinary perspectives and strengthen our interpretation of the limited data collected in this coarse-scale study. Together, we were able to identify major issues related to the conservation and well being of the alpine and the people who rely on this resource.

The plant ecology study (Sherman et al., 2007, 2008) confirmed that the alpine systems of NWY contain high species richness and high levels of endemic and rare species. Overall, the alpine vegetation was found to be highly heterogeneous across the complex mountain landscape. Strong regional patterns in plant species richness were evident, and the species composition was very different among sites. Grazing was prevalent throughout the alpine but the plant data did not suggest a problem of overgrazing such as a high abundance of unpalatable species, dominance by a few nuisance species, or soil erosion. Many of the sites sampled were in various stages of succession from alpine meadow to rhododendron shrub communities. According to the local herders, shrub encroachment onto summer pasturelands was occurring due to a national-level fire ban implemented in 1998 that restricted them from using prescribed fire, a traditional land management tool, as a means to keep pastures open and healthy.

The socioeconomic study (Buntaine et al., 2007) identified important conservation issues at both the regional and local levels. Regionally, the growing scarcity of important medicinal plants due to overcollection appeared to be the most important conservation and livelihood issue as the collection and sale of commercial medicinal plants was a significant source of income for many households. Herders did not feel that there had been any deterioration in the quality of forage in alpine pastures and thus did not feel that grazing was having negative impacts that warranted local concern. There was universal concern over the national-level fire ban that halted the traditional use of fire to control tree and shrub invasions into alpine pastures. Local tourism was viewed as having great potential for income generation and was favored especially by the younger generation. Local issues included wolf predation on livestock, interest in local management plans for better resource management, and one site had a major interest in tourism.

The climate change study (Baker and Moseley, 2007) showed that mean annual temperatures in NWY have been increasing at rates double the national average for China over the last 50 years. Both summer and winter mean temperatures have been rising and summer precipitation has been decreasing. Tree line has advanced 67 m in elevation since 1923 and tall broadleaf evergreen rhododendron, which normally grow in the forest understory, have moved upslope into the dwarf shrub communities. The Mingyong Glacier has retreated significantly since the early 1900s with dramatic changes evident in the extent and volume of the glacial tongue.

5.4 Conservation implications

The complementary research approach used in this study provides a more holistic understanding of the current conditions, uses and issues concerning the alpine by integrating vegetation, and socioeconomic and climate change data. For example, all three studies indicated that shrub encroachment into alpine pastures was an important issue. Whereas the ecology and socioeconomic studies attributed shrub encroachment to the fire ban, the climate change study found strong evidence that trees and shrubs were expanding their distributions in response to a warming climate. It is likely that a combination of climate change and land-use change is contributing to the invasion of trees and shrubs into alpine pastures that threaten both

biodiversity and Tibetan livelihoods. Although the fire ban was instituted with good intentions for protecting lower elevation forests, it was applied universally to all ecosystems with the unanticipated negative consequences on the alpine and users of alpine meadows. Conservation managers will need to recognize that government regulatory policies, land use practices, and global climate change all interact and contribute to conservation issues related to alpine pastures to develop effective solutions.

Another complex issue that will challenge conservation managers is the regional-wide loss of important medicinal plants due to overcollection. Overcollection, however, is driven by more distal forces, such as the shift from a subsistence system to a new cash economy, national and international market demands for traditional medicines, changes in traditional life styles, and a desire by the younger generation to seek new livelihoods. This issue illustrates the global connectivity of CHANS: the behavior of local people in this remote mountain region with largely subsistence economies is directly linked to national and international markets with consequent impacts on these alpine ecosystems. Solutions will require a better understanding of the population dynamics of medicinal plants, the possible role of climate change in affecting their distributions, engagement of local communities to better manage this common property resource, and working with government agencies to establish market regulations to control the sale and distribution of these products.

The results from this case study underscore the complexity of coupled human-natural systems. The ultimate goal of this work is to protect the rich biodiversity of the mountain highlands in NWY. It is clear that studying the ecology of the alpine alone would not have provided adequate information for developing effective conservation strategies. The integrity of the alpine is being impacted by drivers of change that occur at different temporal and spatial scales and include biophysical, social, policy, economic, and cultural components. The integrated research approach presented successfully identified regional trends in resource conditions and use in the alpine systems of NWY. The results offer guidance for immediate conservation action and lay the foundation for more detailed studies and conservation efforts in the future. Overall, we feel that this approach was an effective methodology that is widely applicable to conservation planners needing to efficiently identify key regional trends in widely dispersed ecosystems.

6 Conclusions

The complexity of environmental issues facing the world today demands a paradigm shift in research that recognizes the integrated and coupled nature of social and ecological systems. This will require efforts beyond the historical call for interdisciplinarity. Problems such as climate change, nonpoint source pollution, and unsustainable development must be addressed within a coupled human and natural system framework that uses a systems ecology approach to better understand the complex functioning of the human ecosystem. This provides the context for building interdisciplinary teams to identify and pursue critical and interdependent research questions, which leverages a variety of analytical tools and methodological approaches from the socioeconomic and biophysical sciences. Of course, funding agencies must recognize the need to provide financial support for such work, which needs to be substantial and relatively long-term given the nature of the problems being examined. There is mounting evidence from the United States that the National Science Foundation's Dynamics of Coupled Natural and Human Systems Program is helping to restructure the nation's research community to better address the pressing environmental problems of the day.

The interlinked human and ecological issues emerging from the mountainous regions of Central Asia in the face of rapid social and climate changes call for a concerted coupled systems approach. The International Centre for Integrated Mountain Development has provided a strategic programming focus for the region, which includes Integrated Water and Hazard Management, Environmental Change and Ecosystem Services, Sustainable Livelihoods and Poverty Reduction, Integrated Knowledge Management (ICIMOD, 2009). These provide ideal platforms for building broader collaborative efforts across this multinational region. However, greater involvement by U.S. scientists may be warranted. Chinese scientific institutions, collectively being the most comprehensive and powerful in the region, should seek to develop incentives for rewarding collaboration across disciplines and institutions. The Chinese National Science Foundation and/or the National Basic Research Program could develop interdisciplinary funding competitions that emphasize coupled natural and human systems and further promote collaborative research. The availability of such funds would naturally build new research partnerships to address critical environmental problems facing China and Central Asia, including those across the Hindu Kush-Himalayas, Karakoram, and Pamirs.

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References

Abel N, Cumming D H M, Anderies J M (2006). Collapse and reorganization in social-ecological systems: Questions, some ideas, and policy implications. Ecology and Society, 11(1): 17

Adger W N, Hughes T P, Folke C, Carpenter S R, Rockström J (2005). Social-ecological resilience to coastal disasters. Science, 309(5737): 1036–1039

An L, Linderman M, Qi J, Shortridge A, Liu J G (2005). Exploring complexity in a human-environment systems: An agent-based spatial model for multidisciplinary and multiscale integration. Annals of the Association of American Geographers, 95(1): 54–79

Arrow K G, Dasgupta P, Mäler K G (2003). Evaluating projects and assessing sustainable development in imperfect economies. Environmental and Resource Economics, 26(4): 647–685

Baker B B, Moseley R K (2007). Advancing treelines and retreating glaciers: Implications for conservation in P.R. China. Arctic, Antarctic, and Alpine Research, 39(2): 200–209

Bartholomew G A (1986). The role of natural history in contemporary biology. BioScience, 36(5): 324–329

Berkes F, Colding J, Folke C (2003). Navigating Social-ecological Systems: Building Resilience for Complexity and Change. Cambridge: Cambridge University Press

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

Biersack A, Greenberg J B (2006). Reimagining Political Ecology (New Ecologies for the Twenty-First Century). Durham: Duke University Press

Blair W F (1977). Big Biology: The US/IBP. US International Biological Programme Synthesis Series (No. 7). Stroudsburg: Dowden, Hutchinson and Ross

Boyd J, Banzhaf S (2007). What are ecosystem services? The need for standardized environmental accounting units. Ecological Economics, 63(2–3): 616–626

Brebbia C A, Tiezzi E (2009). Ecosystems and sustainable development VII. Proceedings of the Seventh International Conference on Ecosystems and Sustainable Development, Chianciano Terme (Siena, Italy). Southampton: WIT Press

Brown J, Miller, P C, Tieszen L L, Bunnel F L (1980). An Arctic Ecosystem: The Coastal Tundra at Barrow, Alaska. US/IBP Synthesis Series (No. 12). Stroudsburg: Dowden, Hutchinson and Ross

Buntaine M T, Mullen R B, Lassoie J P (2007). Human use and conservation planning in alpine areas of northwestern Yunnan, China. Environment, Development, and Sustainability, 9 (3): 305–324

Chan, M (2009). Impact of financial crisis on health: A truly global solution is needed. World Health Organization, Media Centre. Retrieved September 23, 2009 from http://www.who.int/mediacentre/news/statements/2009/financial_crisis_20090401/en/index.html

Chapin, F S III, Kofinas G P, Folke C (2009). Principles of Ecosystem Stewardship: Resilience-based Natural Resource Management in a Changing World. New York: Springer

Chapin, F S III, Hoel M, carpenter S R, Lubchenco J, Walker B, Callaghan T V, Folke C, Levin S A, Mäler K-G, Nilsson C, Barrett S, Berkes F, Crépin A-S, Danell K, Rosswall T, Starrett D, Xepapadeas A, Zimov S A (2006). Building resilience and adaptation to manage Arctic change. AMBIO: A Journal of the Human Environment, 35 (4): 198–202

CI (Conservation International) (2007). Biodiversity hotspots: mountains of southwest China. Retrieved September 23, 2009 from http://www.biodiversityhotspots.org/xp/Hotspots/china/Pages/default.aspx

Collier P (2007). The Bottom Billion: Why the Poorest Countries are Failing and What can be Done about it. Oxford: Oxford University Press

Costanza R (1991). Ecological Economics: The Science and Management of Sustainability. New York: Columbia University Press

Cronon W (1983). Changes in the Land: Indians, Colonists, and the Ecology of New England. New York: Hill and Wang

Daily G C, Alexander S, Ehrlich P R, Goulder L, Lubchenco J, Matson P A, Mooney H A, Postel S, Schneider S H, Tilman D, Woodwell G M (1997). Ecosystem services: benefits supplied to human societies by natural ecosystems. Issues in Ecology Vol. 2. Washington D C: Ecological Society of America

Daly H E (1990). Toward some operational principles of sustainable development. Ecological Economics, 2(1): 1–6

Dean C (2009). As Alaska glaciers melt, it's land that's rising. New York Times, May17, 2009. Retrieved September 23, 2009 from http://www.nytimes.com/2009/05/18/science/earth/18juneau.html

Edmonds R L (1982). Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series (No. 14). Stroudsburg: Dowden, Hutchinson and Ross

Folke C, Carpenter S, Elmqvist T, Gunderson L, Holling C S, Walker B (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. AMBIO: A Journal of the Human Environment, 31(5): 437–440

Force J E, Machlis G E (1997). The human ecosystem part II: Social indicators in ecosystem management. Society and Natural Resources, 10(4): 369–382

Gilbert M T P, Jenkins D L, Götherstrom A, Naveran N, Sanchez J J, Hofreiter M, Thomsen P F, Binladen J, Higham T F G, Yohe R M II, Parr R, Cummings L S, Willerslev E (2008). DNA from pre-Clovis human coprolites in Oregon, North America. Science, 320(5877): 786–789

GoB (Government of Bhutan) (2008). Bhutan national human–wildlife conflicts management strategy. Thimphu: Nature Conservation Division, Department of Forests, Ministry of Agriculture, Royal Government of Bhutan

Grabherr G, Gottfried M, Pauli H (2000). GLORIA: a global observation research initiative in alpine environments. Mountain Research and Development, 20(2): 190–191

Greenberg J B, Park T K (1994). Political ecology. Journal of Political Ecology, 1(1): 1–12

Gunderson L H, Holling C S, Light S S (1995). Barriers and Bridges to the Renewal of Ecosystems and Institutions. New York: Columbia University Press

Hagen J B (1992). An Entangled Bank: the Origins of Ecosystem

Ecology. Piscataway: Rutgers University Press

Hays S P (2006). Wars in the Woods: the Rise of Ecological Forestry in America. Pittsburg: University of Pittsburgh Press

Hicks C, Dietmar R, Eugster M (2005). The recycling and disposal of electrical and electronic waste in China: Legislative and market responses. Environmental Impact Assessment Review, 25(5): 459–471

Hobbie J E, Carpenter S R, Grimm N B, Gosz J R, Seastedt T R (2003). The US long term ecological research program. BioScience, 53(1): 21–32

ICIMOD (International Centre for Integrated Mountain Development) (2009). Annual report 2008. Kathmandu: Hillside Press. Retrieved September 27, 2009 from http://books.icimod.org/index.php/search/publication/610

Jordan T E, Lloyd A H, McClelland J W, Langdon C, Mouat D A, Havstad K M, MacMahon J A. (n.d.) Ecological tipping points: Subtle alterations may signal the approach to drastic transformations of ecosystems affected by global climate change. Retrieved September 23, 2009 from: http://www.ecosystemresearch.org/tipping%20points%20ms%20%202%2013%2007.pdf

Kelly B P, Ainsworth T, Boyce Jr. D A, Hood E, Murphy P, Powell J (2007). Climate change: predicting impacts on Juneau. Report to: Mayor Bruce Botelho and the City and Borough of Juneau Assembly Scientific Panel on Climate Change, City and Borough of Juneau, Alaska. Retrieved September 23, 2009 from http://74.125.47.132/search?q = cache:7np4A7Q5hTUJ:www.juneau.org/clerk/boards/Climate_Change/CBJ%2520_Climate_Report_Final.pdf + Juneau + Climate + Report&cd = 4&hl = en&ct = clnk&gl = us&client = firefox-a

Klein J T (1991). Interdisciplinarity: History, Theory, and Practice. Gwynedd: Julie Thompson Klein

Kuzmiak D T (1991). The American environmental movement. The Geographical Journal, 157(3): 265–278

Lassoie, J P, Buck L E, Current D (2009). The development of agroforestry as an integrate land use management strategy for the United States. In: Garrett H E. North American Agroforestry: an Integrated Science and Practice. 2nd ed. Madison: American Society of Agronomy

Lassoie J, Oglesby R, Smallidge P (1998). Roots of American forestry education: trials and tribulations at Cornell University. Forest History Today, 1998: 21–25

Leung A, Cai Z W, Wong M H (2006). Environmental contamination from electronic waste recycling at Guiyu, southeast China. Journal of Material Cycles and Waste Management, 8(1): 21–33

Lewandowski S (1987). Diohe'ko, the three sisters in Seneca life: implications for a native agriculture in the Finger Lakes region of New York State. Agriculture and Human Values, 4(2–3): 76–93

Liu J, Linderman M, Ouyang Z, An L, Yang J, Zhang H (2001). Ecological degradation in protected areas: The case of Wolong Nature Reserve for giant pandas. Science, 292(5514): 98–101

Liu J G, Dietz T, Carpenter S R, Alberti M, Folke C, Moran E, Pell A N, Deadman P, Kratz T, Lubchenco J, Ostrom E, Ouyang Z, Provencher W, Redman C L, Schneider S H, Taylor W W (2007a). Complexity of coupled human and natural systems. Science, 317(5844): 1513–1516

Liu J G, Dietz T, Carpenter S R, Alberti M, Folke C, Moran E, Pell A N, Deadman P, Kratz T, Lubchenco J, Ostrom E, Ouyang Z, Provencher W, Redman C L, Schneider S H, Taylor W W (2007b). Supporting materials for: complexity of coupled human and natural systems. Science, 317(5844):1513–1516. Retrieved September 23, 2009 from www.sciencemag.org/cgi/content/full/317/5844/1513/DC1

Liu J G, Dietz T, Carpenter S R, Folke C, Alberti M, Redman C L, Schneider S H, Ostrom, E, Pell A N, Lubchenco J, Taylor W W, Ouyang Z, Deadman P, Kratz T, Provencher W. (2007c). Coupled human and natural systems. AMBIO: A Journal of the Human Environment, 36(8): 639–649

Ludwig D, Hilborn R, Walters C (1993). Uncertainty, resource exploitation, and conservation: Lessons from history. Science, 260 (5104): 17–36

Ma C, Moseley R K, Chen W, Zhou Z (2007). Plant diversity and priority conservation areas of Northwestern Yunnan, China. Biodiversity and Conservation, 16(3): 757–774

Machlis G E, Force J E, Burch W R Jr (1997). The human ecosystem part I: the human ecosystem as an organizing concept in ecosystem management. Society and Natural Resources, 10(4): 347–367

McPeak J G, Lee D R, Barrett C B (2006). Introduction: The dynamics of coupled human and natural systems. Environment and Development Economics, 11(1): 9–13

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and Human Well-being: Synthesis. Washington D C: Island Press

Mendelsohn R, Dinar A, Williams L (2006). The distributional impact of climate change on rich and poor countries. Environment and Development Economics, 11(2):159–179

Messerli B, Ives J D (1997). Mountains of the World: A Global Priority. New York: Parthenon Publishing Group

Melick D, Yang X, Yang Y, Xu J (2005). Establishing long-term biodiversity assessment and monitoring in Northwest Yunnan, China: a growing need for baseline information. Mountain Research and Development, 26(3): 292–294

Mills L S, Soulé M E, Doak D F (1993). The keystone-species concept in ecology and conservation. BioScience, 43(4): 219–224

Morell J A (2005). Why are here unintended consequences of program action, and what are the implications for doing evaluation? American Journal of Evaluation, 26(4): 444–463

Morrison M L, Marcot B G, Mannan R W (2006). Wildlife-habitat Relationships: Concepts and Applications. 3rd, ed. Washington, DC: Island Press

Myers, N, Mittermeier R A, Mittermeier C G, da Fonseca G A B, Kent J (2000). Biodiversity hotspots for conservation priorities. Nature403 (6772): 853–858

NSF (National Science Foundation) (2008). Dynamics of coupled natural and human systems: abstracts of recent awards made through this program. Retrieved September 27, 2009 from http://www.nsf.gov/awardsearch/progSearch.do?WT.si_n = ClickedAbstractsRecentAwards&WT.si_x = 1&WT.si_cs = 1&WT.z_pims_id = 13681&SearchType = progSearch&page = 2&QueryText = &ProgOrganization = &ProgOfficer = &ProgEleCode = &BooleanElement = true&ProgRefCode = 1689,1691&BooleanRef = true&ProgProgram = &ProgFoaCode = &RestrictActive = on&Search = Search#results

Odum E P (1953). Fundamentals of Ecology. Philadelphia: Saunders

Odum E P (1977). The emergence of ecology as a new integrative discipline. Science, 195(4284): 1289–1293

Orr D W (2009). Shelf life. Conservation Biology, 23(2): 248–251

Pachauri R K, Reisinger A (2007). Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland

Parker D D, Manson S M, Janssen M A, Hoffman M J, Deadman P (2003). Multi-agent systems for the simulation of land-use and land-cover change: a review. Annals of the Association of American Geographers, 93(2): 314–337

Patterson W A, Sassaman K W (1988). Indian fires in the prehistory of New England. Ch 5 In: Nicholas G P. Holocene Human Ecology in Northeastern North America. New York: Plenum Publishing Corporation, 107–135

Perrings C (1991). Reserved rationality and the precautionary principle: Technological change, time, and uncertainty in environmental decision making. Ch. 11 In: Costanza R. Ecological Economics: The Science and Management of Sustainability. New York: Columbia University Press, 153–166

Pickett S T A, Burch W R Jr, Grove J M (1999). Interdisciplinary research: Maintaining the constructive impulse in a culture of criticism. Ecosystems, 2(4): 302–307

Pickett S T A, Cadenasso M L, Grove J M (2005). Biocomplexity in coupled natural-human systems: a multidimensional framework. Ecosystems, 8(3): 225–232.

Raffensperger C, Tickner J (1999) Protecting Public Health and the Environment: Implementing the Precautionary Principle. Washington, DC: Island Press

Risser P G , Birney E C, Blocker H D (1981). The True Prairie Ecosystem. US/IBP Synthesis Series (No. 16). Stroudsburg: Dowden, Hutchinson and Ross

Sayer J, Campbell B (2004). The Science of Sustainable Development: Local Livelihoods and the Global Environment. Cambridge: Cambridge University Press

Schlosberg D, Dryzek J S (2002). Political strategies of American environmentalism: Inclusion and beyond. Society and Natural Resources, 15(9): 787–804

Scheffer M, Carpenter S, Foley J A, Folke C, Walker B (2001). Catastrophic shifts in ecosystems. Nature, 413(6856): 591–596

Shellenberger M, Nordhaus T (2007). Break through: from the Death of Environ- mentalism to the Politics of Possibility. Boston: Houghton Mifflin Company

Sherman R, Mullen R, Li H, Fang Z, Wang Y (2007). Alpine ecosystems of Northwest Yunnan, China: An initial assessment for conservation. Journal of Mountain Science, 4(3): 181–192

Sherman R, Mullen R, Li H, Fang Z, Wang Y (2008). Spatial patterns of plant diversity and communities in alpine ecosystems of the Hendguan Mountains, Northwest Yunnan, China. Journal of Plant Ecology, 1(2): 117–136

Skei J, Larsson P, Rosenberg R, Jonsson P, Olsson M, Broman D (2000). Eutrophication and contaminants in aquatic ecosystems. AMBIO: A Journal of the Human Environment, 29(4): 184–194

Slocombe D S (1993). Environmental planning, ecosystem science, and ecosystem approaches for integrating environment and development. Environmental Management, 17(3): 289–303

Smith K F, Acevedo-Whitehouse K, Pedersen A B (2009). The role of infectious diseases in biological conservation. Animal Conservation, 12(1): 1–12

Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M, Miller H L (2007). Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press

Stern P C (1993). A second environmental science: Human-environment interactions. Science, 260(5116): 1897–1899

Thornton R (1990). American Indian Holocaust and Survival: a Population History Since 1492 (Civilization of the American Indian series). Norman: University of Oklahoma Press

TNC (The Nature Conservancy) (2006). The nature conservancy in China: understanding the alpine mosaic. Retrieved September 23, 2009 from http://www.nature.org/wherewe work/siapacific/china/strategies/art13997.html

Viña A, Bearer S, Chen X, He G, Linderman. M, An L, Zhang H, Ouyang Z, Lui J. (2007). Temporal changes in giant panda habitat connectivity across boundaries of Wolong Nature Reserve, China. Ecological Applications, 17(4): 1019–1030

Walcott R I (1973). Structure of the earth from glacio-isostatic rebound. Annual Review of Earth and Planetary Sciences, 1: 15–37

Walsh S J, McGinnis D (2007). Biocomplexity in coupled human-natural systems: The study of population and environment interactions. Geoforum, 39(2): 773–775

Whitney G G (1996). From Coastal Wilderness to Fruited Plain: a History of Environmental Change in Temperate North America, 1500 to the Present. Cambridge: Cambridge University Press

Worthington E B (1975). The Evolution of IBP. International Biological Programme Synthesis Series (No. 1). Cambridge: Cambridge University Press

Xu J, Wilkes A (2004). Biodiversity impact analysis in northwest Yunnan, southwest China. Biodiversity and Conservation, 13(5): 959–983

Yang X, He J, Li C, Ma J, Yang Y, Xu J (2008). Matsutake trade in Yunnan Province, China: an overview. Economic Botany, 62(3): 269–277

Yeh E T (2000). Forest claims, conflicts and commodification: The political ecology of Tibetan mushroom-harvesting villages in Yunnan Province, China. The China Quarterly, 161: 264–278

Young O R, Berkhout F, Gallopin G, Marco A. Janssen M A, Ostrom E, van der Leeuw, O (2006). The globalization of socio-ecological systems: an agenda for scientific research. Global Environmental Change, 16(3): 304–316

Zurick D (2006). Gross national happiness and environmental status in Bhutan.Geographical Review, 96(4): 657–681

Zong Y, Chen X (2000). The 1998 flood on the Yangtze, China. Natural Hazards, 22(2): 165–184

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