MOVING THE CONSERVATION GOALPOSTS:
A REVIEW OF CLIMATE CHANGE ADAPTATION LITERATURE

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I. ASSESSING THE STATE OF ADAPTATION

As the impacts of climate change become increasingly evident, resource managers and conservationists are being challenged to rethink long-held assumptions and strategies. Preparing for and coping with the effects of climate change—or climate adaptation—is becoming an overarching framework for conservation, and offers insight into the reconsideration of existing goals and strategies. This is an exciting time for the relatively new field of adaptation as it continues to undergo rapid growth, expanding adoption, and continued evolution and refinement. This literature review, developed as a contribution to the *Adaptation 2011*[2] conference, is designed to help characterize the evolution of the field, and highlight key trends underway.

Adaptation 2011 is a sequel to a similar gathering held in June 2009. That previous conference—*Adaptation 2009*—brought together conservation policymakers, practitioners, and thought-leaders to explore the state of this emerging discipline. As part of that earlier conference we reviewed the adaptation literature as it stood at that time, summarized in the paper *A New Era for Conservation* (Glick, Staudt, and Stein 2009). That review covered recent advances in the science of climate change adaptation in the context of fish and wildlife conservation and management, and identified overarching principles for adaptation planning as well as barriers to implementation.

In the two years since that conference, the field has advanced considerably, from the perspective of both planning and implementation. Indeed, many agencies and organizations have begun shifting their focus to better deal with the impacts of climate change and plan for a future that will look very different than the past. For instance, at the federal level, an interagency climate adaptation task force has been convened that is providing high-level guidance to agencies for integrating adaptation into their planning and operations (CEQ 2010,

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2011). Similarly, many non-governmental conservation organizations are now explicitly incorporating adaptation into their strategies and work plans. The collapse in late 2010 of efforts to pass comprehensive federal climate legislation, and consequent set-backs in achieving meaningful reductions in greenhouse gas emissions, has given added urgency and impetus to the field of climate change adaption.

The upcoming *Adaptation 2011* conference provides an opportunity to review and reflect on changes over the past few years, and assess the current state of play in the field of natural resources adaptation. This paper is designed to support the conference by using the published literature as a means for understanding how the field is evolving.

This literature review consists of two major sections. The first is a broad scan of the published literature to identify major trends in the development of the field. This survey was based on queries of the Web of Science, a comprehensive online bibliographic database, and focuses on what can be referred to as self-identified adaptation literature (i.e., the term "adaptation" appears in the article or bibliographic entry). These papers were subsequently reviewed and categorized to provide a quantitative snapshot of the current adaptation literature. The second major section of this literature review focuses on one particular topic of interest to the resource management community: conservation goals in an era of climate change. In this section, we review literature relevant to the topic of reconsidering conservation goals in light of a rapidly shifting climate.

II. SCAN OF CURRENT ADAPTATION LITERATURE

Although climate change adaptation has been discussed in policy circles for nearly thirty years, over much of that time it was largely regarded as a taboo subject, with scientists and activists concerned it would divert attention from addressing the underlying causes of climate change (Pielke et al. 2007). It has become increasingly clear, however, that no matter how vigorously greenhouse gas emission reductions are achieved (referred to as climate mitigation), major shifts in climate will occur, necessitating aggressive action on adaptation as well as mitigation (IPCC 2007, NRC 2010). Consequently, over the past decade, interest in and acceptance of adaptation has increased sharply, both within the conservation community and more broadly.

Adaptation literature has been the focus of several previous reviews (e.g., Glick, Staudt, and Stein 2009, Mawdsley et al. 2009, Heller and Zavaleta 2009). One of the most comprehensive from an ecological and biodiversity conservation perspective was carried out by Heller and Zavaleta (2009), who surveyed 22 years of literature (through March 2007) to identify recommendations for biodiversity management in the face of climate change.

We adopted a similar approach to Heller and Zavaleta in querying the Web of Science[3] bibliographic databases to identify relevant publications. To minimize overlap with that previous effort, our search focused on papers from 2007 to present. Repeating the broad search term strategy used by Heller and Zavaleta, even within this limited time span, returned

[3] http://wokinfo.com/products_tools/multidisciplinary/webofscience/

nearly 10,000 records. To refine our effort, we narrowed our search to identify those publications that specifically used the term "adaptation" in the database search fields. Specifically, we used Web of Science to identify all papers with the keywords "adaptation" and "climate change" or "global warming." To tailor our search for biodiversity or natural resources adaptation, at least one of the following search terms also had to appear as a keyword: management, biodiversity, conservation, restoration, planning, strategy, land-use, landscape, park, vulnerability, adaptive management, transition, resistance, resilience, ecosystem, or wildlife.

Between January 2007 and February 2011, a total of 1,173 papers met these general search criteria. To ensure that we focused only on publications that substantively address climate change adaptation, we screened abstracts for each of these papers and eliminated those that: 1) did not focus on climate adaptation (e.g., dealt with adaptation in the evolutionary sense of the word) or 2) did not explicitly address adaptation strategies or options (e.g., primarily focused on climate impacts with only passing reference to adaptation). This screening process narrowed our focus to 600 papers. To further explore the focus of these papers, we identified four broad topical categories: 1) ecosystem/biodiversity conservation; 2) natural resource management; 3) agricultural systems; and 4) human systems. Each paper was evaluated to determine fit relative to these four categories. We viewed these as non-exclusive categories and scored papers in one or more areas as necessary. For example, if a paper considered adaptation in the context of endangered species protection as well as working forest management, we scored it in both the ecosystem/biodiversity conservation and natural resource management categories. We also considered the target or intent of actions in our scoring. For example, papers that focused on protecting human property from flooding or sea level rise generally were categorized as human systems rather than natural resource management.

As with any such analysis, there are a number of caveats to be considered. First, there are some limitations with focusing exclusively on the published literature. We recognize that a considerable amount of current work on adaptation is appearing in the gray, or unpublished, literature. In addition, there is an inherent lag time as ideas, research findings, and experiences make their way into the formal literature. Attempting to scan the gray literature would be a monumental task, and the published literature represents a transparent and well-documented sample and proxy for what is happening across the broader community. Second, we acknowledge that by focusing our search strategy on "self-identified" adaptation papers we almost certainly have excluded some adaptation-relevant literature that did not use the term adaptation. However, given the growth of the field, we feel that use of this selection term provides a useful sample of the literature as a whole. Finally, our search terms were intended to optimize returns for papers focused on biodiversity conservation or natural resource management. We would expect, therefore, that papers focusing on agricultural or human systems would be under-represented in our sample. Figures for these categories should therefore be considered as conservative, despite their numeric dominance in our analysis.

II.a. Overall Trends in the Literature

Our literature scan confirmed that the body of climate change adaptation literature is growing rapidly. The number of papers that passed our screen increased five-fold from 2007 to 2010 (Figure 1). This growth is further evidence that the conservation and research community now realizes that mitigation alone will not be sufficient to address the challenges posed by climate change. Instead, researchers are starting to examine how to adapt practices to minimize the negative effects of climate change, as well as capitalize on any opportunities that climate change may offer.

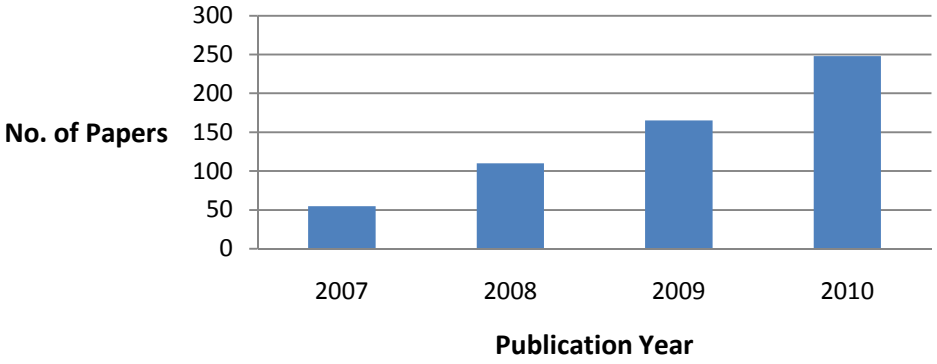

Figure 1. The total number of climate change adaptation papers has increased steadily over the past four years. Note: although we reviewed papers published through February 2011, 2011 is not represented on this graph.

Although our search strategy was designed to identify papers related to biodiversity conservation or natural resource management, it is clear that the literature is heavily skewed towards adaptation of human-oriented systems, which included papers on health effects, urban areas, and governance (Figure 2). We catalogued three times as many human system papers as biodiversity/ecosystem conservation-oriented papers. In fact, biodiversity/ecosystem-oriented papers were the least well-represented topical area in our search results.

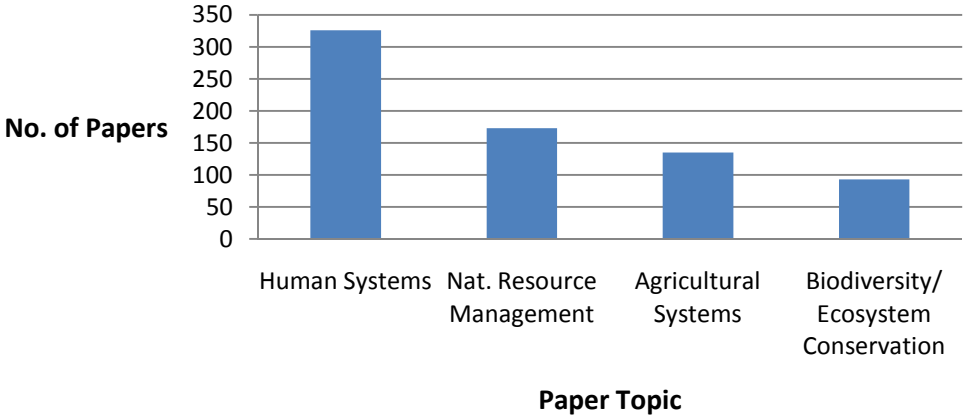

Figure 2. Adaptation literature categorized by topical focus. Human systems literature was the most common while biodiversity/ecosystem conservation was the least well-represented.

Finally, we also catalogued the papers by geographic region to determine how well North America was represented within the adaptation literature. While a large body of literature (roughly one-third) is either not location specific or global in nature, North America (including Mesoamerica) was the most well-represented region, followed by Europe and Africa (Figure 3). The Middle East and South America have the least coverage.

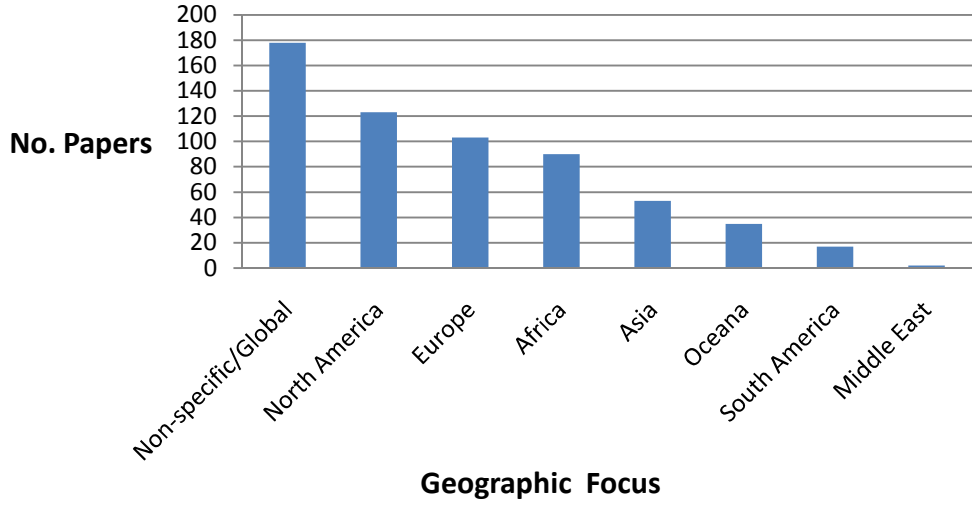

Figure 3. Number of adaptation papers focusing on particular geographic regions. Many papers were not geography specific or were global in nature. North America was best represented in the literature with South America and the Middle East least well represented.

II.b. Exploring Topic Areas in the Literature

II.b.1. Biodiversity/Ecosystem Conservation

Generally, papers categorized as pertaining to biodiversity/ecosystem conservation had a primary focus on species or ecosystem conservation or protected area management. As described above, although our search terms were tailored to highlight this topic area, it was the least well-represented category of literature in our survey. This suggests that in comparison to other topical areas, such as human and agricultural systems, the adaptation community at large is generally focused on other priorities. Interestingly, during the period covered by this review, the term "ecosystem-based adaptation" has gained currency (e.g.,Vignola et al. 2009, Colls et al. 2009, Watts et al. 2011), although it is still very poorly represented in the published literature. The need for additional research on adaptation for conservation of ecosystems and biodiversity is highlighted by the geographic distribution of this literature. Africa, Asia and South America were all poorly represented for this topic area in our literature scan, despite being home to many of the world's most biodiversity-rich regions.

The nature of the adaptation literature in this topic area also seems to be shifting. Previous reviews (e.g., Heller and Zavaleta 2009) found most papers to focus on general recommendations that are not specific enough to be actionable on the ground. While many

recent papers still focus on providing general guidance (e.g., Mawdsley et al. 2009, Hansen et al. 2009, Fazey et al. 2010) an increasing number of papers are starting to provide specific and actionable recommendations (e.g., Gilman et al. 2008, Yates et al. 2008, Galatowitsch et al. 2009, Young et al. 2010). Other papers (e.g., Hodgson et al. 2009, Krosby et al. 2010) are beginning to question or test the effectiveness of general strategies such as "increase habitat connectivity" that frequently have been proposed as key adaptation strategies, and a few are proposing new conservation strategies to respond to climate change (e.g. Manning et al. 2009, Beier and Brost 2010). In addition, some papers are beginning to examine the way institutional regulations and policies, such as those that face the U.S. national wildlife refuges or U.S. national parks, affect the ability of resource managers to pursue adaptation goals (e.g., Griffith et al. 2009, Baron et al. 2009, West et al. 2009). As more regions move beyond planning and wrestle with the challenges of implementation, it is likely that this trend towards more specific and focused adaptation literature will continue.

II.b.2. Natural Resource Management

Papers in this topic area generally focused on active management of specific natural resources, such as forests, fisheries, or water supply, often from a resource extraction or commodities perspective. Natural resource management was the second most common topic for substantive adaptation papers, covered in just under a third of all papers. Given the close connection between resources and the human societies that depend upon them, it is not surprising that roughly 30 percent of papers in this category were also classified as relating to human systems. Papers focused on North America dominated the natural resource management literature, with twice the number of papers for this region than any other. With respect to resource types, water was the focus of much of this literature, making up over half of the papers, with forest resources a close second. Fisheries, grazing, and harvesting of wildlife resources received a relatively small amount of attention.

II.b.3. Agricultural Systems

Papers addressing adaptation of agricultural systems generally looked at either needed changes to agricultural practices (e.g., water management, crop mixes, or timing of planting) or crop improvements to cope with changing climates. Agricultural systems were the topic of just under one-quarter of the literature we reviewed. A preponderance of the agricultural literature focused on regions with a heavy reliance on subsistence agriculture and development assistance. About forty percent of adaptation papers concerned with Africa focused on agricultural systems as did nearly half of the papers addressing South America. In comparison, less than 10 percent of North American adaptation papers in our review focused on agricultural systems. Changes in the management of water supply for agriculture was the focus of many papers in this category, as was ensuring food security in an era of climate change. The literature covered a diverse array of agricultural products from sorghum to citrus, although staples such as wheat, rice, and maize received the most attention.

II.b.4. Human Systems

For purposes of our review, the term "human systems" covered a very wide swath of topics, ranging from governance, community engagement, and health issues to infrastructure risk reduction. Although our literature review was tailored to identify papers focusing on conservation and natural resource management, human systems literature dominated results, comprising over half of the substantive adaptation literature returned by our search. Policy was a main focus of human systems papers, with many describing the needed integration of adaptation planning across multiple political scales (local, regional, national, and international). Other papers focused on integrating climate change adaptation into development planning or poverty alleviation efforts.

A large number of human system papers focused on adaptation at the local-community level, examining the roles that stakeholders, traditional ecological knowledge, and local perception should play in adaptation planning and execution. Many papers with a community-level focus discussed urban adaptation, while others emphasized adaptation in a human health context. A final area of interest was hazard mitigation and risk management with a focus on flooding and coastal development. Related to this, adaptation and the insurance industry was the focus of several papers.

III. CONSERVATION GOALS IN A RAPIDLY CHANGING WORLD

As conservation and resource management professionals wrestle with what climate change means for biodiversity conservation, one particularly vexing issue has emerged: *how will rapid climate change affect our conservation goals?* Numerous authors over the past few years have recognized that adapting to climate change will require a reconsideration of existing conservation goals, objectives, and targets (e.g., Pearson and Dawson 2005, Simenstad et al. 2006, Hobbs and Cramer 2008, Julius and West 2008, Lawler 2009, Game et al. 2010). Of particular interest is how to balance near-term goals for protecting and restoring species and ecosystems, with longer-term goals for sustaining functional ecological systems that are likely to persist under future conditions.

Conservation goals have always been important, but over the past few decades the conservation community has become far more sophisticated in the development and use of goals for driving conservation towards successful outcomes. Indeed, the emergence of the field of systematic or strategic conservation is predicated on having clear goals (e.g., Margules and Pressey 2000, Groves et al. 2002, Theobald and Hobbs 2002, Salafsky et al. 2002, Groves 2003, Tear et al. 2005, Nitschke and Innes 2008). Nonetheless, as Salafsky et al. (2002) point out, even without the added threat of climate change, the conservation community has not been very successful in articulating clear measurable goals designed to help measure what works and what doesn't. As Yogi Berra is reputed to have said "If you don't know where you are going, you might wind up someplace else." In a conservation context, we will likely be very disappointed in where we do end up in the absence of clear goals—a situation compounded by the ecological shifts underway due to climate change.

To help frame discussions about conservation goals at the *Adaptation 2011* conference, as well as contribute to the guidance development efforts of an NWF-convened Climate-Smart Conservation Experts Workgroup, this section of our literature review focuses on this special topic and summarizes issues identified by a number of the relevant papers from the past few years. This review highlights many of the trade-offs inherent in reconsidering and realigning goals, but is not intended to offer or endorse specific recommendations.

III.a. What Do We Mean by "Goals"?

In the conservation literature, as in planning literature generally, the distinction among such related terms as goals, objectives, and targets is not always straightforward. These terms are often used interchangeably, although given organizations and agencies often adopt very specific meanings and uses in their planning processes. For purposes of this review, we are using the term "conservation goal" to refer to the overarching vision for what one hopes to accomplish. Put another way, conservation goals may be thought of as the desired outcome of our conservation strategies and actions. Examples might include recovery of a particular endangered species, maintaining the full complement of species in a region, or sustaining a specific ecosystem service provided by a natural system. Our usage of the term conservation goal can be contrasted with "conservation target," which typically refers to specific features that are the focus of conservation efforts (Groves 2003). Such targets might be particular species or populations, ecosystem or habitat types, or even ecological processes or services.

Conservation goals are inherently a function of human values. As such, multiple goals may apply to the same landscape or biological features, depending on the values or legal mandates of the organization or agency setting the goals. Indeed, most environmental conflicts result from differing values of the same resource—existence values, for instance, versus commodity values, or even differing values among various conservation-oriented stakeholders. It is important to recognize that conservation goals are not universal, and will be highly dependent on the particular values of the organizations, agencies, or people setting them. And while scientists can offer specific information to guide conservation actions, the choice of restoration or management goals is ultimately a process driven as much by societal values, economic constraints, and political feasibility as scientific knowledge (Lackey 2004, Tear et al. 2005, Stein 2009, Lindenmayer and Hunter 2010).

We should also distinguish between goals, which are the focus of this review, and strategies that might be used to achieve those goals. Much of the adaptation literature focuses at the level of strategies; common examples include promoting habitat connectivity, reducing existing stressors, and protecting climate refugia (Heller and Zavaleta 2009, Glick, Staudt, and Stein 2009). In essence, strategies are the *how* to the *why* of goals.

III.b. Past as Precedent: The Evolution of Conservation Goals

While the prospect of reimagining and adjusting conservation goals in light of climate change may be unsettling, the principles and practice of conservation have been far from static over time, and we can gain insights from the past shifts in conservation paradigms. Since establishment of the nation's first national park (Yellowstone) in 1872, for instance, the goals of the national park system have expanded from protection of scenic landscapes to preservation of "fundamental physical and biological processes, as well as individual species, features, and plant and animal communities" (NPS 2006). Similarly, many of the U.S. Fish and Wildlife Service's national wildlife refuges were established specifically to benefit harvestable species, especially waterfowl. The National Wildlife Refuge System (NWRS) mission has over time been broadened to more clearly embrace "biological integrity, diversity, and environmental health" and "conservation of ecosystems" (U.S. Congress 1997, Fischman 2007, Griffith et al. 2009, Hagerman et al. 2010). As our environmental values and understanding of the natural world matured, so too did our collective conservation goals, embodied in such landmark conservation legislation as the Wilderness Act of 1964 and Endangered Species Act of 1973.

A dominant view during much of the development of our conservation ethic was that ecosystems existed in a state of equilibrium—the so-called "balance of nature" (Egerton 1973)—and that management efforts could be built around concepts such as succession—culminating in stable climax systems—and carrying capacity—premised on the maintenance of stable populations (Wallington et al. 2005). By the early 1970s, there was growing recognition that ecosystems are, instead, highly dynamic, and that disturbances play an important role in their overall function. The concept of ecological resilience—defined by Holling (1973) as "the capacity of a system to undergo disturbance and maintain its functions and controls"—became more widely recognized and embraced during this era (e.g., Holling et al. 1995, Peterson et al. 1998, Gunderson 2000, Folke 2006). The 1980s saw the emergence of the academic discipline of conservation biology (Soulé 1985), which placed conservation on a much firmer conceptual footing, as well as coalescence of the overarching concept of biodiversity (Wilson 1988, Noss 1990, Meine et al. 2006), which rapidly became the dominant framework for articulating and setting conservation goals.

Biodiversity conservation efforts typically have embraced the goal of sustaining the full complement of species and ecosystems in the area of interest, with particular focus on use of protected areas as a core strategy. Shaffer and Stein (2000) outlined a framework for achieving this goal within the context of conservation area establishment and management through application of the principles of *representation*, *redundancy*, and *resiliency*. In this context, representation refers to the goal of ensuring that each conservation target is protected in at least one place; redundancy addresses the need for multiple protected populations as a backup against loss of any single population; while resiliency addresses factors associated with ensuring population viability. Griffith et al. (2009), in their review of climate change adaptation for the NWRS, note that this framework continues to have utility for setting goals in an era of climate change.

III.c. Anticipating Change and the Death of Stationarity

Conservation traditionally has been based on a paradigm of maintaining an existing desired condition, or restoring species or habitats to some desired historical state (Craig 2010). Central to this approach to conservation has been the assumption of climatic "stationarity," which Milly et al. (2008) defined as "the idea that natural systems fluctuate within an unchanging envelope of variability." As those authors have declared, stationarity is now dead. Climates already are shifting beyond the historical ranges of variability against which our flora and fauna evolved.

Continued shifts outside the bounds of historical variability are expected to cause dramatic realignments and alterations in the spatial and temporal patterns of biodiversity. Because plant and animal species will respond differentially to these climatic shifts, many ecosystems are expected to disaggregate, while novel, or non-analog, assemblages are expected to appear (Hobbs et al. 2006, Williams et al. 2007, Williams and Jackson 2007, Seastedt et al. 2008). While climate change may be the underlying driver for many of these shifts, the proximate impacts often will be mediated through existing stressors and threats. In the face of such rapid changes, species will be faced with one of three potential responses: 1) adapt in place; 2) shift in distribution to track suitable conditions; or 3) go extinct (Berg et al. 2010).

III.c.1. From Resistance to Transition

Such shifts and realignments will make protecting species and ecosystems in their current locations difficult and in many cases impossible. Given this, one theme that emerges repeatedly in the adaptation literature is the need to move from a paradigm of protection and restoration, to one that is open to anticipating and actively managing change.

The overall options for managing this continuum of change have been described by Millar et al. (2007) as promoting *resistance*, enhancing *resilience*, and facilitating *transitions*. As described above, resilience in this context generally is defined as the ability of a system to cope with a disturbance and return to a particular functional state. Resistance, by comparison, is generally defined as the ability of a system to withstand a disturbance without significant loss of function. Facilitating transitions, on the other hand, suggests that we will need to place greater attention toward anticipating and guiding changes through planned and deliberate management objectives. The three way-stations on this continuum are not themselves goals, but rather represent classes of strategies for achieving goals—both short-term and longer-term—in the face of climate change.

Ultimately, as Millar et al. (2007) argue, efforts to increase ecosystem resistance may be futile attempts to "paddle upstream." West et al. (2009) emphasize that while the primary tenet of adaptation is a means to "reduce the risk of failing to achieve conservation goals," over time there will need to be a "transition from managing for resilience to managing for change." In particular, they stress that "anticipatory thinking will be crucial as climate change will likely exceed ecosystem thresholds over time such that strategies to increase ecosystem resilience will no longer be effective." Hobbs and Cramer (2008) also suggest that the new reality of climate change adaptation and the "no-analog future" entails the need "for a new approach in which ecological restoration focuses on the future as much as, if not more than, the past," and

that “the pathway toward this formulation is not clear and requires new ways of thinking and clearer insights regarding the dynamics of ecosystems under novel conditions.”

III.d. Rethinking our Conservation Goals

We are ultimately faced not with a choice of whether or not to reconsider many of our conservation goals; rather it is a matter of when, how much, and in what ways should they change. Julius and West (2008), for example, noted that “for virtually every category of federal land and water management, there will be situations where currently available adaptation strategies will not enable a manager to meet specific goals, especially where those goals are focused on keeping ecosystems unchanged or species where they are.” Addressing these circumstances, they suggest, will require fundamental adjustments in how ecosystems are managed, including: reformulating goals; improving management across landscapes; and identifying desired future conditions and managing toward those states.

Lemieux et al. (2011) observe that managers “will need to expand their definition of ‘desirable ecosystem states,’ …to accept maintaining ecological processes (i.e., trophic complexity and habitat selection) as an important goal in addition to species identity or ecological pattern.” Meanwhile, Comacho et al. (2010), note that climate change will force us to consider “whether we want to be curators seeking to restore and maintain resources for their historical significance; gardeners trying to maximize aesthetic or recreational values; farmers attempting to maximize economic yield; or trustees attempting to actively manage and protect wild species from harm even if that sometimes requires moving them to a more hospitable place.”

Here we review several of the key themes and issues that emerge from the literature in the context of rethinking our conservation goals. As these issues make clear, there are no easy answers and of necessity there will be trade-offs among long-held values. This review is intended to highlight many of those key issues and trade-offs, but is not intended to offer or endorse specific recommendations for realignment of goals.

III.d.1. From Pattern to Process

Among the most common suggestions in the literature for how conservation goals may need to shift is from those that focus on preserving current patterns of species compositions at particular locations towards goals focused on maintaining processes, both ecological and evolutionary (Harris et al. 2006, Pressey et al. 2007, Prober and Dunlop 2011). It is worth noting that process-oriented goals are not novel in conservation. Resource managers have long known that managing ecological processes is key to achieving desired conditions. What *is* novel is the notion that a focus on process might ensure the continuation of diverse and functioning ecosystems, even if the particular compositional and structural attributes may be strikingly different.

Luck et al. (2003) recommend that resource managers and conservationists expand the focus of efforts to protect biodiversity to include changes in the size, number, distribution, and

genetic composition of populations and the implications of those changes for functioning of ecosystems. Elmqvist et al. (2003) emphasize the importance of maintaining "response diversity," defined as "the range of reactions to environmental change among species contributing to the same ecosystem function." Similar shifts in objectives will be relevant for restoration activities (Choi 2007, Choi et al. 2008). According to Harris et al. (2006), "an increasing emphasis will be on proper functioning condition of a site – ecological integrity – and to a lesser extent on nudging a site back to historical conditions based on species. In general, process, not structure, will prevail." Finally, Traill et al. (2010) suggest that a logical approach for ecologists to assess the nexus between ecosystem function and climate change is to focus on the specific mechanisms by which climate change is likely to affect a host of factors, including "species behaviour, physiological and evolutionary response, population- and species-level interactions, and the knock-on effects for species diversity, system resilience, and function."

It is important to recognize that operational definitions of ecological process and function vary, which poses a challenge for determining conservation goals within this realm (Martinez 1996, Bengtsson 1998). For example, de Groot et al. (2002) propose that ecological functions be defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly and indirectly." Under this definition, the goal of maximizing one or more specific "ecosystem services" may be considered a driving factor for conservation efforts (Daily 1997, Srivastava and Vellend 2005). Others (e.g., Noss 1990, Pacala and Kinzig 2002) suggest less-anthropocentric definitions, focusing on fundamental elements such as primary productivity, decomposition, gene flow, and nutrient cycling (although these processes themselves may support key ecosystem services or other desired functions). As with all conservation goals, identifying which ecological function(s) for which a system should be managed ultimately requires judgments based on societal values (Srivastava and Vellend 2005).

III.d.2. Maintaining the Evolutionary Stage

Although resource managers tend to focus more on ecological processes than evolutionary processes, the latter will be exceedingly important in framing conservation goals under climate change. If managing biodiversity under climate change will largely be about "facilitating nature's response" (Prober and Dunlop 2011), then having explicit goals for allowing adaptation in an evolutionary sense to proceed will be important, as will maintaining the distinctive evolutionary character of regional floras and faunas.

One approach to retaining evolutionary potential that is gaining currency in the literature focuses on geophysical settings as promoters of future evolution. Anderson and Ferree (2010), for example, found that in the Northeastern United States certain geophysical settings harbor a disproportionate amount of biodiversity, including unusual or unique species, and serve as reliable predictors of overall diversity. Setting goals for the conservation of such unique geophysical "stages" may play an important role in enabling the continuing adaptation and evolution of species in a region and in sustaining overall diversity even if the individual "actors" or species will be different.

Beier and Brost (2010) similarly highlight the strong correlation between the distribution of many plant and animal species and certain topographic features such as elevation, insolation, slope, aspect, and landform. Understanding which of these variables is important for a given area and/or species can assist in the design of corridors that are more likely to support range shifts and maintain evolutionary potential under climate change. The authors point out that an important benefit to using what they term "land facets" as a tool to prioritize land conservation efforts is that it does not require use of specific climate change scenarios. Acknowledging that a focus on land facets will not conserve every species of concern, they argue that "conserving the stage for ecological and evolutionary processes should be an overarching goal for conservation biologists."

III.d.3. Resilience as a "Goal"

As agencies and organizations attempt to adapt to climate change, no word is invoked more frequently than "resilience," and enhancing ecosystem resilience is often identified as a specific management goal. Unfortunately, the term resilience is being used so broadly and indiscriminately—and proffered so often as an adaptation panacea—that its utility as a meaningful conservation goal is being undermined. Furthermore, as noted above, resilience is not really a conservation goal—at least in the way in which we use the term here—but rather may be a means to achieve one's goal. That point becomes clear by asking the operational question, promoting resilience "of what, to what" (Carpenter et al. 2001). In the context of protected area management, for example, Zavaleta and Chapin (2010) suggest that "one must define what should be resilient—what core, desired attributes or functions define the system to be maintained." They add that "resilience can be a means to sustaining values such as ecosystem services, native biodiversity, and aesthetic landscapes. It can also be an end in itself, as in the pursuit of more resilient parks, as long as it is with reference to desired values or attributes."

In practice, resilience "goals" often are intended to maintain status quo conditions rather than to anticipate and manage towards future transitions. In this sense, resilience is often suggested as a means of "buying time" for the protection of current conservation targets. Griffith et al. (2009), for instance, identify resilience as the "capacity of an entity to tolerate disturbance without transitioning to a different state that is controlled by a different set of processes." Similarly, in Julius and West (2008), resilience is defined both as a particular state: "the ability of a system to return to its initial state and function in spite of some major perturbation," as well as a measure: "the amount of change or disturbance that a system can absorb before it undergoes a fundamental shift to a different set of processes or structures."

There are, however, notable inconsistencies and wide variance in how the concept of resilience is defined and applied (Brand and Jax 2007, Zavaleta and Chapin 2010). Several studies suggest that the concept of resilience may be more open to the prospect of ecological transitions, at least to the extent that they might happen autonomously. According to Folke (2006), "resilience is not only about being persistent and robust to disturbance, as many suggest. It is also about opportunities that disturbance opens up in terms of recombination of evolved structures and processes, renewal of the system, and emergence of new trajectories."

Similarly, Lawler (2009) acknowledges that a resilient system may function "differently" in an altered climate. Heller and Zavaleta (2009) describe managing for resilience as a strategy that "explicitly focuses on increasing the flexibility and ability of systems to adapt and self organize in response to change."

III.d.4. The Role of Non-Native Species

One of the primary areas in which our perspective about conservation goals and objectives will be tested in an era of climate change is in how to define and deal with non-native and invasive species (Scott and Lemieux 2005, Green and Pearce-Higgins 2010, Schlaepfer et al. 2011). In particular, as conservationists adopt goals focused more on ecosystem processes than compositional patterns (which traditionally emphasize native species), what role are we willing to accept for non-natives as we envision and manage towards future conditions?

Invasive species are one of the primary threats to the nation's native species and ecosystems (Wilcove et al. 2000) and a number of studies suggest that climate change is likely to benefit some invasive species and harm others (Dukes and Mooney 1999, Hellmann et al. 2007, Thuiller et al. 2007, Vilà et al. 2007). However, because invasive species are by their very nature highly opportunistic, it is likely that climate change will often favor them over native species (Mooney and Hobbs 2000, Burgiel and Muir 2010).

Willis and Birks (2006) also acknowledge that the distinction between what is native and what is non-native can be unclear. For example, research using paleoecological data has helped scientists determine whether species currently considered to be exotic in some areas may, in fact, have existed there at some point in the distant past. The authors suggest that one's management response to non-natives might depend on whether those species are the "triggering mechanism" for ecological change, or they are "merely opportunists taking advantage of environmental change caused by other biotic or abiotic factors" (e.g., Gurevitch and Padilla 2004, Didham et al. 2005, Henderson et al. 2006).

Some non-native species, even where currently considered harmful, may perform useful ecological functions in a climate-altered system (Pyke et al. 2008). As climate change enables species (both native and non-native) to move into new areas, we will be faced with difficult decisions about when to accept (or even promote) the role of such newly established species as components of novel ecosystems.

III.d.5. The New "Natural"

An overarching conservation goal for many agencies and organizations focuses on the concept of "naturalness" (Cole and Yung 2010). As species shift in response to climate change, existing ecosystems disaggregate, and novel ecosystems (composed of both native and non-native species) emerge, what will be viewed and accepted as the "new natural"? This question is of more than just theoretical interest. U.S. national parks, for example, currently are managed to maintain "natural conditions," a term used to describe the condition of resources that would occur in the absence of human dominance over the landscape (NPS 2006).

Contrary to popular beliefs, most of our wild or natural lands already are subject to human management or intervention of one form or another; even the decision not to intervene in pest infestations or wildfires may be considered a form of management. Indeed, nature conservation has always been more about managing human activities and actions than about managing "nature" itself. In an era of climate change, however, we will undoubtedly need to accept the need for even more-intensively managed systems (Hobbs et al. 2010, Dawson et al. 2011, Prober and Dunlop 2011). Such active management will pose particular challenges for wilderness and other areas that have been established under a mission to be as pristine as possible (Cole and Yung 2010). Camacho et al. (2010), for example, note that "climate change may make it impossible to maintain the combination of goals we have come to expect of landscapes designed as reserves: historical continuity, protection of current features, 'naturalness' in the sense that our ecological processes occur with only limited human direction/assistance."

III.d.6. Triage

As conservation goals are adjusted in light of climate change, resource managers will increasingly be forced to grapple with the disconcerting notion of triage. Bottrill et al. (2008) define triage as "the process of prioritizing the allocation of limited resources to maximize conservation returns, relative to the conservation goals, under a constrained budget." In other words, conservation triage entails deciding which of one's conservation targets should be protected and how much intervention is necessary in a given place at a given time (Hagerman et al. 2009).

The concept of triage is likely to be met with considerable resistance, as many people may consider it admitting defeat, or perhaps "playing God." Certainly, it is morally difficult to decide that a particular species or population is "not worth the effort." Nevertheless, conservation triage is nothing new—trade-offs have always been a part of conservation planning and investment, with some places or species receiving more attention and investment than others (Metrick and Weitzman 1996). What is new is the likely number and impact of such decisions (Mastrandrea et al. 2010). As West et al. (2009) stress, "even with substantial management efforts, some systems may not be able to maintain the ecological properties and services that they provide in today's climate. For other systems or species, the cost of adaptation may far outweigh the ecological, social, or economic returns it would provide. In such cases, resources may be better invested elsewhere."

III.e. Barriers to Reconsidering Conservation Goals

The questions that rapid climate change poses for reconsidering conservation goals are not easy to fathom, let alone answer. Even though the principles and practice of conservation have evolved in the past, there are formidable institutional and psychological barriers to shifting from our current conservation paradigms and realigning our goals (Jantarasami et al. 2010).

III.e.1. Institutional Barriers

Julius and West (2008) identify four categories of institutional barriers to climate change adaptation for federal land and water management efforts: 1) legislation and regulation; 2) management policies and procedures; 3) human and financial capital; and 4) information and science. In terms of legislative barriers, some agencies or offices may have more flexibility to interpret and/or adjust management goals and objectives than others. For example, many of our existing conservation laws (e.g., the Endangered Species Act and the Wilderness Act) obligate managers to take a species- or protected area-based approach, which might limit an agency's ability to effectively address climate change threats across a broader, ecosystem-level scale. On the other hand, in a survey of managers in U.S. national parks and forests, Jantarasami et al. (2010) found that more process-oriented environmental laws, such as the National Environmental Policy Act (NEPA), might actually enable adaptation by providing established procedures to assist decision makers in analyzing and choosing among management options. The issues are not necessarily clearcut. Several recent legal reviews (e.g., Fischman 2007, Glicksman 2009, Craig 2010, Ruhl 2010), offer some insights on the nuances of federal conservation laws as they relate to climate change adaptation.

III.e.2. Psychological Barriers

Psychological barriers may prove to be even more of a challenge to overcome. Hagerman et al. (2010) underscore the fact that many conservationists find it difficult to move beyond the familiar goals of restoring and protecting existing patterns of biodiversity and *a priori*-selected conservation targets due a strong resistance to making trade-offs – a concept described in the psychology literature as "protected values" (Gregory et al. 2006). In their 2009 paper, Hagerman et al. put it bluntly: "The current dominant character of conservation adaptation decisions in the literature is one in which new inputs (e.g., climate envelope models) are used to inform one or more of the same means (protected areas or migration corridors) for the purposes of achieving the same set of objectives (protection of *a priori* identified species or ecosystems)."

This perspective was underscored by a recent study by Poiani et al. (2011), in which Nature Conservancy managers were asked to develop climate change adaptation strategies for their respective projects. The majority of the proposed adaptation strategies centered on resistance approaches, likely due to the "inherent tendency of conservationists to keep things as they are." Paradoxically, Repetto (2008) adds that there is a strongly held "ethos of managing by letting nature take its course with minimum intervention, despite the momentous changes that climate change will bring." Perhaps more notably, many people in the conservation community share the concern that, once current conservation policies are opened for debate (for instance, implementation of the Endangered Species Act)—even in efforts to improve their effectiveness under climate change—political interests may instead be successful in gutting the laws (Glicksman, 2009, Craig 2010).

Interest in and concern about realignment in conservation goals is not restricted to conservation and resource professionals. For instance, proposals to shift The Nature

Conservancy towards ecosystem service-based goals focused on providing benefits to people provoked a vigorous response—pro and con—from readers of *Nature Conservancy* magazine . This challenge for reconsidering goals is summed up by one reader who wrote "I was appalled…which ideas represent the goals of the Conservancy? " (Rosenblum 2011).

Overcoming institutional and psychological barriers will no doubt require considerable attention as climate change adaptation efforts progress. In particular, effective communication will be increasingly important. As Prober and Dunlop (2011) suggest, "to avoid an 'anything goes' response, we need to be more explicit about what we value in our biodiversity and encapsulate those values in new conservation goals," adding that "establishing these goals requires a philosophical debate that is only just beginning." Finally, Eastaugh (2011) argues that "society's perceptions of nature are fluid" and that "climate change presents us with the opportunity to move beyond the dichotomy of people as separate from nature and to re-establish the idea of nature as society's responsibility."

IV. CONCLUSION

This literature review, prepared as background for the *Adaptation 2011* conference, reveals that the field of adaptation is in a rapid period of growth and evolution. In particular, five times as many adaptation papers were published in 2010 as in 2007. Nonetheless, although our review was designed to identify papers focused on biodiversity and ecosystem-related adaptation, this was the least well-represented topic area among the more than 600 papers we reviewed in detail. Not surprisingly papers focused on adaptation of human systems dominated the published literature over this period. Among the papers that focused on biodiversity/ecosystem conservation, there has been growing emphasis on identifying more specific, actionable management options—a trend that will likely continue as climate change adaptation becomes more mainstream among practitioners.

Our review also looked at how the literature is addressing the issue of conservation goals in light of climate change. With extensive climate-driven shifts expected for many species and ecosystems, resulting in the disaggregation of existing ecosystems and emergence of novel ecological assemblages, the conservation community is grappling with what it means to reconsider and realign goals. Ultimately, goals are derived from and reflect societal values. There are as yet no easy answers to how our conservation goals should shift, but a number of themes and issues are emerging in the literature that highlight some of the projected trade-offs. A number of papers suggest a shift from pattern-based efforts—focusing on existing biodiversity distributions—to process-based efforts—focused on sustaining key ecological and evolutionary processes. Other papers address such issues as maintaining the geophysical stage upon which evolutionary process may continue to play out, use and overuse of the term "resilience" in conservation goals, the potential role of non-native species in future ecosystems, and the unsettling topic of conservation triage.

Conservation goals have evolved in the past, and can be expected to continue to do so as the community struggles with how to respond to the daunting challenges of rapid climate change. Clearly, there are no easy answers. The challenge climate change poses, however,

presents us with an opportunity to reassert the importance of nature to human well-being, and re-establish the idea of nature as society's responsibility.

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