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SPECIAL TOPIC ON BIODIVERSITY AND CLIMATE CHANGE

Editor's notes: Biodiversity provides basic needs for livelihoods and development of human beings. China, as one of countries with richest biodiversity in the world, contains 17 globally significant biodiversity hotspots. It was observed that climate change has impacted the biodiversity more or less from physiological, phonological and species level, to ecosystem level, and in some cases extinction of species. With the increasing climate change, the biodiversity subject to be more significantly impacted and human intervention is expected to amplify the impacts. Climate change is believed to be one of key threats of the biodiversity conservation. What kinds of cost-effective strategies and measures may be taken to allow biodiversity to adapt climate change impacts is a great challenge in China. This special issue invited three authors to share actions and experiences on the adaptation of biodiversity to climate change, including a case study, a review of adaptation planning and an introduction of national strategy and research developments. The editors hope these articles can provide useful information for the biodiversity conservation under climate change in China.

Climate Change Adaptation Planning for Biodiversity Conservation: A Review

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Abstract

Climate change has been linked to well-documented changes in physiology, phenology, species distributions, and in some cases, extinction. Projections of future change point to dramatic shifts in the states of many ecosystems. Accommodating these shifts to effectively conserve biodiversity in the context of uncertain climate regimes represents one of the most difficult challenges faced by conservation planners. A number of adaptation strategies have been proposed for managing species and ecosystems in a changing climate. However, there has been little guidance available on integrating climate change adaptation strategies into contemporary conservation planning frameworks. The paper reviews the different approaches being used to integrate climate change adaptation into conservation planning, broadly categorizing strategies as continuing and extending on "best practice" principles and those that integrate species vulnerability assessments into conservation planning. We describe the characteristics of a good adaptation strategy emphasizing the importance of incorporating clear principles of flexibility and efficiency, accounting for uncertainty, integrating human response to climate change and understanding trade-offs.

Keywords: climate change adaptation; conservation planning; species conservation; vulnerability analysis

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1 Introduction

There is little doubt that the ongoing human-forced climate change event will become one of the main contributors to the global loss of biodiversity and has already caused accelerated rates of species' extinctions and changes to ecosystems across the Earth [*Sala et al.*, 2000; *Thomas et al.*, 2004; *Pimm*, 2008]. Two international conventions, the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity (CBD), recognize that climate change is one of the greatest threats to biodiversity and that some of the actions proposed to mitigate climate change may also be threats to biodiversity. Within the CBD, there are key programs of work (e.g., forest biodiversity, mountain biodiversity) that address climate change adaptation. And the UNFCCC explicitly recognizes that adaptation is vital to reduce the impacts of climate change. For example, the Bali Action Plan, which was adopted at UNFCCC COP13 in Bali, December 2007, identified adaptation as one of the key building blocks required for a strengthened future response to climate change to enable the full, effective and sustained implementation of the Convention (UNFCCC) through long-term cooperative action, now, up to and beyond 2012. At the Cancun Climate Change Conference in December 2010, Parties established the Cancun Adaptation Framework (CAF) with the objective of enhancing action on adaptation, including through international cooperation and coherent consideration of matters relating to adaptation under the Convention.

Despite the importance placed on adaptation in these conventions, and the recent development of frameworks and work plans, there has been slow progress in the development of appropriate methodologies for integrating climate change adaptation strategies into conservation planning [*Hannah*, 2010; *Poiani et al.*, 2011]. One of the reasons for this slow progress is the considerable confusion over what an adaptation plan/strategy/action is in contrast to contemporary conservation [*Andrade et al.*, 2011; *Seimon et al.*, 2011; *Watson et al.*, 2011a]. This confusion is not bound in the ivory towers of academia-policy makers, practitioners and donors from all over the world are commonly asking for more guidance over what adaptation is (and is not), and what adaptation strategies are most appropriate at particular localities [*Andrade et al.*, 2011; *Seimon et al.*, 2011]. It has not helped that many groups conducting conservation are advocating "business as normal" solutions as adaptation strategies at international conferences and policy meetings, so as to ensure they get continued funding.

In order to encourage debate and discussion among the conservation arena, we wanted to first describe some of the different strategies being used to integrate climate change adaptation into conservation planning (with some examples) and then to compare them. Specifically, the main objectives of this review are to categorize adaptation strategies that are currently being implemented around the world, and analyze their effectiveness for conserving biodiversity in the context of human-induced climate change. By doing this review, we have found a number of characteristics that appear to be important in effective adaptation planning.

2 What is a climate change adaptation strategy?

Adaptation, as defined by the *IPCC* [2007], is an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". Accordingly, a key aspect of integrating adaptation into conservation planning is to ascertain what the future will look like (and accepting the uncertainties around this), and then integrate this knowledge into all activities (and not just conservation-oriented planning) that are currently in place. While this is simple on paper, reviews of the conservation literature when searching on terms such as "climate change", "climate adaptation", and "conservation planning and climate change" highlight that this integration of knowledge about future conditions into current planning is very rare [*Watson et al.*, 2011a; 2011b]. There has been little critical review of what distinguishes some of the very familiar conservation approaches and actions (e.g., protecting corridors) touted as adaptation strategies as truly addressing the new or enhanced challenges faced by species in the context of rapidly changing climate conditions and their impacts. It is unclear which activities are appropriate and which are not.

We hope to overcome some of this uncertainty by classifying some of the adaptation strategies that are currently being conducted. In order to do the following classification, we have reviewed much of the planning literature in academic journals as well as the grey literature generated from governments and non-government organisations over the past decade. We have also spent considerable time talking to conservation practitioners around the world who are undertaking climate change adaptation planning or action (some of these are captured in *Andrade et al.* [2011] and *Seimon et al.* [2011]). We note that our classification is highly subjective, and we provide this as not the final statement on the issue but rather to encourage discussion and debate over what is a suitable adaptation activity and what is not.

3 The three general strategies of adaptation

To date, we believe that almost all conservation planning activities that have been labelled in some form as "climate change adaptation" can be placed into three broad strategies: 1) continuing "best practice"; 2) extending on "best practice" principles in consideration of species and ecosystems response to past climate change; and 3) integrating assessments on species vulnerability to climate change into a conservation planning framework. The following sections describe the strategies in more detail and outline how they differ from each other.

3.1 *Strategy 1: Continuing "best practice"*

Given the limited extent of natural or semi-natural habitats remaining outside conservation networks in many parts of the world and the continued loss and fragmentation of unprotected sites, the development of conservation networks, and especially protected areas, will remain a cornerstone of future conservation strategies. A review of the text in the latest strategic plan of the CBD highlights this with many of the targets focused on increasing the protected area estate. For example, Target 11 of the Aichi Biodiversity Targets states that by 2020, at least 17% of terrestrial and inland water and 10% of coastal and marine areas, especially areas important for biodiversity and ecosystem services are effectively managed and include well-connected systems of protected areas.

The growth of spatial conservation planning over the past two decades [*Moilanen et al.*, 2009; *Watson et al.*, 2011a], has led to the identification of a series of key "best practice" principles that are focused on enhancing conservation networks: 1) identify and protect representative habitats (e.g., all habitats in a region are represented in conservation areas); 2) identify a persistence (adequacy) target of protection; 3) avert risk through replication (i.e., protection of multiple examples of each target); 4) protect critical habitats for threatened species; and 5) ensure the design is efficient, and aiming to reduce current threats to natural systems.

These principles are now used by governments and non-government organisations all over the world to justify new conservation action. Importantly, they are now being widely accepted as entirely consistent as an adaptation strategy [*Hannah et al.*, 2002; *Steffen et al.*, 2009]. A nice example comes from the Daurian Steppe of East Asia which is a vast temperate grassland that is globally significant for its biodiversity and unique herder communities [*TGCI*, 2010]. Existing and emerging development pressures are placing both the biodiversity values and livelihoods of the local people in peril. The region is undergoing an unprecedented period of economic growth with rapid expansion of urbanization and mining. Hence, many organisations are urging for the expansion of the protected areas beyond the existing 7% coverage as an immediate need to address a spectrum of threats facing the Dauria [*TGCI*, 2010]. Expanding and improving the protected area system is expected to ensure the adequate protection of habitat and migration area for fauna species such as the Mongolian gazelle (*Procapra gutturosa*) and eastern great bustard (*Otis tarda dybowskii*). These actions are likely to provide protection of grassland and other habitats from accelerating development including mining, ensure the conservation of wetlands and rivers to safeguard scarce water supplies and, as such, ultimately provide resilience to climate change [*Chan et al.*, 2004; *Olson et al.*, 2005].

As we will discuss in depth later, relying solely on actions based on a strategy of continuing "best practice" is problematic as it is based on two false assumptions: 1) a relatively stable climate, and 2) that biological attributes are inextricably linked to place. When the problematic logic to these assumptions are ignored, the "best practice" conservation paradigm is largely predicated on static spatial planning, and focused almost entirely on the establishment of protected areas and the identification of "gaps" of important habitat. While these actions are important for conservation, especially in a time of human-forced climate change, they cannot encompass a holistic adaptation strategy as species, and ecosystems are likely to change their geographic space as the climate changes.

3.2 *Strategy 2: Extending on "best practice" principles*

A goal of simply trying to achieve an adequate and representative system of reserves based on current species and ecosystem distributions and conditions is now regularly being rejected by most planners that are interested in incorporating future climate change into their plans [*Mackey et al.*, 2008]. It has been replaced by the identification of a series of extensions of these principles, all of which are based on the fact that climate change is a natural phenomenon and that species have overcome past climate change events [*Heller and Zavaleta*, 2009; *Mackey et al.*, 2009; *Watson et al.*, 2009; 2011a]. These principles are: 1) significantly expanding the current protected area estate to maintain viable populations of species and maximize adaptive capacity; 2) significantly expanding the current protected area estate so as to capture refugia; 3) assign priority to protecting large, intact landscapes; and 4) ensure functional connectivity is maintained beyond protected areas.

These principles have recently been operationalized in the conservation planning field, with data and methods now becoming available that quantify key ecological and evolutionary processes at appropriate spatial scales [*Pressey et al.*, 2007; *Mackey et al.*, 2008], and using these data to plan future protected area networks [*Klein et al.*, 2009]. It is not just the planning arena that are beginning to use the strategy 2, with action being urged across the world to protect large intact landscapes based on the back of this [*Watson et al.*, 2009; *Locke and Mackey*, 2009]. For example, the Tibetan Plateau, with an average 4,000 m altitude, covering 2 million km^2 is a regional conservation priority. Given its geographical location, topography and special climate systems, the plateau is anticipated to experience climate change impacts with repercussions for the hydrological systems that influence major Southeast Asian river basins, which support 1.4 billion people. The plateau includes the Changtang National Nature Reserve (the world's second largest terrestrial reserve at 300,000 km^2), a vast grassland landscape (alpine steppe and alpine meadow) and a diverse assemblage of rare and endangered wild ungulates including the Tibetan antelope or chiru (*Pantholops hodgsonii*) and wild yak (*Bos grunniens*) (Convention on International Trade in Endangered Species of Endangered Flora and Fauna (CITES) Appendix I, China Protection Level I and IUCN status endangered chiru and vulnerable wild yak). Assigning priority to protecting large ecosystems such as the Changtang Nature Reserve and significantly expanding the protected area system to especially capture refugia for endangered species is an important climate change adaptation strategy that extends on "best practice" principles.

While it is widely accepted that strategy 2 is useful and much more appropriate than strategy 1, it must be remembered that this anthropogenic-driven climate change event is different in terms of both the size and rate of change [*Kingsford and Watson*, 2011]. As a consequence, simply adhering to the principles outlined above is unlikely to capture a coherent conservation adaptation agenda as some species and ecosystems will not be able to simply rely on their adaptive capacity to ensure their persistence. It is therefore necessary that conservation planning and action explicitly account for this unique human-forced climate change event, and the vulnerabilities and impacts it will cause.

3.3 *Strategy 3: Integrating assessments on species vulnerability to climate change into a conservation planning framework*

To overcome the limitations of relying on a series of best practice principles, there are a set of methodologies being developed that aim to understand how vulnerable species are to climate change and integrate this knowledge into planning frameworks. Most of the work so far has been done on the first component (assessing vulnerability) but there are some examples of utilizing these vulnerability assessments into planning.

3.3.1 *Undertaking species vulnerability assessments*

The vulnerability of species to climate change is generally assessed as a product of its susceptibility/sensitivity (defined by its intrinsic biological traits), exposure (does the species occur in a region of high climatic change?), and adaptive capacity [*Foden et al.*, 2009; *Hole et al.*, 2011]. There are a number of methods that assess species vulnerability and integrate this into conservation planning [*Hole et al.*, 2011]. Arguably the most commonly used methods utilize some variation of climate-envelope (or empirical niche) models [*Guisan and Thuiller*, 2005]. Climate-envelope models use current distributions of species to articulate the range of climatic conditions that suit them. Climate model projections for the future are then examined to determine where on the landscape the optimal "envelope" of climate conditions may be located in the future. For many species, these models have shown that large geographic displacements and widespread extinctions will take place [*Araújo and Rahbek*, 2006]. A critical following step is to integrate assessments of a species' vulnerability to climate change into conservation planning.

3.3.2 *Integrating species vulnerability into a conservation planning framework*

while undertaking species' vulnerability assessments is an important first step in developing an adaptation plan, it can only be considered a first step, and there needs to be a process of integrating the data into a holistic planning framework. While still in its infancy, there are now a number of tools aimed at overcoming the considerable uncertainty and complexity of climate change by tailoring adaptation strategies to particular species, human communities and geographies [*Groves et al.*, 2010; *Seimon et al.*, 2011]. Common to many of these tools are the following steps: 1) Identify features targeted for conservation (species, ecological processes, or ecosystems) and specify explicit, measurable management objectives for each feature. 2) Build a conceptual model that illustrates the climatic, ecological, social, and economic drivers of each feature. 3) Examine how the feature may be affected by multiple plausible climate change scenarios. This can be a threats-based analysis of current and future states, and often takes the form of a vulnerability assessment. 4) Identify intervention points and potential actions required to achieve objectives for each feature under each scenario. 5) Prioritize potential actions based on feasibility and tradeoffs. 6) Implement priority actions, monitor the efficacy of actions and progress toward objectives, and re-evaluate to address system changes or ineffective actions.

The Adaptation for Conservation Targets (ACT) Framework is one such tool that was developed by conservation planners and practitioners[①]. The ACT Framework is a participatory and iterative process for generating adaptation strategies that is practical, proactive, place-based, and helps to overcome the reluctance to take actions due to uncertainties inherent in future projections (Fig. 1). The logic is now part of a research plan being developed by an international NGO, the Wildlife Conservation Society in Tibet. Focusing on endangered migratory ungulates in the Changtang Nature Reserve in the Tibetan grasslands, the project seeks to use climate change models to identify potential future refugia for wildlife and generate information on the spatial distribution of future grazing conflict areas. The aim is to build capacity of community and management authorities on

① Cross, M. S., E. S. Zavaleta, D. Bachelet, et al., in review: Adaptation for Conservation Targets (ACT) Framework: A tool for incorporating climate change into natural resource conservation and management, accessed http://www.cakex.org/virtual-library/2285

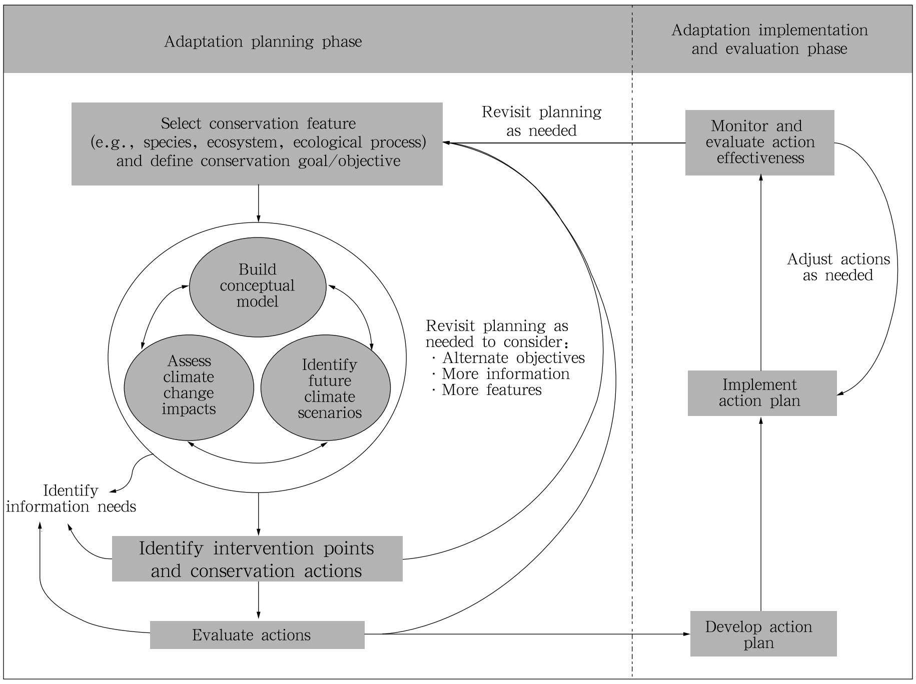

Figure 1 The Adaptation for Conservation Targets Framework①. An online description of this framework is available at the Climate Adaptation Knowledge Exchange (CAKE, http://www.cakex.org/virtual-library/2285)

sustainable pasture management practices aimed at reducing grassland degradation and human-wildlife conflict, both of which are tightly linked to the continued survival of globally significant grassland steppe ecosystems and associated ecological communities.

Rather than simply relying on "rules of thumb", this type of structured adaptation planning explicitly considers the long-term impacts of climate change when determining appropriate and necessary conservation actions. Targeted climate change planning also attempts to strategically direct where adaptation actions are needed most. Importantly, once this planning is conducted, some of the solutions that are implemented may be similar to the strategies outlined in either strategy 1 or strategy 2. The key difference is that this strategy has incorporated a vulnerability assessment into the planning phase, and hence does not rely on best guesses or "rules of thumb".

For example, the Przewalski's gazelle (*Procapra przewalskii*) is classified as endangered and a conservation target on the Qinghai-Tibetan Plateau but many gazelles do not live within protected areas [*Hu and Jiang*, 2011]. Using measures of species range shift in species distribution models, *Hu and Jiang* [2011] explored how the distribution of Przewalski's gazelle may be impacted by projected climate change, evaluating the uncertainty in the projections of the risks arising from climate change. Their study shows that current localities of gazelles will undergo a decrease in their occurrence probability and clearly suggests climate change poses a severe threat and increases the extinction risk to Przewalski's gazelle. Their findings highlight why it is extremely important that conservation strategies consider the predicted geographical shifts of endangered species and are planned with full knowledge of the reliability of projected impacts of climate change. To avoid the species becoming restricted to a few sites across a fragmented landscape, the authors recommend the following: 1) to conserve all possible habitats given the endangered status of the gazelles and the uncertainty of the impacts of climate change; 2) to secure existing protected areas and establish new reserves in regions projected to be suitable over longer timescales or habitats with high suitability (i.e., refugia as shown in the models); 3) to establish migration corridors between populations of the gazelle as well as between highly suitable habitats since a large proportion of projected highly suitable habitats are under pressure from intensive human activities. These types of recommendations can now feed into a robust and dynamic planning process that works out where actions are needed most when climate change is considered.

4 What are the characteristics of a good adaptation strategy?

Regardless of the strategy being developed, our review of the planning literature has allowed us to identify some fundamental principles that are characteristics of a good adaptation strategy.

4.1 *Incorporate clear planning principles (flexibility, efficiency)*

Flexibility is a key principle of systematic conservation planning. This is primarily because economic, political and social considerations influence decision-making on proposed expansions of existing protected area networks. Given that socio-economic constraints are often dynamic and not accurately estimated, a flexible conservation plan provides alternative solutions and assists planners to take account of opportunities [*Knight and Cowling*, 2007]. It must be clear, however, why certain areas are selected and others not, and hence transparency is a clear part of flexibility [*Nicholls and Margules*, 1993]. For example, a piece of land with high conservation value might not initially be available for conservation management, but may later become available for sale, lease or other management intervention [*McDonald-Madden et al.*, 2008]. Adopting a flexible plan also gives scope for sensible resolutions of resource use conflicts.

Efficiency in representation of species, habitats and ecological processes is an important aspect of a good adaptation strategy and complementarity is a key concept in achieving representation "efficiently". The concept underlying efficiency through complementarity is that conservation areas should complement one another in terms of the "features" they contain, the species, communities, habitats, ecological processes, etc. Each conservation area should be as different from the others as possible until all the "differences" (e.g., different species, communities) are adequately represented. It is important to note that the principle of efficiency is not simply about achieving complementarity. Achieving an efficient network is also a matter of achieving objectives for the least possible cost, where cost may reflect the financial cost of implementing and managing protected areas or the costs of lost opportunities for economic development [*Naidoo et al.*, 2006].

4.2 *Account for uncertainty*

There is some level of uncertainty in every aspect of conservation planning [*Regan et al.*, 2009]. For example, parametric uncertainty is rife in all the data that are used to develop conservation plans and sensitivity analyses often help address this type of uncertainty [*Whittaker et al.*, 2005]. Frameworks for defining conservation priorities that use decision theory help achieve explicitly stated objectives while acknowledging constraints on conservation actions and the levels of uncertainty involved within the decision process. Overall, good adaptation strategies must take into consideration the various forms of uncertainties relevant to the conservation problem.

4.3 *Understand trade-offs*

It is important to recognize that trade-offs will be an inherent part of designing and implementing a good climate adaptation strategy [*Mertz et al.*, 2007]. For example, the achievement of adaptation planning objectives will depend on the spatial congruence between identified refugia for endangered species and ecosystem services. Any given planned conservation action has been traded off with all other actions and also against the cost of delayed action. Probably the best way forward for conservation planners is to explicitly acknowledge and derive trade-offs, recognizing that no single objective is best, but instead offering a range of alternative options that optimize different societal aspirations [*Whittaker et al.*, 2005; *Polasky*, 2008].

4.4 *Manage for both climate variability and long-term climate change*

The impacts of climate change are not simply those of glacial thawing or sea level rise; the extremes may be far more important. Good adaptation planning moves away from managing simple long-term changes in mean climate variables to one that takes into account changes in the extremes. There is already clear evidence that extreme temperatures can devastate ecosystems and species (e.g., coral bleaching). Conservation planning and adaptation needs to consider discrete impacts, principally extreme weather events (e.g., storms, droughts, fires, extreme temperature or rainfall events, king tides) that drastically alter the resilience and persistence of ecosystems and species. This can be done with vulnerability assessments that integrate the impacts of climate variability and climate change into spatially explicit planning and management tools [*Watson et al.*, 2011a].

4.5 *Integrate human response*

Implementation of adaptation involves societal intervention to manage systems based on the knowledge that environments will change with climate, where actions reduce risks from the change, particularly within vulnerable systems. The linkages between the impacts and responses of people and biodiversity to climate change are strong, and often require "ecosystem based adaptation" (EBA) frameworks that use biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to adverse effects of climate change [*Grantham et al.*, 2011]. Such EBA approaches need to build clear objectives for conservation of biodiversity. Such approaches can account for the role of ecosystem services in human adaptation, helping people adapt in equitable and participatory ways that avoid short-term costs but reduce long-term additional pressures on natural systems, on which people depend. We believe that while in its infancy, the tenets of EBA can be integrated into mitigating impacts of climate change and be used to find optimum solutions to balance the needs of both humans and biodiversity.

4.6 *Clarity of adaptation goal: Resilience vs. resistance*

A good climate adaptation strategy explicitly recognizes a clear goal that either promotes resistance, which is the ability of a system to remain unchanged in the face of climate change or resilience, which is the ability of the system to recover from perturbations [*Holling*, 1973]. In theory, resistance strategies attempt to bolster a system's defenses to rapid environmental change, while resilience strategies attempt to bolster a system's ability to absorb rapid environmental change [*Heller and Zavaleta*, 2009]. One of the limitations of many adaptation projects (and in fact, many conservation projects in general) is that it is unclear what the goal is of an overall project [*Watson et al.*, 2011b]. In many cases it is simply unclear whether the action aims to achieve a resilient or resistant set of goals. There is not "right" or "wrong" answer to which goal is right when you consider climate change (resilience or resistance) but there may be projects where one goal is far more suitable than another [*Lawler*, 2009]. The key to goal setting in the adaptation planning process is that it needs to be identified by all the relevant stakeholders, and should lead to transparent and achievable targets being generated.

5 Conclusions

Climate change is a fact of our times. It is already altering species from the poles to the tropics [*Root et al.*, 2003; *Parmesan*, 2006] and because greenhouse gas emissions to date commit the Earth to substantial climate change, will do so for decades or centuries to come regardless of the mitigation efforts we undertake. In this paper, we have identified a number of broad strategies being used by conservation planners to overcome the challenge presented by climate change. We are critical of an approach that relies solely on status quo and continuing "best practices" as we think it is inappropriate and in the long-term, could lead to conservation activities that are maladaptive. Planners must adapt to deal with the new reality that climate change presents, and abandon the current focus on the preservation and restoration of 20th century reference conditions, as they will no longer be relevant in a changing world. We believe that a refocus on extending "best practice" principles is a more appropriate response as the set of "common sense" general principles outlined above for conserving species and ecosystem viability are based on adaptive responses to past climate changes and should always be considered and enacted, especially if there is limited access to data on future climate changes and associated impacts [*Heller and Zavaleta*, 2009; *Mackey et al.*, 2009; *Watson et al.*, 2009]. However, integrating future climate change forecasts and scenarios into conservation strategies is going to be vital for long-term biodiversity protection as this human-induced climate change event is different from past climate changes [*Heller and Zavaleta*, 2009]. This is especially true in the context of the many other current threats to natural systems that will also be affected by changes in local climate [*Sala et al.*, 2000; *Orr et al.*, 2008]. Structured climate change planning needs to consider not just how species will be affected by climate, but also how humans are going to be affected. Many species are likely to go extinct because of the direct and indirect consequences of climate change unless we develop proactive planning frameworks within a new, more dynamic conservation paradigm.

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