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BIODIVERSITY VIEWPOINT

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Incorporating sociocultural adaptive capacity in conservation hotspot assessments

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ABSTRACT

Aim To highlight the importance of combining the geographies of sociocultural adaptation and biodiversity risk for creating global change conservation strategies.

Location Global.

Methods We review global conservation adaptation strategies and the geographies that influence biological risk, as well as sociocultural capacity to set priorities for a conservation response. We then describe relationships among these geographies and discuss criteria for prioritizing areas that will have the greatest potential for effective adaptive action.

Results Strategic conservation requires integrating biological geographies with physical and cultural geographies to maximize potential success with limited resources.

Main conclusions Biogeography is important for strategic conservation, but it is not the only geography that matters. There is a physical geography of global change providing a complex backdrop against which biodiversity is responsive. Additionally, there is a human geography that drives the degree of threat through variations in anthropogenic disturbance of natural systems and also drives variation in potential mitigation through sociocultural capacity for conservation action. Conservation biogeography typically considers the physical geography of change and the biogeography of threat; it must expand to consider the sociocultural geography of intervention, negative and positive, if it is to be effective. Consideration of these varying geographies also drives different choices for how to implement conservation strategies.

Keywords
Biodiversity, biogeography, climate change, global change, sociocultural adaptation, sociocultural vulnerability.

INTRODUCTION

> Even the most stringent mitigation efforts cannot avoid further impacts of climate change in the next few decades, which makes adaptation essential, particularly in addressing near-term impacts.
>
> IPCC 2007b

A decade after Myers's refinement of his biodiversity hotspot analysis (Myers *et al.*, 2000) and the observation that human population density is 71% higher in hotspots than outside of them (Cincotta *et al.* 2000), conservation biogeographers still lack compelling strategies for integrating the sociocultural geography into measures of biodiversity threats. Conservation biogeography (Whittaker *et al.*, 2005) has emerged as a critical area of study with which to understand climate change as a threat to biodiversity (e.g. Thomas *et al.*, 2004, 2006). Climate change (IPCC 2007a) and biotic responses to climate change (Parmesan & Yohe, 2003; Parmesan, 2006) have forced conservation scientists to incorporate adaptation strategies for maintaining biodiversity (Mawdsley *et al.*, 2009). Adjusting conservation strategies to maintain diversity in recognition of climate change requires a complex suite of considerations, including a strong consideration of conservation biogeography (Whittaker *et al.*, 2005). Nevertheless, combining the physical geography of global change with the biogeography describing diversity and threat is not sufficient to predict future

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outcomes, or appropriate management responses. The geographies of human populations, economics, politics and culture have profound impacts on the capacity to do successful conservation. Not only does human geography affect the threat to biodiversity, but also the suite of appropriate management responses to that threat (Borgerhoff-Mulder & Coppolillo, 2005; McBride *et al.*, 2007).

We argue that effective conservation management responses must better incorporate a geographical approach to characterizing both the human threat to biodiversity and the adaptive capacity of human cultures. The capacity to implement conservation measures varies across institutions, landscapes and political domains. Human data are often readily available (e.g. see Brooks *et al.*, 2005), but are not explicitly and generally used in the context of strategic conservation. We propose that it is now time to redress this oversight.

In this article, we outline a broad suite of geographical considerations that ought to drive global change adaptation strategies for the preservation of biodiversity. We describe multiple geographies requiring consideration to manage 21st century biodiversity. We argue that it requires more than simply understanding biodiversity hotspots, or overlapping those biodiversity hotspots with the geography of climate change, to create an effective conservation strategy. Conservation must also explicitly consider sociocultural geography as a landscape of opportunities impeding or facilitating meaningful action (Moore *et al.*, 2004). We caution that an emphasis on adaptation cannot cure the dire and perhaps irreversible effects of global change on biodiversity or indeed human welfare (Orlove, 2009); that is, we must be wary of the suggestion that partial melioration matches prevention. Rather, we argue that adaptation that includes a holistic geographic framework, along with strong, sustained mitigation, has a better chance of some success than a less comprehensive framework. We begin with a simple illustration using the US States. We then review how conservation biogeography informs conservation strategies and then describe how human *sociocultural vulnerability* and *adaptive capacity* relate to this process. (We use the term 'sociocultural' throughout to encompass the behavioural, economic and political, especially as they affect individual action and institutional context.) We conclude by considering how these myriad attributes can be used to focus appropriate adaptation strategies.

> *Sociocultural vulnerability*: The degree to which a [culture] is susceptible to, and unable to cope with, adverse effects.
>
> *Sociocultural adaptive capacity*: The ability of a [culture] to adjust to [environmental change], to moderate potential damages, to take advantage of opportunities or to cope with the consequences. Adapted from IPCC 2007b

A SIMPLE CASE STUDY

Our thesis that physical, biological and cultural geographies must be combined to maximize conservation impact begs the question of how best to accomplish this goal. To illustrate the degree to which simple sociopolitical metrics can change the relative prioritization of biodiversity hotspots, we use the US states to illustrate potential metrics and demonstrate the impacts these might have on strategic conservation decisions. Imagine a hypothetical conservation organization that is deciding how to allocate resources among US state programmes that it runs. The criteria for decisions rest on the distribution of biodiversity, the degree to which the landscape is threatened by human land use attributes, and the economic capacity of the state to self-fund conservation actions. In this sense, this example exemplifies real decisions that international conservation organizations make when considering investing in countries. Variation in sociocultural vulnerability and capacity will vary much more across international boundaries than across US state lines, making our demonstration case a conservative one. This case study illustrates a simple approach to incorporating the geography of sociocultural adaptive capacity (e.g. governance, human health, education) in prioritizing conservation investment.

Our hypothetical organization requires a scheme to determine which states should receive special attention. We can assess biodiversity vulnerability at the state level using databases managed by NatureServe (http://www.NatureServe.org). Our biodiversity vulnerability score combines three measures: (1) rare species in each state, where rare is defined as all taxa ranked as G3 or higher (see Master, 1991 for G-rank definitions); (2) the total number of plant associations found in a state, where associations are defined by NatureServe; and (3) the number of high-risk invasive species found in each state (NatureServe.org). We calculated a standard score (mean = 0, standard deviation = 1, Sokal & Rohlf, 1995) for each of the three values and summed them to get an overall biodiversity vulnerability score in which more rare species, more communities and more invasive species all represent biological risk. These summed scores were then transformed to positive values (for mapping purposes) and scaled so that differences among states could be visualized across a colour or 'heat' ramp. Maps were created using the lattice package in R. The resultant biodiversity map (Fig. 1) looks much like one would expect, and much like many previous biodiversity assessments, with southern and western states receiving the highest vulnerability scores.

Landscape vulnerability represents risk from direct human impacts. In this case we used: (1) population density; a measure of population size surveyed for year 2000 by the US Census Bureau (http://www.census.gov/), divided by state land areas; (2) an estimate of population growth rate between 2000 and 2009 (http://www.USCensus.gov); and (3) the fraction of state land in public ownership. Land areas for each state and the fraction of that land in public ownership were estimated by The National Wilderness Institute (1995) and reported by the Natural Resources Council of Maine (http://www.nrcm.org/documents/publiclandownership.pdf, 2009). Creating a single vulnerability value by summing standard scores, this map looks much like we would expect, with states along the eastern seaboard achieving higher potential priority by virtue of having high population densities and relatively little public land (Fig. 2).

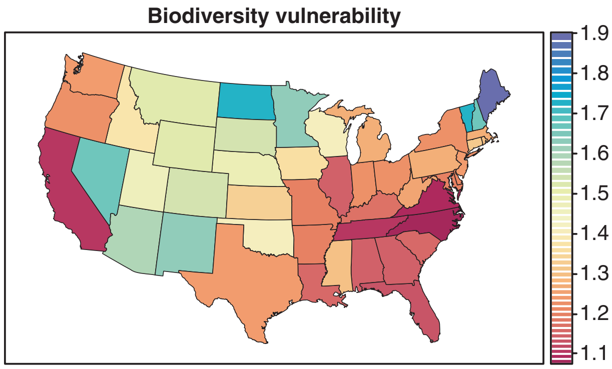

Figure 1 Biodiversity vulnerability among states mapped as a function of rare species, number of plant associations and number of high-risk invasive species found in each state. We calculated a standard score (see text) for each of the three values and summed them to get an overall vulnerability score. Summed scores were scaled so that differences among states could be visualized across a colour or 'heat' ramp. Lower values represent increased vulnerability.

For sociocultural adaptive capacity, we summed standard scores from (1) 2006–2008 poverty rates as reported by the US Census Bureau; (2) variance in the household income of state residents (a measure of economic inequality) as reported by the US Census Bureau; and (3) the per capita size of the state budget. State budgets were gathered from the National Association of State Budget Officers (http://www.nasbo.org/, The Fiscal Survey of States, December 2009). State budgets were divided by the estimated 2009 population size. We used state-based poverty rates and fiscal capacities to represent the potential environmental programme investment capacity differences among the US states. Within each state, standard scores were summed across all factors within each assessment. In this case, we would further downgrade California as a priority, as well as significantly downgrade Florida, and focus more on southern-tier states such as Louisiana, Mississippi and Alabama (Fig. 3).

This assessment is presented to make two simple points. First, mapping cultural adaptive capacity alongside biological vulnerabilities can significantly change strategic conservation priorities. Second, choosing metrics, deciding how to weight them, and then balancing these alternative geographies is a subjective matter, and although difficult, is important. Each of our maps presents a somewhat different picture. All, whether represented in some weighted combination, or considered intuitively, are likely to be important.

GLOBAL CHANGE HOTSPOTS

Biodiversity hotspots

Decision-making for strategic conservation began with assessing the distribution of biodiversity (e.g. Pianka, 1966) along latitudinal gradients. Conservation biologists considering global strategies for conservation have spent considerable time and effort reframing this conceptualization of diversity (e.g. Gaston, 2000; Whittaker *et al.*, 2001; Willig *et al.*, 2003) into maps identifying more focused hotspots of biodiversity (Margules & Pressey, 2000; Myers *et al.*, 2000; Olson & Dinerstein, 2002; Roberts *et al.*, 2002; Wilson *et al.*, 2006). Most conservation organizations have adopted variations on the hotspot concept to identify priority conservation management regions. Conservation International uses biodiversity hotspots (http://www.biodiversityhotspots.org/Pages/default.aspx), Birdlife International focuses on what they call Endemic Bird Areas and Important Bird Areas (http://www.birdlife.org/action/science/endemic_bird_areas/index.html), and The World Wildlife Fund identifies a suite of the Global 200

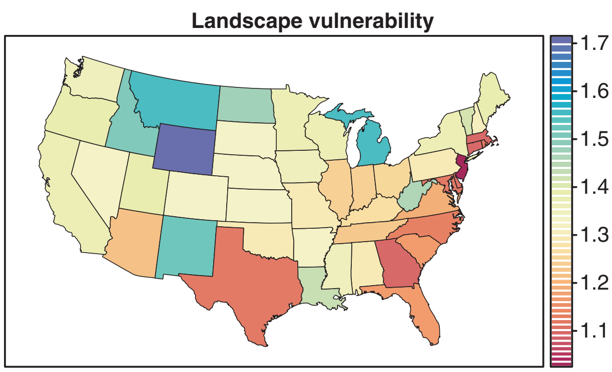

Figure 2 Landscape vulnerability among states mapped as a function of human population density, population growth rate and land in public ownership for each state. We calculated a standard score (see text) for each of the three values and summed them to get an overall vulnerability score. Summed scores were scaled so that differences among states could be visualized across a colour or 'heat' ramp. Lower values represent increased vulnerability.

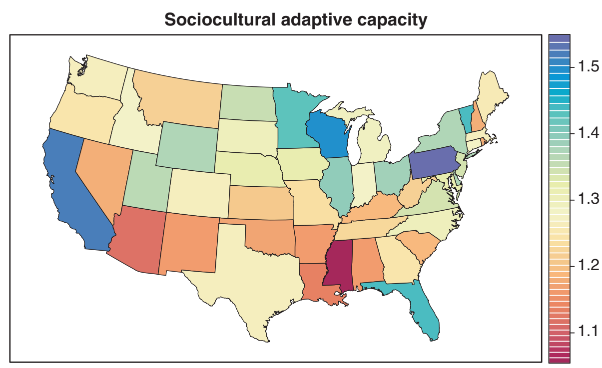

Figure 3 Sociocultural adaptive capacity among states mapped as a function of poverty rates, variance in resident income and per capita state budget size for each state. We calculated a standard score (see text) for each of the three values and summed them to get an overall capacity score. Summed scores were scaled so that differences among states could be visualized across a colour or 'heat' ramp. Lower values represent decreased capacity (increased vulnerability).

ecoregions-based hotspots (http://www.worldwildlife.org/science/ecoregions/item1847.html). Each organization has chosen a suite of criteria relative to their particular mission to describe the geography of biodiversity.

The observation is emerging, however, that there are important variables aside from the distribution of biodiversity itself that are vitally important to its conservation. Threats to biodiversity vary among hotspots (Brooks *et al.*, 2002; Orme *et al.*, 2005), including increasing biological invasions (Dukes & Mooney, 1999; Mack *et al.*, 2000). Conservation costs vary geographically (Balmford *et al.*, 2003; Moore *et al.*, 2004) as well. Although vital, the science and practice of linking the geography of biodiversity to the geography of threat and conservation opportunity remains in its infancy.

Landscape change hotspots

Biogeography has a fundamental linkage to earth's physical geography (von Humboldt & Bonpland, 1807; Merriam, 1894). Landforms and climate are integral to the distribution of biota; they are the template (Southwood, 1977) on which organisms experience the various niche dimensions essential to survival. In a world where that climate is rapidly changing, we have to consider the complex geography of global change to forecast biological response. That forecasting is necessary to create robust conservation strategies. Some components of global change appear fairly certain. For example, rising atmospheric CO_2 has direct effects on the pH of ocean water (IPCC 2007a). Nevertheless, predicting biological responses to these environmental changes is an element of biogeographic science in its infancy, and still carries high uncertainty (Widdicombe & Spicer, 2008).

Similarly, climate change has a distinct geographic signal. The highest temperature increases are expected at high latitudes, and the largest decreases in precipitation are likely to occur over continental regions (IPCC 2007a). The norm, however, is again a large degree of uncertainty, compounded by the complexities inherent in forecasting ecological processes. There is uncertainty in future atmospheric greenhouse gas emissions, forcing differing amounts of radiative warming (IPCC 2007a). The same must be said of air pollution control and the radiative cooling that is a consequence of aerosols in the atmosphere (IPCC 2007a). Overlain on these uncertainties are differences among global circulation models that treat the earth climate system slightly differently (IPCC 2007a). These components of the problem are compounded by other vectors of global change that can have strong impacts on the capacity of biodiversity to persist within their native distributions. Global deposition of biologically active nitrogen from anthropogenic sources, for example, now exceeds the amount of nitrogen fixed through natural resources (Vitousek *et al.*, 1997; Millennium Ecosystem Assessment 2005).

The complexity of the multiple interacting global changes warrants caution (Botkin *et al.*, 2007). Nevertheless, the demand for forecasting of ecological response is increasing (Botkin *et al.*, 2007). Projected climate scenarios provide a compelling background against which to begin to forecast biological response (Midgley *et al.*, 2002; Dulvy *et al.*, 2003; Skov & Svenning, 2004; Araujo *et al.*, 2005; Keith *et al.*, 2008) using our knowledge of landscape and species biogeography. This process will be best served if it incorporates, from the very earliest stages, the sociocultural geographies on which successful adaptive mitigation rests.

Finally, the geography of human density and anthropogenic impact, including habitat loss, is a critical factor contributing to global change. This human footprint is not independent of either climate or the distribution of biodiversity (Balmford *et al.*, 2001; Burgess *et al.*, 2007). People tend to live in habitats with high biodiversity (Schwartz *et al.*, 2002). Understanding the mechanisms that drive differential human impacts on biodiversity is a first step in considering the synthetic geography of conservation priorities. For instance, Dinerstein & Wikramanayake (1993) jointly considered both human impact and conservation action (reserves set aside) as a means of prioritizing regions for conservation in Southeast Asia. Their approach assessed anthropogenic forest loss rates and related damage in light of previous conservation action. In their approach, countries with high potential future habitat loss and few protected lands would receive a higher priority than those with lower potential threat or those that have already substantially met conservation goals. This is a big step towards capturing the complex suite of interacting geographic factors that could drive strategic conservation.

SOCIOCULTURAL HOTSPOTS

The sociocultural landscape creates a third geographical overlay integral to strategic conservation. This sociocultural geography is, like the previous two, complex. In addition to human density and human land use choices, however, are additional economic, political and social concerns that may drive the likelihood that any conservation action instigated in a particular region could succeed (Moore *et al.*, 2004). Information such as political stability, economic capacity and governmental structures are used to decide on conservation investment. A more detailed approach, however, would be to explicitly consider the geographic variation of these attributes alongside the geographic distribution of biodiversity and the geographic assessment of global change to that biodiversity.

Although social scientists are concerned mainly with the prospect of preserving sociocultural diversity, their work potentially has implications for how local cultures vary in their preparedness to implement biodiversity conservation management. We think of this preparedness in terms of both commitment and capacity. In effect, we are proposing that the management of biological diversity to weather global change is one facet of the human adaptive capacity to weather the same conditions. There is one main hypothesis here: societies in political contexts that make them highly vulnerable to climate change (i.e. have low sociocultural adaptive capacity, as ascertained by social science research) should also have less capacity to implement conservation management. By this we mean they are less likely, for instance, to have strong civil institutions, public health infrastructure and access to planning arenas (Adger *et al.*, 2007). Low-lying island nations that may become completely inundated through sea level rise are an obvious example of countries with high commitment but low adaptive capacity. Less obviously a country such as Netherlands may have the economic wherewithal for many conservation solutions and commitment, but few options that are actually effective for species threatened by climate. As a third type of example, societies in developing nations may have threatened biodiversity resources and a local commitment to protect, but they may vary significantly in their economic and political capacity to invest in a conservation portfolio.

Rapid loss of diversity, biotic or sociocultural, is important because it is irreversible. A language lost, a species lost, an ecological community lost fundamentally reduces the amount of information in the world, information that cannot be recovered. Because of this ratcheting down, the window in which human adaptive responses can make the biggest difference is the earliest one open to us (IPCC 2007b). Thus, if biogeographic approaches are used to focus conservation efforts, and if our hypothesis is plausible, then it is imperative that the distribution of sociocultural vulnerability and adaptive capacity be included in the analysis alongside the geographic distribution of physical factors and biodiversity. Otherwise, we risk making conceptually faulty cost-benefit analyses, with the implication that we will misdirect our limited resources. Trade-offs are upon us, and in the same way that we would not wish to waste limited resources on sectors of biodiversity that are perceived to be of relatively low value or risk (Bottrill *et al.*, 2008, 2009), we do not want to expend resources in geographic regions with low likelihoods of successful implementation unless the biotic resources available there are of exceptional importance or short-term gains (sensu Wilson *et al.*, 2006) are sustained through continued support. Feeding into our sense of the importance of this point is the observation that high income per capita is neither a necessary nor a sufficient indicator of the capacity to adapt to climate change (Moss *et al.*, 2001; in Adger *et al.*, 2007; Tol & Yohe, 2007). The social science that provides insight on our hypothesis will have to be more complex than that.

There is a growing research tradition concerning how to best allocate conservation investments when resources are limited (Bode *et al.*, 2008a). These studies call for the incorporation and assessment of socioeconomic factors (McBride *et al.*, 2007; Bode *et al.*, 2008b), modelling for return on investment (Ando *et al.*, 1998; Wilson *et al.*, 2006; McBride *et al.*, 2007; Underwood *et al.*, 2008) and incorporating data on region-specific threats as defined by regional experts (Wilson *et al.*, 2007). As suggested by this listing, conservation biologists expect that economics will play a critical role in determining human behaviour and values. We argue that a broader incorporation of social science phenomena, from institutional scale to social organization, to belief systems, will improve our understanding and should be incorporated into any decision framework. Depending on the scale of available data, such sociocultural factors may enter decision frameworks upstream or may be included in the previous models. Specifically, how these data should be used within these frameworks is beyond the current scope. Our point is that myriad data are available because of the omnipotent challenge of adapting humanity to global change and that these data must find their way into the data stream to effect complete and accurate conservation biology. This work is just beginning.

It is tempting to propose that sociocultural vulnerability declines with socioeconomic development and that adaptive capacity increases. This need not be the case. Highly developed market economies may be unusually vulnerable; some less developed societies may be quite resilient. Additionally, increased social complexity of landscapes can inhibit environmental management goals, even population ones (Epanchin-Niell *et al.*, 2009). Adaptive capacity likewise may be only loosely related to development, in part because of the intervening variable of commitment. We are only beginning to understand the properties of human societies that determine how decisively they will be affected by climate change, and how well they will respond. This issue is an important frontier in environmental science (Change, 2005; Eakin & Luers, 2006; Eriksen & Kelly, 2007; Nelson *et al.*, 2007; O'Brien *et al.*, 2007). For example, Brooks *et al.* (2005) proposed eleven key factors of sociocultural vulnerability, grouped into three broad categories (health status, governance and education) for 205 countries around the world. They used the judgment of experts to weight these factors, and then determined which of them predict how well the societies (countries) buffer their citizens from extreme climatic events. Table 1 lists some of these factors (for which many data are available world-wide and easily accessed). Many such factors are not typically on the

Table 1 Examples of national-level data that may serve as proxies for sociocultural vulnerability to environmental change. Categories are taken from Table 1 in Brooks *et al.* (2005) and the first proxy from each category is presented.

Category	Sociocultural vulnerability proxy*
Economy	GDP per capita
Health and nutrition	Health expenditure per capita
Education	Education expenditure as % of GNP
Infrastructure	Roads (km, scaled by land area with 99% of population)
Governance	Internal refugees (1000s) scaled by population
Geography and demography	km of coastline (scaled by land area)
Agriculture	Agricultural employees (% of total population)
Ecology	Protected land area (%)
Technology	R&D investment (% GNP)

*Data sources in the Brooks *et al.* study included the World Bank, Human Development Index, UNEP/GRID-Geneva, and Center for International Earth Sciences Information Network at Columbia University.

minds of conservation biologists when ranking regions for biodiversity risk, but if we are correct that there is a strong relationship between sociocultural adaptive capacity and the ability to manage biodiversity risk, then factors like these will be vital to the success of conservation programmes. The relationship between sociopolitical and biophysical vulnerability and their impact on conservation entails a broad suite of overlapping considerations.

ADAPTATION SCIENCE FOR CONSERVATION

Conservation biologists have a limited set of adaptation strategies at their disposal. Mawdsley *et al.* (2009) list 15. Simplifying this list, we can consider a gradient of responses for altering habitat or species protection in ways that may allow adaptation to global change. Business-as-usual approaches are doomed to failure (Pressey *et al.*, 2007; Hannah, 2008; Lawler, 2009; Mawdsley *et al.*, 2009). Alternatively, conservationists can consider global change threats as shifting the landscape of conservation and take steps to move reserves in response (Pressey *et al.*, 2007). This could include adding reserves to an existing network, connecting reserves through dispersal corridors or designing moveable reserves. Each of these design strategies acknowledges that protecting biodiversity is likely to require both more and different lands than are currently designated for conservation (Mawdsley *et al.*, 2009). Conservationists might also decide that effective conservation requires trade-offs: the unhappy and hard choices of limitation and constraint. In this case, triage, or conservation prioritization becomes an integral part of conservation, with ecologists committed to deciding what, where and when biodiversity is, or is not, salvageable (Bottrill *et al.*, 2008, 2009; McCarthy *et al.*, 2008; McDonald-Madden *et al.*, 2008). Finally, conservation ecologists may focus on species level interventions. These vary from moving genotypes within a species range to maximize its adaptive potential (McKenney *et al.*, 2009), to managed relocation of species outside their historical distributions (McLachlan *et al.*, 2007; Hoegh-Guldberg *et al.*, 2008; Richardson *et al.*, 2009; Swarts & Dixon, 2009), to giving up on conservation in the wild and focusing instead on *ex situ* conservation efforts (Lynch *et al.*, 2007).

Application of specific management options will depend jointly on physical, biological and cultural factors. How is global climate change expressed on a local landscape? What biotic or other resources (e.g. water) are placed at risk? What sociopolitical institutions are in place that exacerbate that risk, or provide opportunities to mitigate it? Whether or not a habitat protection-based strategy will work depends on habitat availability, and the degree to which global change impacts a particular landscape. Once the potential for conservation can be identified, a typical pursuit of conservation biogeography, conservation action will depend on (1) adequate political capital; (2) domestic or international financing; (3) and the infrastructural and institutional capacity to implement work-arounds (e.g. set aside additional reserve land). The success of a strategy that involves moving plants and animals will again depend on both the physical environment, biogeographic factors and human capacity and commitment to implement the changes required for relocation (Richardson *et al.*, 2009).

HOTSPOTS OF CONSERVATION POTENTIAL

There are a daunting number of proposals for how humans might manage biological diversity in the face of climate change (Heller & Zavaleta, 2009), but we know relatively little about the factors that will make which strategies feasible or successful. Specific solutions will vary regionally, largely because of institutional differences reflecting local sociocultural adaptive capacities (Nelson *et al.*, 2007). As mentioned earlier, studies have ranked countries and regions for their sociocultural vulnerability to climate change and their cultural adaptive capacity (see Eriksen & Kelly, 2007 for a review of such studies). However, the efficacy of these rankings remains empirically untested (Adger *et al.*, 2007). We do not yet know what variables matter most, and how effectively better indicators will guide mitigation policy and actually succeed in preserving sociocultural diversity. For example, it is a long way from conceptualizing adaptive mitigation to actually saving the lifeway of indigenous Quechua herders of the high altitude Andes (Orlove, 2009).

Sociocultural vulnerability (i.e. health, education and governance) and sociopolitical opportunity (i.e. political will, economic capacity and infrastructure) directly influence both local and global policies on conservation. Correlates of sociocultural vulnerability, such as human health, are being explored for the ways in which they might directly improve conservation efforts. For example, the NGO, Conservation Through Public Health, has been promoting the improvement in human health as a means to conserve Mountain Gorillas in Uganda (http://gorilladoctors.org/). In this case, there is a direct connection between human and gorilla health because of common primate disease vectors. But it is possible too that in the absence of such direct connections, the improvement in health access for local people would be useful as a conservation tool, not least because of its impact on commitment.

Cultural adaptive capacity may also drive the local-to-national level response to global processes, thus influencing local risk to biodiversity. Hence, in addition to regional biophysical factors (e.g. biodiversity, local climate effects, habitat availability), regional biodiversity risk from global change is partly a function of the adaptive capacity of the culture of nation states. An important area of research will address the question of whether or not nations with greater adaptive capacities actually conserve more habitats and whether or not they take more actions to conserve biodiversity, within and beyond their borders. Assuming a robust adaptive infrastructure is in place, biodiversity management requires legislation, political will, and often, economic investments, all of which imply trade-offs. So if Hotspots A and B are equally vulnerable to rapid change because of, say, high biological endemism, perhaps more effort (including political aid and advocacy) should be allocated towards Hotspot A if it has greater sociocultural vulnerability. Culture B, having lower sociocultural vulnerability, should be more prepared to establish future reserves, assist with critical migrations and create adaptive legislation. Some less developed regions may have meager sociocultural adaptive capacity, but may also serve as areas of opportunity where increases in sociocultural adaptive capacity could shepherd cultures into sustainable trajectories. Economies that depend more on external, and non-biological inputs, or where current agriculture stands to gain from climate change (e.g. regions with increasing precipitation) should be better situated to help preserve local biodiversity or more likely to at least convert it less quickly (T.M. Waring, personal communication).

We propose considering multidisciplinary information streams to identify conservation hotspots. Each of these criteria has a spatial signature, a geography that needs to be understood to make strategic conservation decisions (Table 2). These geographies overlap at (1) places having high biophysical vulnerability, where climate change and human impacts put great numbers of species at risk; and (2) places where improvements in global change adaptive capacity can be made via cultural, economic and political investments. Together, these criteria define places having high conservation opportunity, when political will for conservation exists and investments in resource preservation are sustainable (i.e. not dependent on perpetual external investments). Further, these geographies may inform the type of conservation investment that would likely maximize effective conservation return (Table 3). There are clearly places with low sociocultural vulnerability where habitat destruction likelihoods are low, or where internal capacity to provide conservation resources is very high. However, there are also likely to be places that are so vulnerable that conservation investment becomes too risky (e.g. war zones). As with biophysical vulnerability, the difficulty lies in balancing the cultural, economic and political attributes that comprise sociocultural vulnerability so as to create a combined geography that helps to establish priorities (Table 2). Conservation organizations must then jointly consider the attributes that comprise multiple axes to fully make strategic conservation investments. Treatments of these combined factors will be subjective, in part, and open to dispute. Thus, clear statements of values will be critical.

THE CONSERVATION LANDSCAPE

With these geographic concerns in mind, there may be several indicators of sociocultural opportunity that might simplify strategic conservation decisions. Most countries have signed on to the concept of conservation through international agreements such as the Convention on the International Trade in Endangered Species (CITES) or the Convention of Biodiversity (CBD). Countries vary, however, in how assiduously they have pursued, and achieved, the objectives of these international agreements. The history of action is likely to have predictive value in the potential of a country to design proactive conservation strategies for global change and may be the kind of complex response variable that one could use to assess

Table 2 A proposed comprehensive suite of geographies for developing a cross-disciplinary conservation geography. Designing global change adaptation strategies for biodiversity conservation requires not simply an understanding of the distribution of diversity, anthropogenic threat and climate change (biophysical vulnerability), but also the cultural context for conservation opportunities.

Focal geographies	Critical concepts
A. Biodiversity	
I. Biogeography of targets	What attributes (species, communities, ecosystems, ecosystem functions) of biodiversity are of interest to the actors and how are they distributed geographically?
II. Biogeography of threats	What are the global change threats involving introduced species? What are the threats associated with the disruption of trophic interactions?
B. Global change	
I. Physical geography of global change	What is the spatial pattern of change among attributes of global change (climate, nutrient loading, habitat loss) that pose the largest threats to biodiversity targets?
II. Landscape geography	Does the physical landscape afford the potential for conservation designs that are robust to global change threats?
III. Human geography	What habitats or systems are most prone to human alteration and loss?
C. Sociocultural	
I. Sociopolitical geography	What is the potential for robust reserve creation? Are there human – wildlife conflicts that require management?
	What is the economic potential for conservation action? What are the boundary issues associated with conservation under shifting climates and shifting distributions? What are the political constraints on effective conservation?
II. Cultural geography	What are the cultural incentives, or constraints, to conservation action?

Table 3 Possible conservation strategies (modified from Mawdsley *et al.*, 2009) for landscapes with high biodiversity value that vary with respect to physical vulnerability to global change and sociocultural adaptive capacity and vulnerability.

Landscape status	Possible conservation strategy
Low physical vulnerability to global change	
Very low sociocultural capacity	
Low cultural vulnerability	Debt for nature swaps, Conservation development, *Ex situ* protection of species, invest in government stability measures
High cultural vulnerability	Debt for nature swaps, Conservation development, *Ex situ* protection of species, Cultural preservation programmes, Invest in government stability measures
Moderate sociocultural capacity	
Low cultural vulnerability	Reserve acquisition, Conservation development, *Ex situ* protection of species
High cultural vulnerability	Reserve acquisition, Conservation development, *Ex situ* protection of species, Cultural preservation programmes
High sociocultural capacity	
Low cultural vulnerability	Reserve acquisition, *Ex situ* protection of species
High cultural vulnerability	Reserve acquisition, Cultural preservation programmes
High physical vulnerability to global change	
Very low sociocultural capacity	
Low cultural vulnerability	Reserve acquisition, Debt for nature swaps, Conservation development, moveable reserves, *Ex situ* protection of species, Invest in government stability measures
High cultural vulnerability	Reserve acquisition, Debt for nature swaps, Conservation development, moveable reserves, *Ex situ* protection of species, Cultural preservation programmes, Invest in government stability measures
Moderate sociocultural capacity	
Low cultural vulnerability	Reserve acquisition, Conservation development, Moveable reserves, Managed relocation, *Ex situ* protection of species
High cultural vulnerability	Reserve acquisition, Conservation development, Moveable reserves, Managed relocation, *Ex situ* protection of species, Cultural preservation programmes
High sociocultural capacity	
Low cultural vulnerability	Reserve acquisition, Managed relocation, *Ex situ* protection of species
High cultural vulnerability	Reserve acquisition, Managed relocation, *Ex situ* protection of species, Cultural preservation programmes

conservation opportunity (e.g. Dinerstein & Wikramanayake, 1993).

Countries also vary with respect to how they treat biodiversity external to reserves. For example, countries differ with respect to landowner rights and responsibilities towards wildlife. These laws may inform an assessment of conservation potential. In addition, zoos and botanical gardens are increasingly important contributors to conservation programmes (Caughley, 1994; Balmford *et al.*, 1996; Guerrant *et al.*, 2004; Havens *et al.*, 2006). Globally, we lack adequate facilities to broadly conserve diversity through these sorts of facilities (Rahbek, 1993). Assessing domestic capacity for *ex situ* conservation in zoos and botanical gardens may be a useful metric of societal investment in biodiversity. Economics, in general, ought to play a role in predicting whether a country can effectively augment conservation through activities such as captive breeding programmes. Similarly, politics and economics may predict whether countries are willing to export captive breeding of their endangered species to countries that do have the capacity. Planning for long-term conservation within a country must include an assessment of the potential for local *ex situ* conservation efforts, or an assessment of expatriate *ex situ* conservation.

Lastly, the scale at which conservation hotspots is identified may differ from the scales at which they are acted upon (i.e. the scale of authority). Organizations with a global mandate, such as Conservation International, may use global hotspots as a framework for action prioritization. Individual nations and provinces also face the challenge of managing biodiversity risk against the same complex suite of geographies that operate at an international level. Thus, nations and provinces are likely to use these geographies on a completely different scale. For some countries, the economic, political and social landscapes may be heterogeneous within a country. Thus, prioritization schemes are applicable at multiple scales. However, our argument is that the next step forwards in geographical approaches to conservation ought to be careful thinking about how to incorporate sociocultural data. Thus, our focus is generally on a large scale.

CONCLUSION

Biodiversity hotspots provide a geographical focus to conservation efforts and have received intensive research focus over the past decade. Conservation biogeography has been at the centre of ecological forecasting currently being applied to strategic conservation decisions. We argue, however, that this forecasting, even if it is reliable within its own terms, is insufficient. Sociocultural vulnerability and adaptive capacity may be equally important information when prioritizing conservation action. Although considerable cultural and biophysical data are available, it is surprising that they are not more frequently explicitly and geographically linked to conservation decisions. Biologists have modelled the risks to biotas under climate change mostly without accounting for sociocultural vulnerability and adaptability. An integrative approach linking biological and cultural data is necessary to identify global areas of high biodiversity where the most effective improvements in human adaptive capacity can be made. The demonstration that even in the case of US states—a conservative case because of relative homogeneity among states—separate consideration of the physical, biological and sociocultural will produce different priorities. The analogues that will guide future conservation action must be securely based in multidisciplinary research to test both metrics and strategies to combine and weight different types of data. Even in the hottest hotspots, conservation outcomes depend on political will, institutional capacity and cultural support. It is becoming increasingly obvious that people have a limited capacity to care about other species when their own lives lack health, education and personal security.

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