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A Global Conservation System for Climate-Change Adaptation

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Abstract: *Climate change has created the need for a new strategic framework for conservation. This framework needs to include new protected areas that account for species range shifts and management that addresses large-scale change across international borders. Actions within the framework must be effective in international waters and across political frontiers and have the ability to accommodate large income and ability-to-pay discrepancies between countries. A global protected-area system responds to these needs. A fully implemented global system of protected areas will help in the transition to a new conservation paradigm robust to climate change and will ensure the integrity of the climate services provided by carbon sequestration from the world's natural habitats. The internationally coordinated response to climate change afforded by such a system could have significant cost savings relative to a system of climate adaptation that unfolds solely at a country level. Implementation of a global system is needed very soon because the effects of climate change on species and ecosystems are already well underway.*

Keywords: adaptation, climate change, global, protected areas

Un Sistema de Conservación Global para la Adaptación al Cambio Climático

Resumen: *El cambio climático ha creado la necesidad de un nuevo marco de referencia para la conservación. Este marco necesita incluir nuevas áreas protegidas que consideren cambios en la distribución de especies y manejo que atienda el cambio en gran escala a través de fronteras internacionales. Las acciones en este marco deben ser efectivas en aguas internacionales y a través de fronteras políticas y tener la habilidad para incorporar grandes discrepancias en ingresos y capacidades de pago entre países. Un sistema global de áreas protegidas responde a estas necesidades. Un sistema global de áreas protegidas plenamente implementado ayudará en la transición hacia un nuevo paradigma de conservación robusto al cambio climático y asegurará la integridad de los servicios climáticos proporcionados por el secuestro de carbono de los hábitats naturales del mundo. La respuesta al cambio climático coordinada internacionalmente y enmarcada por ese sistema podría tener ahorros significativos comparados con un sistema de adaptación climática que se lleve a cabo solo a nivel de país. La implementación de un sistema global se requiere muy pronto porque los efectos del cambio climático sobre las especies y los ecosistemas están en marcha.*

Palabras Clave: adaptación, áreas protegidas, cambio climático, global

Introduction

Climate change is driving upheaval in many biological systems (Parmesan & Yohe 2003; Root et al. 2003; Walther et al. 2002). Current conservation strategies are based on an implicit assumption of a relatively stable climate (Hannah et al. 2002). This combination of dynamic threat and static response points to the need for new conservation tools, particularly those that facilitate cross-border and cross-jurisdictional responses. A global conservation system to ensure adequate coverage and management of species and ecosystems as climate changes is a necessary part of a new, more dynamic conservation paradigm.

Conservation strategies have been developed since the late 1800s under the assumption that biological attributes are inextricably linked to place. In the past quarter century, conservation goals have been reframed around biological diversity, but this more technical goal is still often tied to a paradigm of place—each site or region has its own suite of species, ecosystems, and genetic

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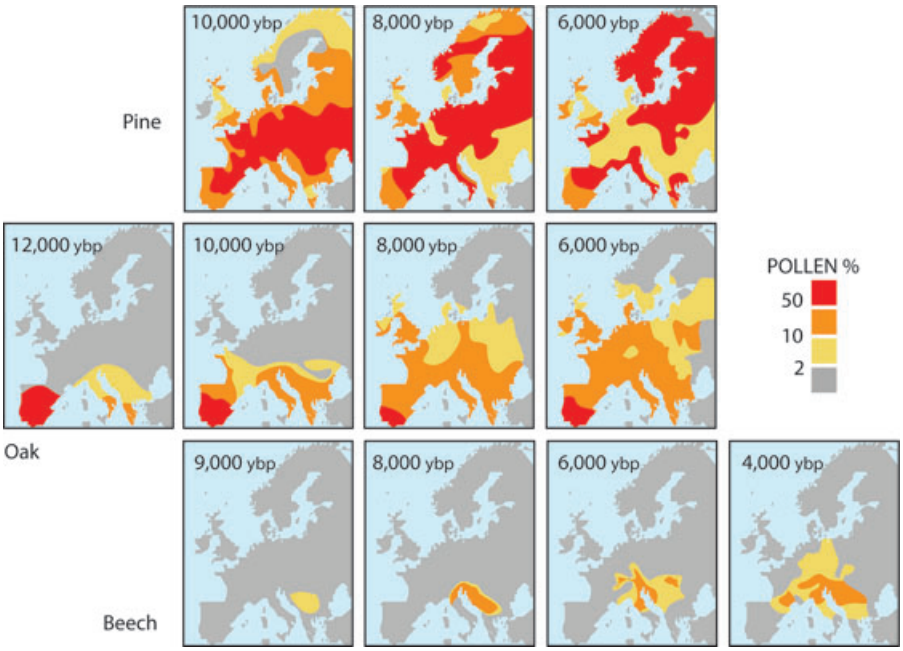

Figure 1. Pollen isopleths for major tree species in Europe following the last glacial maximum. Response to climate change in this example spans the territories of over 20 nations (from Huntley & Birks 1983).

attributes to be conserved. This biology-and-place association is reinforced because our main conservation tools—protected areas—are place focused.

But the link between biology and place is not permanent. The paleoecological record shows that range shifts have been a predominant biological response to climate change, with each species tracking its preferred climatic conditions (Fig. 1), often over long distances (Coope 2004; Graham & Grimm 1990; Huntley 1996). If the future is like the past, vegetation associations will be torn apart and reassembled in response to climate change. Species currently occurring together will not necessarily be together under future climates (Williams et al. 2001).

Conservationists should have been anticipating, and planning for, climate change even in the absence of large-scale human impacts on the atmosphere (Bush 1996). Certainly now, with huge greenhouse gas emissions coupled with strong, unidirectional, and rapid human-induced climate change already underway, the world's attention is turning to climate change adaptation, and conservation adaptation is an important part of that new focus.

Recent work indicates that protected areas, the current mainstay of conservation efforts, will remain relevant conservation tools as climate changes—provided that new areas are added to help counter the loss of species representation caused by climate change (Hannah et al. 2007). Additional protected areas, properly sized and placed, can compensate for the shift in species ranges out of existing protected areas. Limiting climate change to within the range of the lower end of current proposed international goals (2 °C) is likely to offer scope for limiting biological damage (O'Neill & Oppenheimer 2002) and constraining range dynamics to scales that can be captured by protected areas (Hannah et al. 2005).

If protected areas remain relevant under climate change, then the strategic framework in which they are applied seems destined for overhaul. National protected areas systems do not seem well equipped to cope with range shifts that will span national boundaries. Conflicting strategies for managing change in species or ecosystems are likely to arise in the absence of coordination across borders. Protection in international waters is needed to protect dynamic marine systems in which change is already evident. Freshwater systems are badly in need of conservation efforts that can cope with shifts in both species and in water availability due to climate change. The costs of adapting conservation to climate change in these cases often cannot be equitably or efficiently borne without international coordination. Finally, the services of ecosystems (especially the climate service of carbon sequestration) may not be maintained without international mechanisms for conservation adaptation.

Here the case is made for a global conservation system for climate-change adaptation. New protected areas are needed to respond to climate change. Ecosystem services are in need of conservation on biologically relevant scales. Management plans need to be established that cross national, regional, and continental boundaries. A coordinated global system best fits these needs.

Additional Protected Area Required for Climate-Change Adaptation

Additional protected area will be required with climate change because current protection has not been designed

with climate change in mind. Climate change will require multiple solutions, tailored to individual species, each with their own unique climatic tolerances, unique range or phenology shifts, and unique conservation needs as climate changes. Additional protection needs fall into at least four categories: compensatory, restorative, spatially or temporally variable, and places of refuge from diseases and pests. Compensatory protection will make up for loss of protection of individual species due to range shifts or losses in abundance. Restoration will provide future habitat or connectivity pathways for one or more species and will allow species or ecosystems to recover from climate-induced large-scale change, such as wildfires or storm damage. Spatially or temporally variable protection will move in space or change over time to track changes in range, abundance, or phenology. Disease and pest refuge protection will protect areas that are naturally sheltered from large-scale pest and disease outbreaks and so provide a source of natural regeneration and recovery after episodes of mass mortality.

The first three of these categories define responses to climate change challenges defined by habitat quality (present and future) on two axes—climatic suitability and integrity of habitat. Where habitat integrity is currently high and climatic suitability rises, compensatory protection is called for. Where current habitat integrity is low but future climatic value is high, restoration protection is appropriate. Restoration protection is currently practiced in some special circumstances, but generally protection is focused on high-integrity habitats. Under climate change, some areas already lost will have high climate suitability. Where current integrity is high but climatic suitability varies over time, for instance rising then declining, protection that is flexible in time or space may be the best response so that protection can be moved to track the most valuable habitat for a target species or ecosystem.

Outbreaks of diseases and pests caused by climate change create a special case in which habitat integrity rapidly breaks down. Pathogen and pest refuges are needed because mass mortality driven by climate change may affect continental or subcontinental areas that jeopardize entire species. Pine bark beetle outbreak in North America and chytrid fungus mortality worldwide are examples. Bark beetle outbreaks have affected tens of millions of lodgepole pine (*Pinus contorta*) trees and other pine species in western North America this decade and may eventually spread to the entire continent (Logan et al. 2003). Chytrid fungus is responsible for the first climate change-linked extinctions in Central and South America (Pounds et al. 2006). In these and other cases of large-scale, climate-driven outbreaks, some areas may prove resistant to outbreaks or have characteristics that make defense from the outbreak possible. When these areas are identified, protection to allow sources of recolonization and population recovery will be beneficial. This zoning concept is already used for coral reefs, where resistant and resilient areas are protected to preserve important sources of colonization after a bleaching event (Salm et al. 2001).

Each of these protection types requires large-scale, international collaboration to be effective. Outbreak refuges are required when pest or pathogen mortality occurs on subcontinental or continental scales, implicating multiple nations in effective response. Variable protection follows shifting climatic suitability that cross country boundaries, including those between territorial and international waters. Compensatory areas and restoration protection are needed because of range shifts but will often be multinational in nature.

Multiple examples are now available of species moving out of protected areas due to climate change (e.g., Araújo et al. 2004; Williams et al. 2004) and of the need to add protection to balance these losses in taxa as diverse as plants in South Africa and mammals in Mexico (Hannah et al. 2007) or to add new habitat in areas that will become climatically suitable (Hannah et al. 2008). International collaboration is required for all species not endemic to individual nations, estimated at 38–78% of all plants (Pitman & Jorgensen 2002) and about 60% of all land mammals (Ceballos et al. 2005). Up to a third of all threatened mammals may be included. Significantly, as climate changes, many species that are currently endemic to individual countries may see their ranges expand or shift to encompass multiple countries. Thus, well over half the species in the world are in need of transboundary management.

Transboundary Management

The need for transboundary management is an indispensable complement to designation of protected areas for climate change. Managing processes such as range shifts and large-scale disease outbreaks is essential as climate changes. For most species, this implies cross-border, multinational management, which will require new administrative structures, new political agreements, jointly implemented research agendas, technology transfer, and training.

Precedents of transboundary management are important in indicating whether large-scale collaboration is possible and productive between nations and beyond national jurisdictions. Existing transboundary conservation areas (TBCA) provide insight into cross-border collaboration of the type needed to manage range dynamics driven by climate change. Globally, 136 international protected-area complexes are currently recognized, involving nearly 500 individual protected areas. These transboundary efforts have included siting of new protected areas to complement existing protection and joint management planning across borders, elements that will

be essential as climate changes. For example, the La Amistad ("friendship") reserve was created in Costa Rica in 1983 with the intention of eventually linking it to an area of adjacent montane habitats in Panama, and nearly a decade later protection was decreed on the Panamanian side, creating a TBCA. In the Vilcabamba-Amboro region, internationally coordinated protection spans three countries (Peru, Bolivia, and Brazil) and habitats from the Andes to the Amazon. Objectives of TBCAs range from joint management of species of special concern, such as mountain gorillas (*Gorilla beringei beringei*), to full joint management plans for adjoining protected areas, such as Gemsbok National Park, which is shared between Botswana and South Africa (Mittermeier 2007). The mountain gorilla experience has demonstrated that transboundary conservation can endure, albeit with setbacks, even in times of conflict. Experiences with the Cordillera del Condor TBCA between Peru and Ecuador show that transboundary management can defuse border tensions and promote peace (Mittermeier 2007). Despite major shortcomings in global environmental governance, programs such as migratory bird protections, collaboration to save marine mammals, and a series of other treaty and management efforts have proved their worth in international conservation (Speth 2004). The management tools needed to address climate-change adaptation have been pioneered and are now much needed for broader implementation in response to climate change. What is missing is an international structure for supporting these efforts with training, science, and finance.

Examples of the Need for International Response

Marine Ecosystem Change

Changes in the Bering Sea ecosystem and sea-surface temperature (SST) fronts provide examples of the need for new and novel protection. The North Bering Sea is experiencing large-scale ecological changes caused by climate change. Bivalve abundance and species composition have shifted radically in response to warming. Walruses (*Odobenus rosmarus*) and Spectacled Eiders (*Somateria fischeri*) feed on bivalves and rest on sea ice. Sea ice extent has decreased, which has reduced the availability of haul-out areas for both species. Animals experience much less thermal loss resting on ice than they do in water (Lovvorn et al. 2003), so the walrus of the Bering Sea are losing energy input because of declining prey at the same time that they are experiencing increased heat loss while resting (Bluhm & Gradinger 2008). Complicating this deteriorating energy balance is the breakdown of a sill of cold water that excludes ground fish from the benthos in this region. As SSTs warm, the cold water sill disappears, allowing ground fishes to enter the region and compete with walrus for bivalve prey (Grebmeier et al. 2006). Bottom trawlers will likely follow ground fishes into the Bering Sea, destroying benthic habitat and further reducing walrus survival.

Analyses of these changes suggest that an exclusion zone for bottom trawling should be instituted in the Bering Sea before the cold water sill fails completely and the fishery becomes established (Cooper 2008). This is compensatory protection in the sense that this species did not formerly need protection, but projected abundance declines due to climate change are so severe that adding protection seems prudent. This region is in international waters, so addressing the problem is outside the scope of national protected-areas systems. International conservation action is called for in this region because of climate change.

A novel international protection mechanism may be needed for large marine species that depend heavily on sea surface temperature (SST) fronts (Franks 1992). Telemetry data for blue whales (*Balaenoptera musculus*) and loggerhead, green, and olive ridley sea turtles (*Caretta caretta, Chelonia mydas*, and *Lepidochelys olivacea*, respectively) indicate their strong association with SST frontal zones (Etnoyer et al. 2006). SST fronts are areas of strong thermal gradients that change location season to season and year to year (Fig. 2). They are expected to shift in location and intensity with climate change. Fixed protection of the entire area in which SST fronts currently migrate is probably not feasible, either in terms of enforcement over such large areas or the economic implications of permanently excluding fishing. Mobile protection, on the other hand, can target the feature of conservation interest, the frontal zone, as it moves in space and time. Sea surface temperature fronts preferentially used for foraging by whales and sea turtles can be readily identified with remote sensing (Etnoyer et al. 2006), which makes protection linked to the feature itself technically possible. As front duration and mobility vary with climate change, mobile protection is well suited to adapt, making it more effective and less expensive than a traditional exclusionary approach that is fixed in time and space. Completely new challenges such as the Bering Sea changes and SST fronts give rise to the need for a truly new global system of coordinated protected areas.

Management of Range Shifts

The quiver tree (*Aloe dichotoma*), an aloe of South Africa and Namibia, is noted for its tree-like growth form (Fig. 3). The quiver tree is dying over large areas of its range because of climate change. Namibian populations are declining, except at high elevations, resulting in a poleward and upslope range shift (Foden et al. 2007). Successful conservation of quiver trees in the future rests with the upper-elevation Namibian populations and South African populations of all elevations. Maintaining a viable population in Namibia might require survival

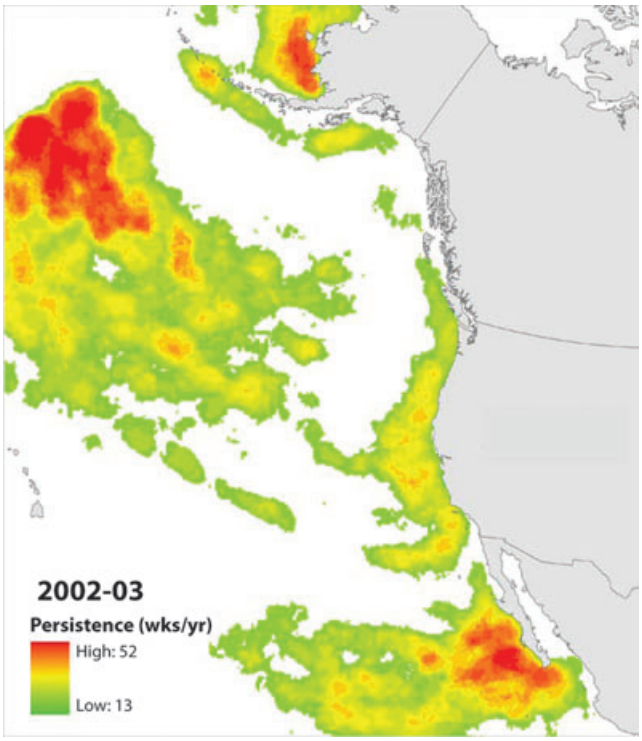

Figure 2. Sea-surface temperature fronts and blue whale (Balaenoptera musculus) *telemetry off Baja California and California coastal waters during the El Nino of 1997–98. These frontal features emerge at the interface of warm and cool water masses, areas that are preferentially used by many species, including blue whale.*

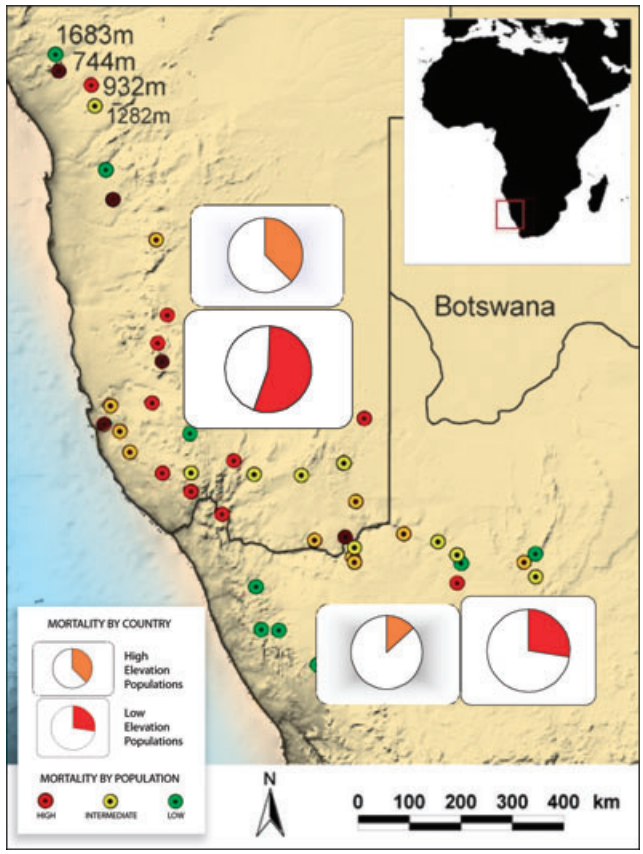

Figure 3. Range shift in the quiver tree (Aloe dichotoma) *across the borders of South Africa and Namibia. Red indicates mortality proportion in individual populations. Higher latitude and higher elevation populations show markedly lower mortality because the suitable range of the species shifts southward with climate change. Figure courtesy of Wendy Foden.*

of all remaining stands, which may be considerably more expensive than conserving expanding South African populations. Efficient conservation of the species can only be planned when the population status, current area protected, and future protection needed is known for both countries.

Similar concerns apply to many other species. One of the first whole-range shifts documented due to climate change was for Edith's checkerspot butterfly (*Euphydryas editha*). Edith's checkerspot is declining in Mexico, whereas stable populations exist in California and other poleward and upper-elevation portions of its range (Parmesan 1996). Conservation strategies that target maintenance of populations in Mexico without considering northern populations will be inordinately expensive and may be futile in the long term. In both the quiver tree and Edith's checkerspot examples, planning across a shared border will be much more cost-effective than isolated national plans. Compensatory protection can be added in the country with stable or expanding populations, rather than in marginal habitats in the country of decline. Climate change creates the need for a new international response in these settings.

Training, Science, and Resource Transfer—Restoration Protection in Madagascar

Until recently, conservation in Madagascar focused, quite correctly, on arresting rapid deforestation in high-priority areas. Climate-change assessments now suggest that the areas saved from deforestation need to be reconnected to facilitate future species range shifts in response to climate change, particularly movements along major riverine corridors and within areas of high genetic richness (Wilme et al. 2006; Hannah 2008). Restoration protection emerges as an important counterpart to saving the remaining forests of the country. With as much as 90% of the island's forest lost already, the scope for restoration is huge.

The cost of restoration is much higher than the cost of conserving standing forest. Nurseries, seed collection, and planting must be supported, in addition to the cost of managing land for conservation. Land tenure issues affect deforested land because clearing may be a prerequisite to establishing title and because tenure is often poorly documented in Madagascar. Clarifying tenure may require research, consultants, or legal proceedings, all of which are costly. In sum, restoration protection is two to three times more expensive than conservation of standing forest, meaning that restoration protection on only 3% of national area might equal or exceed all current conservation investments (Hannah 2008). Large-scale restoration needed for climate-change adaptation in Madagascar requires science to guide restoration and a workforce of restoration technicians.

Because so little forest connectivity remains, some species may require assisted migration or need to be captively bred until suitable habitat has been restored. These efforts are technically complex and costly as well.

Investment in state-of-the-art restoration, assisted migration, and captive breeding are beyond the means of Madagascar's own government. Madagascar is one of the poorest countries in the world. Training, technology transfer, and funding will need to be mobilized internationally, which illustrates the importance of a mechanism for international resource transfer for adaptation of conservation efforts to climate change.

A Global Conservation System for Climate Change

An international conservation system for climate change is needed because the dynamics of climate change transcend national boundaries, extend to international waters, and often entail investment beyond the means of the countries in which the adaptation burden is greatest. Protected areas specifically chosen to protect nature as climate changes would be a major feature of such a system. Mechanisms for decision making about assisted migration and the rescue of species unable to survive in natural settings would complement protection. Management structures, training, and science and resource transfers would complete the system. In some situations, the system would build on strong traditions of international cooperation. In other realms, such as freshwater systems and international waters, important innovations will be needed to deal with present challenges and climate change together.

Existing global coordination of protected areas and conservation provides experience on which to build. World Heritage sites qualify for additional funding and must meet certain minimum standards, both for induction and for ongoing management. Bilateral transboundary management agreements, as described above, provide for joint management in many areas and revenue sharing in some. The convention on biological diversity is considering a proposal for a voluntary fund to assist low income countries, and a science body like the intergovernmental panel on climate change (IPCC) has also been proposed. The scale and urgency of the problem dictate that new mechanisms replace these partial solutions.

A new program of additional protection and coordinated management, coupled with international resource transfers would provide the best avenue for proactive climate-change adaptation. Voluntarism ensures sovereignty, and incentives can be justified by the gains in economic efficiency that accrues with collaboration. Regional protected-area targets, similar to the EU Natura 2000, could be implemented through other regional governance mechanisms such as Southern African Development Community (SADC). The IPCC provides an example of an inclusive, voluntary, yet technically effective international structure, which demonstrates that the necessary ingredients for international problem solving can be assembled, even when complex environmental problems are at stake.

Mechanisms of protection under the system should include multiple-use lands and incentives for private landholder participation. In many settings, scope for public reserves is declining, making private participation essential. Nevertheless, implementation of the Natura 2000 system in Europe and tripling of Madagascar's protected estate illustrate that new protection can be achieved, even in the world's most densely populated and most impoverished regions.

Where protection fails for individual species or systems, assisted migration or ex situ conservation may be viable solutions for avoiding extinctions. Decisions about which species are in need of translocation or rescue will need to be made internationally in many cases, to take into account species' status throughout their range in multiple countries. Like protected-area management, instituting a global system of these last-ditch management tools will require administrative cooperation, training, and technology transfer.

Climate change impacts on natural systems are already being felt and will intensify in the next decade. Nevertheless, greater changes are expected in 20–30 years, so a system that becomes operational in the near term will allow for adequate response measures to be implemented prior to the onset of the most severe impacts. Uncertainty should not be an excuse for inaction. Having a system in place well in advance of the greatest impacts ensures that adaptive management and monitoring can be initiated with existing information and are well refined as impacts intensify.

Costs of Adaptation to Climate Change

Adding protected area, coordinating management, and systematizing monitoring will all incur costs. First

estimates of some of these costs have been made, and they indicate that investment of billions of dollars will be required to repair the biological damage done by climate change. These early estimates also make it clear that there will be large regional and national differences in cost, due to differences in the scale of needed response and to economic differences between countries.

The assessment in Madagascar described above concluded that up to 4 million ha of natural forest restoration will be needed to restore riverine corridors and reconnect fragmented forest to cope with climate change (Hannah 2008). At typical restoration costs of US$500/ha, this amounts to some US$2 billion over a 10–20-year period.

To place these numbers in perspective, US$60.4 billion flowed through carbon markets in 2007. The United States is likely to allocate about 40% of carbon-credit auction proceeds for adaptation of conservation strategies, for a total investment of approximately US$30 billion. Current annual investment in conservation is estimated at some US$6 billion (Balmford et al. 2003). Some nations, such as those of the European Union, will be able to afford the costs of adaptation. Others, such as Madagascar, will be unable to finance adaptation without international transfers. More-detailed estimates are currently being developed that will help refine the estimate of the cost of adaptation of conservation efforts for climate change.

Funding for a global system commensurate to these challenges could come from carbon-auction proceeds, international development funds, and other sources of adaptation finance. The principle of payment by countries that have caused the problem, to countries that have suffered the damages parallels ability to pay between developed and developing countries. Financing that links adaptation to mitigation revenue streams seems particularly appropriate. Carbon-auction revenues are therefore a suitable potential source of financing for this and other adaptation efforts. Development funds may be appropriate to provide technical assistance and to cover coordination costs. Nevertheless, uniform funding for these efforts is essential to a well-functioning system; thus, international commitments will be required, rather than ad hoc support that is at the mercy of changing foreign relations. Funding should be phased, with early funding supporting proof-of-concept trials prior to full operation of the system, later funding building capacity and implementation experience, and final financing stages supporting full implementation. Because progress in mitigation will have to be staged as well, linking adaptation funding to mitigation income is an attractive option—carbon-auction revenues are the best prospect for system funding.

Conclusion

Establishing a global protected areas network will be difficult. Allocation of financial resources on a global scale, international agreement on governance structure, and greatly increased integration of science and management will all be required. The alternative seems to be inefficient use of billions of dollars in adaptation funding, or, worse, inadequate conservation response that dooms much of the world's natural heritage to extinction.

Marine, terrestrial, and freshwater realms must be addressed by the network. Many terrestrial protected areas are not in optimal locations as climate changes, whereas marine and freshwater protected areas are only beginning to be established in many areas. These are opportunities to address climate change and current conservation needs simultaneously. The costs are large but not prohibitive. Investment on the order of 10–20% of human adaptation funding will be required. These funds need not compete with human adaptation assistance if both are properly designed into adaptation financing (such as carbon auctions) at the outset.

The time to begin building the system is now. Financing agreements, international negotiations on governance, and international and interagency coordination will be needed to make the system fully operational. These processes will require a lead time of at least a decade, and perhaps more. Beginning an international response early and in increments ensures that a system adequate to address the problem is in place before many of the problems arrive.

Action can begin immediately, even if full implementation takes years. Immediate trials of the transboundary approach can be initiated now for high-priority species and ecosystems. For example, restoring 1–5% of Madagascar's forests for climate change connectivity would provide a strong base for learning about adaptation techniques and yield strong positive effects on current conservation efforts and local incomes. Climate change-related changes such as the bark beetle outbreak in North America can be used as tests of transboundary collaboration in management response that will serve as models in other settings. Species such as the quiver tree can provide early experience in management implementation.

Climate change is a global problem, with impacts on conservation that are global in reach; thus, a global system for adaptation is warranted. The problem is clear, the cost of the solution must be measured, and the needed response mobilized. Anything less leaves nature to survive on its own in climates unseen in millions of years, in landscapes unfriendly to change.

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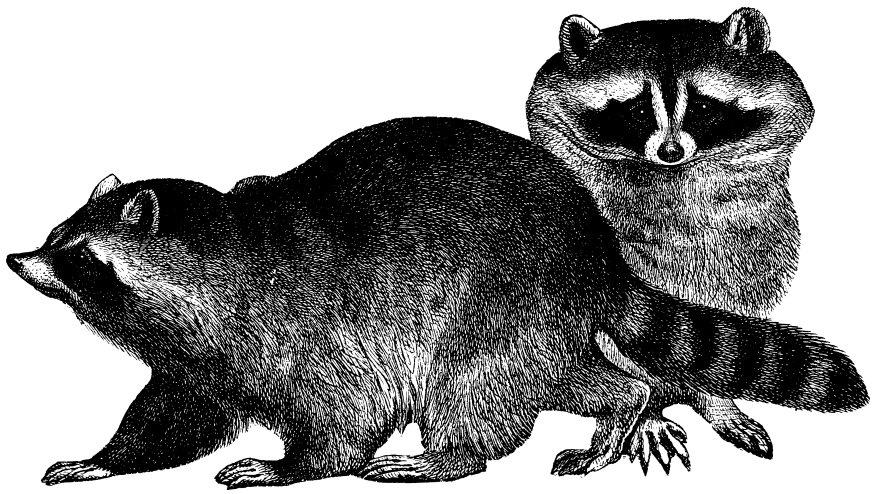
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