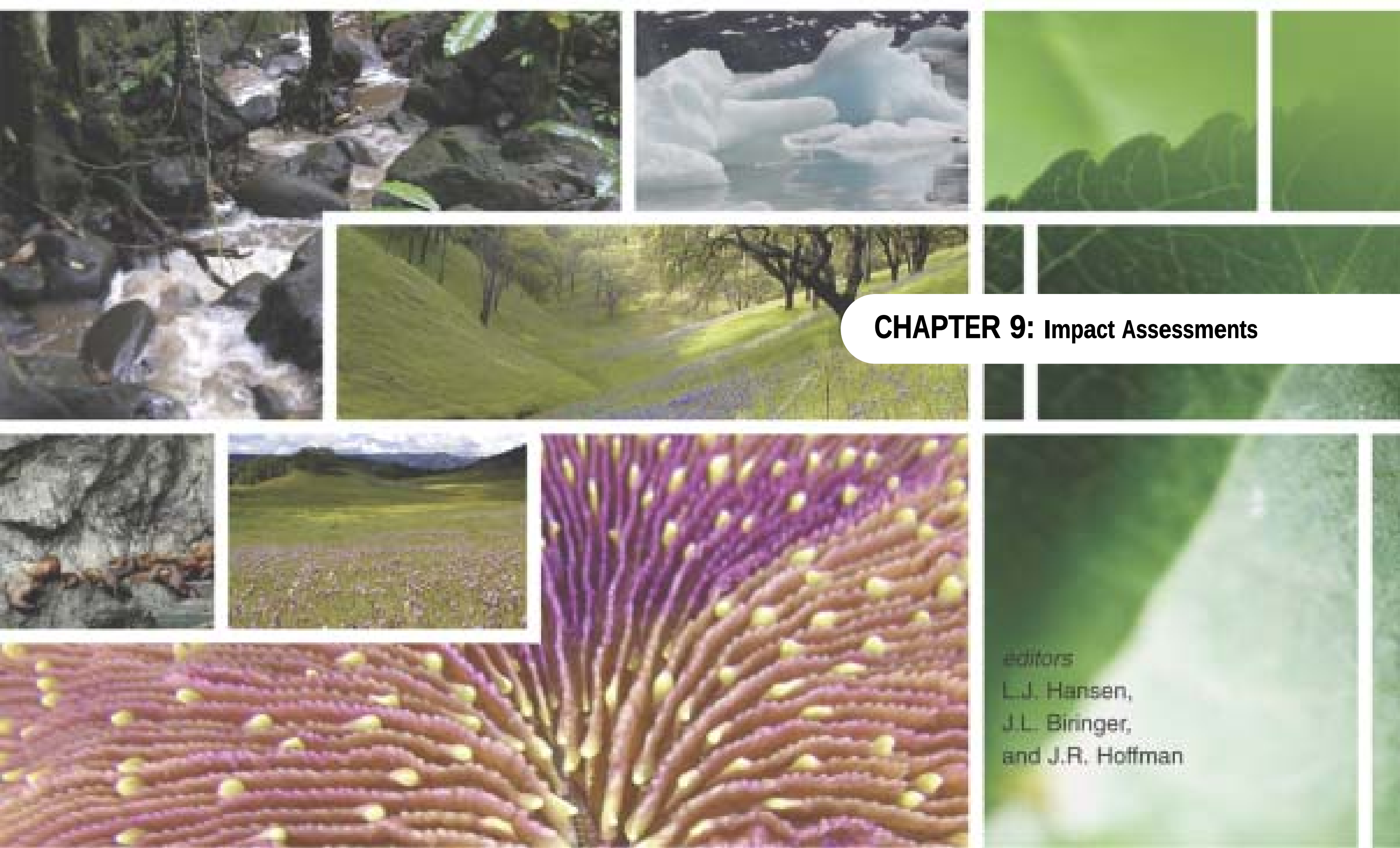
BUYING TIME:

A User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems



CHAPTER 9: Impact Assessments

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Regional Biodiversity Impact Assessments for Climate Change: A Guide for Protected Area Managers

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PROTECTED AREAS MANAGERS ARE increasingly concerned about the possible impacts of climate change on the sites they manage. Tools for assessing these impacts are now often in desktop form, including Regional Climate Models (e.g., the Hadley Centre's PRECIS) and species range shift models (e.g., desktop GARP). However, while these tools are now within the computing capacities of some protected areas, they require a long time to run (up to 6 months for a regional climate model like PRECIS), coupled with specialized training and interpretation. For these reasons, protected areas managers will probably remain reliant on studies done by university researchers or assessment agencies for the immediate future. This chapter explores some of the issues protected areas managers need to understand to properly interpret and apply studies of regional biotic effects of climate change.

The chapter opens with a discussion of modeling tools now available for regional analyses. Protected areas managers need to be aware of these tools so that they can judge the quality and appropriateness of regional studies for application at their sites. The second part of the chapter outlines issues of interpreting these studies. Knowing how to interpret studies can help avoid either their being taken too literally or ignored due to the considerable uncertainty they carry. Finally, the chapter examines some modes of collaborative research between protected areas managers and researchers that may help move ahead both understanding of climate change impacts on biodiversity, and the formulation of effective conservation responses.

Assessment Tools

Major regional universities and biological research centers will increasingly have the capacity to generate assessments of biotic impacts of climate change. Regional Climate Models (RCMs) are now available which run on a desktop PC. Such RCMs give climate projections at a scale that is useful for regional impact analysis, in contrast to models of global climate, called General Circulation Models (GCMs), which are generally run at scales too coarse for meaningful regional analysis.

The output of a Regional Climate Model may be used in species range shift (or ‘niche’) models, to provide species-level projections of possible biotic impacts. Such models use the current climatic tolerances of a species to infer possible changes in its distribution due to alterations in climate. Biological impact assessments using these tools are likely to proliferate in the coming years, and not all will be of equal quality. It is therefore important to understand the broader range of assessment tools to put gauge the utility of these studies for protected areas planning.

Several major types of tools are available for assessing the impact of climate change on biodiversity. These include:

- global climate models,
- regional climate models,
- dynamic and equilibrium vegetation models,
- species bioclimatic envelope models (Figure 1), and
- site-specific sensitivity analysis.

Models of global climate, General Circulation Models (GCMs), provide broad resolution projections of future climate changes. A typical protected area occupies just a small fraction of a GCM grid cell, and there are substantial differences in projected climate changes among GCMs. Nonetheless, GCMs are an essential entry point for conservation assessments of climate change, since they represent the only source for estimates of future climate changes due to global greenhouse-gas forcing. Global GCM projections for several models are available on the internet (e.g., http://www.meto.govt.uk/research/hadleycentre/models/modeldata.html). Software is available on CD-ROM for personal computers which allows the comparison of simulated results from several models, which is useful given the considerable inter-GCM uncertainty (see Wigley et al., 2000 for mailing address for CD/software requests).

Most current GCM assessments are transient simulations, that is, they simulated a realistic, gradual buildup of greenhouse gases. Simulations that use an unrealistic, all-at-once increase are called equilibrium simulations and generally should be considered outdated. Equilibrium simulations (i.e., a step increase in CO_2) show increasing temperature change poleward in both hemispheres, while more sophisticated transient simulations show temperature change decreasing with latitude in the southern hemisphere outside of Antarctica. Northern and southern hemisphere climate system dynamics are markedly different and GCM hemispheric coupling is problematic, so models developed with a southern hemisphere focus (e.g. several excellent modeling exercises in Australia) may be more appropriate in southern hemisphere applications. Using inappropriate models or simulations may bias results, especially in the southern hemisphere. GCM relevance to biodiversity assessment is also improved by selecting results from fully-coupled ocean-atmosphere models appropriate to the region in question.

Regional climate models may be imbedded within GCMs to provide higher resolution results for use in regional assessments. Two major regional climate models in wide use are MM5 (Mesoscale Model version 5) and RAMS (Regional Atmospheric Modelling System). These models capture the regional influences that in some settings may be more important than global forcing in determining local climate changes. For instance, conversion of forest to pasture in the Amazon may produce local precipitation effects that overwhelm likely precipitation changes due to global greenhouse gas forcing. Regional models represent both the land-use changes and resultant cloud formation dynamics of this effect in ways impossible in a GCM. Regional models run at national or sub-continental scales useful in conservation planning. Their results are less widely available than those of GCMs and they are not available for all regions. However, the Hadley Centre has released a relatively new RCM called PRECIS, which is relatively simple to run on a personal computer, although it can take 6 months or more of continuous computing for a single model run (thus multiple runs for various emissions scenarios or multiple GCMs might take several computers or several years). Training for PRECIS is available in one-week workshops in many parts of the world. Regional climate modeling is therefore now within the grasp of most major regional universities.

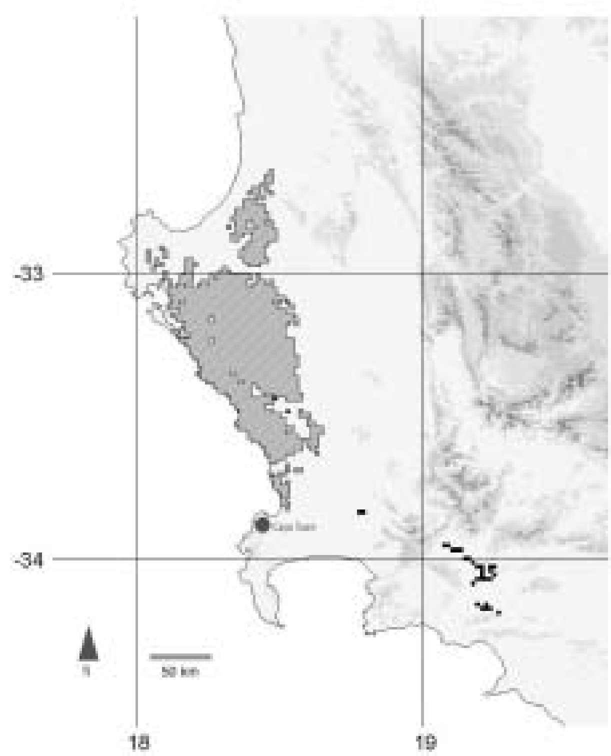
Dynamic vegetation models, forest 'gap' models, biome envelope (or 'correlative') models and species envelope models all use GCM and regional climate model results to provide insights into different aspects of the biogeography of future climate change. Dynamic Global Vegetation Models (DGVMs) use first principles of photosynthesis, carbon processing and plant physiology to predict plant functional types. Forest 'gap' models simulate species-specific succession dynamics at the stand-level (<1 ha), but have limited ability to represent landscape-level changes. They have data requirements that limit their application primarily, but not exclusively, to temperate forests. Global biome models use the climatic boundaries of current vegetation to simulate future distributions in changed climates. Global biome models assume vegetation is in equilibrium with climate and so cannot model dynamic transitions, while DGVMs incorporate dynamics but do not yield species specific results. Forest 'gap' models do both, but only for a small area and only for species for which growth and reproductive characteristics have been studied.

Species bioclimatic envelope models are the best available tool for producing the species-specific information necessary in conservation planning (Figure 1). They are similar in principle to biome envelope models, in that the present distribution of a species is used to 'train' a model to predict the climatic conditions in which the species may exist in the future. Envelope construction may be done manually on a GIS platform or through rule-based techniques such as genetic algorithms or general additive modeling . Unfortunately, these models currently face numerous limitations, including the inability to model dynamic transitions, the effects of inter-specific competition, herbivory, dispersal, or other factors (e.g. soil type in some models).

To make the results of species bioclimatic envelope models most applicable to real-world conservation problems they must be coupled with land-use projection models. Land use projection models represent the current pattern of habitat fragmentation and model future patterns based on projections of parameters such as population and consumption levels. The potential range shift of a species approximated by bioclimatic models is then reduced to the available habitat as projected by the land use model. For example, a species whose potential climate envelope shifts into an area entirely dominated by agriculture or urban development may be faced with extinction.

Integrative and sensitivity analysis based on the ecology of sites and individual species is an essential supplement to modeling, even if it may lack the attractive spatial specificity of models. Models cannot predict species composition at a landscape scale in a dynamic, competitive environment (dynamic vegetation models lack species-specificity, envelope models lack dynamic and competitive elements, 'gap' models lack spatial resolution). Evidence of paleoecological and paleobiogeographic responses to climate change form a central element of this analysis.

Figure 1



Bioclimatic model of the range shift of *Leucospermum tomentosum* in the Cape region of South Africa in a double CO_2 climate (approximately 2050). The GCM projection used is CSM without sulfates. Present modeled range is indicated by cross-hatching. Future modeled range is indicated by black rectangles. Figure courtesy of the Center for Applied Biodiversity Science at Conservation International.

Sensitivity analysis in a site assessment considers possible cooler climates, as well as anthropogenic warming. A sensitivity analysis asks what would happen if various climate variables changed, systematically testing each variable for changes that are both positive and negative in sign. The end result of this process is a picture of what responses may be expected under a wide range of climatic conditions. Paleoclimatic evidence suggests that global climates may be capable of switching rapidly between states. The possibility of reversal of current warming trends within centuries argues that sound conservation plans should be robust to both warming and possible cooling. An excellent introductory review of climate models, biogeographic models and sensitivity analysis in regional environmental assessment is given by (Sulzman et al., 1995).

Interpreting Modeling

Regional modeling, interpreted carefully, may provide critical input to practical conservation strategies. First, protected areas managers must accept that there are major uncertainties associated with climate change projection and species range shift models. This does not mean that their results are useless or should be ignored. Rather, it means that their results should be viewed as an aid in risk management. Protected areas management is often about identifying threats, weighing future risks and designing management strategies accordingly. Climate change is a threat which should be treated similarly.

An insurance analogy is useful in this context. Insurance companies provide a service that helps their customers manage risk. Their customers want to avoid future scenarios in which low probability but high cost events (such as an auto accident) disrupt their lives. They therefore weigh the likelihood of future high cost events and invest in insurance accordingly.

Protected areas management alternatives are often explored as insurance against future threats having unacceptable impacts on biodiversity. For instance, a park may have a management strategy in place for dealing with a large catastrophic fire, even if none has occurred in recent history. In the insurance analogy, the fire is a low probability event with high costs to biodiversity, so having a plan in place to minimize the damage is a sound investment, just as an insurance policy is often a sound investment.

This type of risk management applies to climate change as well. Any particular projection of the future is unlikely to be exactly correct, but it is wise to plan for a range of possible futures to balance risk and minimize large negative consequences. Certain effects of climate change, such as temperature increase, are now relatively high probability events, while other effects suggested in modeling may be low probability events, some with highly negative consequences. Sound application of modeling results in protected areas planning requires balancing the risk of possible future events and creating management strategies that minimize the probability and impact of scenarios that have large negative consequences for biodiversity.

The output of a typical single-species model is illustrated in Figure 1. While model output is expressed as a map of future species range, it should be recognized that this is only one of many possible alternatives for the future range of the species. Different climate models (both RCM and the GCM in which it is embedded), different emissions scenarios, different species models and different input data might all present different results. A first principle in judging regional modeling or assessments is therefore 'the more scenarios the better'.

Second, assessments can be conducted with coarse-scale GCM climate scenarios or finer-scale regional (RCM) projections. The finer scale of RCM output is much more appropriate to regional analysis, and RCMs capture the effects of regional land use change (such as effects on precipitation due to forest clearing) as well. As second general principle is therefore 'a study done with RCM climatology is more reliable than one that uses GCM climatology'.

However, many assessments in the near future will be limited to a few scenarios and GCM-scale climatology. What use, if any, are these assessments? Here a return to the risk management perspective is useful. If one has no information about the likelihood or severity of a future event, it is extremely difficult to manage the associated risk. Therefore, even one scenario of low probability can be a major help in management. It allows some assessment of risk, and allows other, independent lines of evidence to be explored to refine the estimate of risk.

For example, a range shift projection such as illustrated in Figure 1 provides one assessment of the relative vulnerability of the species to long-distance dislocation due to climate change. This estimate can be refined by examining other relevant factors, such as land use in the direction of shift, dispersal capability of the species, and other factors. The modeling itself may also be examined to determine what climatic factors drove the simulated shift. If these factors seem relevant for the species, the probability of the projection goes up. By adding projections and lines of evidence, uncertainty can be reduced, negative impacts in the future balanced, and management strategies evolved.

Protected Areas Management

Refinement of management practices in response to the results of an impact assessment can be done in four major steps:

- scenario-building;
- enhanced monitoring;
- biological survey; and
- review and revision of management practices.

Scenario-building is an iterative process in which modeling is used to refine management and management revisions suggest further areas of enquiry for modeling. Scenarios are created that span the range of uncertainty in climate change and biotic response modeling, and that capture important management variables. Monitoring and management are tested repeatedly against the scenarios and the scenarios themselves are repeatedly revised as more data becomes available and uncertainties change or decrease.

Scenarios should be created that capture possible major ecological events in the system being conserved. For instance, dynamic vegetation or envelope model results should be examined for biomes or habitats ‘on the edge’—systems that are near threshold for conversion to a different growth form, dominant vegetation or disturbance regime. Scenarios should also be constructed for rare, threatened and climate-sensitive species. Rare and threatened species may be vulnerable to further population reductions due to climate change, and these should be considered in management plans for these species. Climate-sensitive species include species with small ranges (even if abundant), species with limited (<500-1000 m) elevational ranges, and upper elevation species whose habitat may be reduced with warming. Finally, scenarios should be constructed that describe the possible impact of climate change on ecosystem processes. Droughts and storms often limit plant functional types or open forest canopies for regeneration. Change in frequency of these events may therefore alter vegetation structure, succession, and species diversity and composition.

An expanded monitoring program is based on the scenarios developed. Testable scenario predictions monitored in the field permit adaptive management responses. Many parameters of enhanced modeling will be biological, including climate-sensitive species and processes. Installation or upgrading of weather-data gathering capability is a physical monitoring step to be considered. Collection of sound weather data has proven important in documenting climate correlates to species range changes, changes in abundance (amphibian decline) and even possible extinctions in the Monteverde cloud forests of Costa Rica. Remote sensing and regional modeling may help in the design of a monitoring system which focuses on variables that may be vulnerable to change, for instance lifting cloud bases in tropical montane settings such as Monteverde (Lawton et al. 2001).

Biological survey work can complement monitoring and scenario refinement by providing key data. Detecting individualistic species range shifts requires data on distribution and abundance generally not available nor previously considered necessary at most protected areas. Survey programs can help fill this data need and provide baseline data for monitoring. For example, scenarios from modeling may show that a species not known from a reserve may find favorable climatic conditions there in the future (Rutherford et al., 1999). Such species may exist in the reserve but have escaped documentation. Survey work can help find outliers of the species or increase confidence that it does not exist in the reserve, information critical to the design of effective monitoring systems. Additional distributional data even on common species may be required for effective monitoring. Inexpensive GPS units make park staff on regular patrol or even tourists on remote trails potential data gathering allies in this effort. Additionally, species range shifts may respond not just to climatological changes, but to changes in community interactions as well (e.g. Harley, 2003). Biological surveys will help refine models to reflect key biotic as well as abiotic variables.

Review and revision of management practices is the final step in an iterative process of revision of management based on modeling, scenarios, monitoring and survey. Modeling results and management scenarios will suggest management practices to be reviewed and revised. Examples of management practices that will often qualify for review are management of fire or other disturbance regimes, classification of 'sensitive' areas, and management for 'representative' species.

Fire and other disturbance regimes are often intensively managed in protected areas. These management practices will interact with climate change effects in ways that may not be apparent without careful monitoring. Fire may maintain certain vegetation types past their climatic optimum, or, if managed uncritically, suppress new vegetation types that are becoming climatically favored. For example, in Central Canada, long-grass prairie is predicted to be climatically favored over present forest types in future warmer climates (Scott and Suffling, 2000). Fire suppression may retard this transition. Fire management therefore has an effect that must be judged against regional conservation goals—either maintenance of forest or promotion of grassland in newly suitable climate space.

Sensitive areas form an important part of management in many protected areas. Climate change will introduce a new class of sensitive areas. Climate change-driven alterations in range or abundance may render once resilient species sensitive. Rapid range shifts may make robust systems sensitive. Changes in disturbance regime may create new or recovering vegetation sensitive to many types of use. Non-analogue communities may arise with unknown sensitivity requiring conservative management until they are more fully understood. Heavy tourist traffic may facilitate dispersal of invasive species into areas vulnerable because they are in transition to new vegetation types. These and other climate change sensitivities should be considered as sensitive areas are designated and managed.

Many protected areas are established or managed to conserve 'representative' ecosystems that may no longer exist in future climates. Minor vegetational elements or even outlier pockets may become dominant vegetation types in the future. Site goals will be difficult to set for changing vegetation without reference to regional trends and conservation goals. In the Central Canada example above, management for 'representative' forest is appropriate if the regional management goal is to retard biotic response to climate change, while promoting fire to stimulate transition to long grass prairie is appropriate if the regional goal is to allow natural transitions to take place while maintaining representation goals in a flexible regional protected areas network. Many other management issues will evolve from a systematic modeling, and management scenario analysis.

Finally, almost all protected areas management plans have 3- to 10-year time horizons, which are insufficient to allow for anticipatory management responses to climate change. A minimum appropriate planning time horizon for climate change is 50 years, while a 100-year horizon is necessary to capture many possible climate change effects.

Incorporating sensitivity analysis and climate change management scenarios into a management plan will require that at least part of the management plan has a longer time horizon.

Species range shifts, impacts of extreme events and resource asynchronies often occur on regional scales, so an effective management strategy includes mechanisms for coordinating conservation actions at the regional level. Regional coordination is necessary for conservation goals and management to be coherent on the same scale at which these climate change impacts will operate. Examples above show that managing for 'representative' vegetation is a relative term at the site level when climate is changing. Regional goals for representation can only be maintained in a dynamic climate when management at multiple protected areas is harmonized (Rutherford et al., 1999). This coordinated management may require formal agreements, for instance when national boundaries are crossed, or may simply involve appropriate planning within existing protected areas systems and conservation agencies.

Modeling and monitoring will often be more effective when coordinated within a region. Monitoring must be done in a way that is relevant to management goals, so regional goals require regionally coordinated monitoring. Sharing technical and financial inputs for modeling across multiple users on a regional basis increases cost-effectiveness as well. Regional coordination will become increasingly important as climate change progresses. In the short-term, identifying and establishing these collaborations is a priority. Peace Parks initiatives and other collaborative management efforts are already paving the way for these systems.

Collaborative Research

Creation of a climate change-integrated conservation strategy requires synergy among a novel set of actors and funding sources. Conservation managers, biogeographers, ecologists and climate change scientists are all needed to formulate an effective management strategy. Funding from research sources will be required for modeling and assessment activities with clear connections to applied conservation. Conservation agencies will need to source funding for major new investments in monitoring and revision of management practices. Creation of this synergy will carry a cost, and responding to the new challenges of climate change to the conservation of biodiversity will require major new financial commitments.

In a world filled with conservation challenges, managers will not be able to undertake all of the elements of climate change-integrated conservation strategies described here in the short term. What is important, is that managers, biogeographers and ecologists begin to consider the impacts of climate change in their area, and adopt at least some elements of a management strategy, progressively building capacity at the local level as the challenges posed by climate change mount.

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