CHAPTER 1

Introduction

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Over the past decade, biodiversity and anthropogenic climate change have seen intermittent coverage in the popular media, having to depend on popularly reported links to environmental disasters such as wild fires, droughts, tropical storms and floods to warrant international news worthiness. Scientific interest in climate change issues has been more consistent, if less spectacular from a media point of view. A consensus scientific opinion of the global nature of climate change was first formalized in the First Assessment Report (FAR) of the Intergovernmental Panel on Climate Change (http://www.ipcc.ch) (IPCC 1990a,b,c). At that time, the report had a mandate to review the state of knowledge about climate change, and to present an up-to-date consensus scientific opinion. The report, which consisted of three volumes, placed considerable emphasis on the detection of climate change signals amidst long-term natural climate variation and assessing the evidence for anthropogenic sources for these changes. It is unclear if the 1990 report directly stimulated climate change related investigations but the subsequent political controversy about who is responsible for how much climate change raised the profile of climate change to a legitimate global concern. Although a Second Assessment Report was scheduled for 1995, mounting evidence prompted the IPCC to release Supplements to the Scientific Assessment and Impacts Assessment of FAR in 1992 (IPCC 1992a,b) as well as Special Reports on radiative forcing (IPCC 1994a), national greenhouse gas inventories (IPCC 1994b) and technical guidelines for studying impacts and adaptations to climate change (IPCC 1994c). Further momentum for the global awareness of climate change as a real threat was gained at the Earth Summit in Rio de Janeiro in 1992. At this meeting the United Nations Framework Convention on Climate Change (UNFCCC, http://unfccc.int) was signed by about 170 countries, including the United States, who is responsible for approximately a third of global carbon dioxide emissions. The UNFCCC called for a voluntary reduction of greenhouse gas emissions to 1990 levels by the year 2000. By the time the 1995 Second Assessment Report (SAR) (IPCC 1995a,b,c,d) was released, signatories to the UNFCCC realized that a more binding commitment to the reduction of green house gas emission was needed if any real progress was to be made. As a result, the Kyoto Protocol came into being in 1997, and will become legally binding for signatories as soon as 55 Parties to the Convention ratify (or approve, accept, or accede) the Protocol. These 55 parties have to include enough Annex I Parties (developed countries, or countries transitioning to a market economy, http://unfccc.int/resource/conv/annex1.html), to account for at least 55% of the carbon emissions of all Annex I Parties. As of 6 June 2003, 110 countries have ratified the Protocol, accounting for 43% of 1990 global carbon emission levels (http://unfccc.int/resource/convkp.html#kp).

Although the United States refused to ratify the Kyoto Protocol after initially supporting the UNFCCC, the resultant media coverage catapulted climate change into the limelight and raised global public awareness. This increase in global interest following the SAR in climate change is reflected not only in the number of special reports (five) the IPCC commissioned before the 2001 Third Assessment Report (TAR), but also in the scope covered by these reports: regional impacts (IPCC 1997), aviation (IPCC 1999), technology transfer (IPCC 2000), emissions scenarios (IPCC 2000) and forestry and land use change (IPCC 2000).

The TAR 2001 (IPCC 2001 a,b,c,d) summarised a growing body of evidence that the global climate was indeed changing at an unprecedented rate, most likely due to anthropogenic activities, and that these changes in climate are causing severe, and possibly irreversible, changes in physical and biological systems (IPCC 2001c). Given the severity of the situation, there is a strong focus on assessment of vulnerabilities and an identification of adaptation and mitigation strategies.

It is clear then, that the IPCC reports underwent a shift in focus from just detecting climate change at a global scale, to attributing these changes to anthropogenic activities, to estimating general effects at finer scales, to quantifying effects on specific systems and finally, to adaptation and mitigation strategies. In the context of this thesis, the interest lies in climate change effects on biodiversity. Biodiversity conservation lacks a global coordinating body similar to the IPCC (see Mace et al. 2000) and subsequently, public and scientific awareness of the biodiversity crisis (Pimm 2001) is slower to gain momentum. Seminal papers on vulnerable hotspots (e.g. Myers et al. 2000), the value of biodiversity dependent-ecosystem services (Costanza et al. 1997, Balmford et al. 2002) and specific case studies of the decline of charismatic mammals (e.g. Walsh et al. 2003) all contribute to raising biodiversity awareness. By virtue of its association with sustainable development, biodiversity received a lot of coverage at the recent World Summit on Sustainable Development held in Johannesburg, August 2002. Although this association between biodiversity and sustainable development is not as clear-cut and definitive as publicized catastrophic impacts of climate change, the net effect of raising public awareness was very similar. The IPCC responded to this increased awareness by publishing a Technical Paper on Climate Change and Biodiversity in 2002 in response to a request from the United Nations Convention on Biological Diversity (IPCC 2002).

It is against this backdrop of increased awareness of the immediacy of climate change and the biodiversity crisis that this thesis on the interface between climate change and biodiversity for South Africa is presented. Even without climate change, land-use change poses a serious threat to biodiversity (Schlesinger et al. 2001). In-depth studies of the biodiversity responses to climate change have been identified as a conservation research priority for the next decade (Schlesinger et al. 2001). This thesis is intended as a starting point to address three major shortcomings identified by the IPCC reports: climate change impacts at finer than regional scales, climate change impacts on biodiversity, and finally, climate change impacts on biodiversity at these finer scales. The existing reports on climate change effects at regional scales and climate change effects on biodiversity primarily deal with Africa as a region, with some isolated examples (IPCC 2002). However, conservation planning is usually done at the scale of individual countries (Erasmus et al. 1999) (with the possible exception of transfrontier conservation areas, (see http://www.peaceparks.org)) and therefore country specific studies are critical for climate change-integrated conservation strategies (Hannah et al. 2002).

At any scale, the interface between climate change and biodiversity is by no means a simple one and therefore this study is not meant to be a comprehensive guide to potential climate impacts on South African biodiversity. Instead this thesis has two main foci: first, to quantify the potential responses of biodiversity to climate change and assess the resulting conservation implications, and secondly, to investigate the robustness of the methodologies followed to arrive at these assessments. As such it provides a point of departure for further, more focused studies, as well as a methodological reference.

The first four chapters of this thesis make up the first focus. In chapter 1, a climate envelope model to predict the potential responses of species distributions to climate change is developed. Essentially, this model derives a typical climate envelope for a particular species, and given a changed climate, identifies areas where the changed climate matches the climatic conditions of the climate envelope that was derived from the species' present range. Such areas are then identified as potential novel distribution ranges for the particular species. For illustration purposes, the model is applied to antlion distribution data.

The fact that this approach ignores several other factors that might be critical in determining the final distribution range does not render the approach useless as suggested by Davis et al. (1998), and to a lesser extent by Petchey et al. (1999). Huntley (1998) has shown that climate is an important determinant of species distributions, and that species have responded to climate change in the paleontological past by range shifts. Several studies (Pounds et al. 1999, Parmesan 1996, 1999) and reviews (Hughes 2000, Stenseth et al. 2002, Walther et al. 2002, Parmesan & Yohe 2003, Root et al. 2003) have shown that individual species have already responded to climate change by shifting distributions. Midgley et al. (2002) provides further support for modeling individual species instead of an entire biome. The climate-dependent individual species-based modeling approach that was followed is a hybrid approach between what the IPCC (IPCC 2002) calls an ecosystem movement approach and an ecosystem modification approach. Due to species' differential responses to a changing climate, ecosystems will not move as units, but rather disassemble and form new assemblages (IPCC 2002). By modeling individual species, the ecosystem modification approach was followed, but due to a lack of knowledge on species interactions for any large number of species, only climate was used as a determinant for the new assemblage. The validity of this approach has sparked an ongoing debate in the literature (see critique on Samways et al. 1999 by Sutherst 2003, and the response in Samways 2003), and it will be further elucidated where relevant in each chapter.

Chapter 2 sees the application of the model developed in chapter 1 to a selection of representative South African biodiversity elements. The analysis proceeds on a taxon by taxon basis, and the potential distribution changes for the country as a whole as well as for a flagship conservation area are quantified. A subset of species regarded as vulnerable and/or endangered is also analysed separately. Finally, these potential distribution shifts are put into context by looking at the availability of suitable habitat corridors between current and predicted distribution ranges.

Chapters 3 and 4 have more indirect links to conservation. Conservation is a legitimate land-use that has to compete with other forms of land-use, such as intensive agriculture and forestry, for a limited resource pool. The viability of conservation as an alternative form of land-use will change with a changing climate as conservation goals change with shifting distribution patterns. However, competing land-uses will experience similar climatic constraints, and their response to climate change might be beneficial to conservation, i.e. currently marginal agricultural lands might become too marginal for crop production but still be sufficient for more biodiversity-friendly rangeland farming. Therefore, it is of interest to conservation planners to also have a measure of the potential response of competing land-uses to climate change. Two case studies are presented; chapter 3 predicts the future distribution of two economically important forestry pathogens and chapter 4 investigates the effects of reduced precipitation on the agricultural sector in the Western Cape. Chapter 4 also touches on the social dimension by looking at potential consequences for the labour force as production patterns shift in response to decreased precipitation.

The last two chapters form the second, more methodological, focus area of this thesis. During the analyses in chapters 1 to 4, limitations of the modeling approach were identified and two of these shortcomings were addressed in the last two chapters. Once again, the analyses are not meant to be exhaustive in their description of unwanted model behaviours, but they rather serve as solution oriented case studies. Chapter 5 quantifies the variation associated with any particular probability of occurrence value by using a resampling jackknife procedure. This enables the modeller to use variation in the predicted probabilities of occurrence as an additional constraint to refine predicted distributions.

Finally, chapter 6 compares 3 different kinds of predictive distribution models. The comparisons are done in a spatially explicit manner, and it was found that disagreement between models occurred in an area of ecological transition. Identifying such transition areas prior to a predictive modeling exercise can significantly improve model performance.

I present this work as a point of departure for further, more focused studies of climate change-biodiversity interactions in South Africa. It is not intended as a complete handbook of potential impacts or methods; instead, I hope to elucidate commonalities with IPCC regional assessments and hope that the results will be useful to feed into policymaking processes. As a final product, I summarize lessons learnt from this entire thesis into recommendations for a national study on climate change effects on biodiversity.

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