Foreword

This volume presents six expert reports commissioned by the Council of Europe and discussed by the Group of Experts on Biodiversity and Climate Change at its meetings in 2007 and 2008. This Group of Experts was set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern, 1979), commonly know as the Bern Convention, at the end of 2006, reflecting the importance of this new challenge for the conservation of Europe's natural heritage.

This publication also includes, as an appendix, the full text of Recommendation 135 (2008) of the Standing Committee of the Bern Convention on addressing the impacts of climate change on biodiversity, adopted on 27 November 2008. The key messages and suggested actions listed in the recommendation are based on the conclusions of the expert reports presented here, which is why they are published together in a single volume. As the work of the Group of Experts continues, this publication will be complemented with further volumes in the future, covering other themes and issues related to the linkages between biodiversity and climate change.

The Bern Convention aims to conserve Europe's wild flora and fauna and their natural habitats, especially those requiring the co-operation of several states. The convention places particular importance on the need to protect endangered natural habitats and vulnerable species, including migratory ones. The work of the Bern Convention on biodiversity and climate change takes place within the framework of the main obligations for parties to the convention, which include the need to take account of the impacts of mitigation and adaptation measures on biodiversity. In this sense, the main task of the Group of Experts on Biodiversity and Climate Change is to present to the Standing Committee "specific proposals, guidance and/or Recommendations to help Parties address the challenges of climate change in the implementation of the Convention and its objectives". Recommendation 135 (2008) is the first advice on this issue, addressed to both parties and observers and offered "as examples of action that may be taken by authorities at all levels of governance" to address the impacts of climate change on Europe's biodiversity, and its adaptation needs.

I. Climatic change and the conservation of European biodiversity: towards the development of adaptation strategies

*Mr Brian Huntley, Institute of Ecosystem Science,
Durham University, United Kingdom*

EXECUTIVE SUMMARY

Introduction

Prepared for the Group of Experts on Biodiversity and Climate Change of the Bern Convention, this "discussion paper" focuses upon the principles that must underpin the development of adaptation strategies for biodiversity conservation in the face of climatic change, as well as providing the background evidence from which these principles emerge.

Context – predicted 21st century climatic change

Europe is projected on average to experience warming greater than the global mean. Winter warming is projected to be greatest in the north, where the December-January-February (DJF) mean warming is likely to be approximately double the global mean warming, whereas during the summer months warming is projected to be greatest in the south, where the June-July-August (JJA) mean warming is again likely to be approximately double the global mean warming in many areas, and as much as three times the global mean warming in some areas. Seasonal temperature extremes are projected to increase even more markedly, with annual minimum temperature increases of 6-18°C projected for central and eastern Europe and annual maximum temperature increases of 6-12°C projected for areas south of around 50° N. Annual precipitation is projected to increase in the north but to decrease in the south, with greatest changes in the summer in the south (JJA precipitation projected to decrease by > 40% south of 40° N) and in the winter in the north (DJF precipitation projected to increase by 20-50% north of 40° N). Such changes can be placed in context by comparing them to the present spatial gradients or to past climatic changes. During the Quaternary geological period, the difference in global mean temperature between glacial and interglacial stages is comparable in magnitude to the upper end of the range of possible global mean warming projected by the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report, whilst at the lower end of this range the warming results in conditions at least as warm as any during the past two million years. The projected rate of global mean warming exceeds by at least an order of magnitude the rate of global warming during the most rapid large magnitude events of the Quaternary period.

Species' responses to past climatic changes

Species' principal response to past rapid climatic changes was a spatial response, their geographical range changing as the area in which their climatic tolerances and/or requirements were met shifted. This spatial response was complemented by adaptive genetic responses of the population at any given locality as the climatic conditions at that locality changed. Species unable to achieve a sufficient spatial and/or adaptive response suffered extinction, at least regionally and in some cases globally. The magnitude of the spatial response required was less in regions of high topographic diversity, where species could shift elevation or utilise areas of contrasting topography, especially aspect and slope. In areas of lower relief, species' range boundaries shifted by between a few hundred and around 2 000 km in response to the climatic change from the last glacial stage to the Holocene. Such extensive range boundary shifts took place at long-term average rates of 200-500 m yr^{-1}, exceptional taxa achieving rates of as much as 1-2 km yr^{-1}. Species' spatial responses were individualistic. Evidence of species' responses to 20th century climatic change complements the Quaternary record and provides independent evidence of the importance of the spatial response and of its rate, which has averaged 610 m yr^{-1}.

Ecosystems and climatic change

The individualistic response of species to climatic change renders species assemblages (communities) and ecosystems impermanent. A sustained climatic change results initially in quantitative changes in the relative abundance of component species, followed by qualitative changes in species composition. As species composition changes so too, in many cases, do the structural and functional attributes of the ecosystem. Species composition changes often are facilitated by some form of disturbance of the present ecosystem. Changes in the functional attributes of ecosystems often affect their ability to deliver various of the ecosystem services upon which human society depends. Combinations of environmental conditions without a present analogue are characterised by species assemblages and ecosystems without analogues amongst those found today. An important minority of ecosystems depend upon a physical habitat that itself is threatened by global climatic change, notably the ecosystems of the Arctic sea ice and of many coastal wetland areas.

Species' potential responses to projected climatic change

"Climate envelope" models of various types can be used to simulate species' potential distributions under a given scenario of projected future climatic conditions. Although subject to criticism by some, such models of the relationship between a species' realised geographical range and biologically relevant climatic variables nonetheless offer valuable insight into the magnitude and rate of species' potential spatial responses to projected climatic change. Although rarely highlighted, the principal limitation of such models arises from the frequency with which future combinations of environmental conditions are without a current analogue. Such models only portray species' potential future geographical ranges; the dynamics of species' range shifts, and the time scales over which these potential range shifts might in practice be achieved, are simulated using a separate class of dispersal or "migration" model. Work to combine the two classes of model is a current topic of active research.

Application of "climate envelope" models to various European taxa leads to important conclusions about the rates and magnitudes of species' potential range shifts. By the late 21st century, the mean potential range shift relative to the late 20th century is by a distance of several hundred kilometres in a north-eastward direction, although some individual species' potential ranges are displaced in quite disparate directions and by distances in excess of 2 000 km. The mean rate of potential range shift is between a few times and more than an order of magnitude faster than past rates of range shift estimated from the Quaternary record or from historical data. Species on average have future potential ranges of smaller extent than their present ranges; as a result, the mean number of species potentially occurring in an area is reduced. Some species that occur today in Europe have no potential range in the continent by the end of the present century, and for a larger number their potential range does not overlap their present range. A small but significant proportion of European species are, as a result, likely to face a substantial threat of eventual extinction in Europe and, in some cases, global extinction. A much larger proportion of species are likely to suffer substantial loss of genetic diversity as a consequence of a combination of range and population reductions resulting from their failure to adjust their geographical ranges sufficiently rapidly. Species at most heightened risk of eventual extinction will include those that already are rare and/or threatened, those with limited geographical ranges and some migratory species. Species not present in Europe today as "natives" but found in adjacent regions are likely to find suitable climatic conditions in Europe in the future.

Implications for biodiversity conservation strategies

Adaptation strategies must be developed that take into account the implications arising from the evidence presented above. Adaptation strategies alone, however, will be insufficient: stringent mitigation measures also will be necessary if the rate and eventual magnitude of climatic change are not to exceed the resilience threshold of the biosphere.

In particular, adaptation strategies must take account of:

- species' spatial response to climatic change; **[*Recommendation 1*]**
- the need to facilitate, rather than to hinder, gene flow through species' populations to enable the adaptive component of their response to climatic change; **[*Recommendation 2*]**
- species' individualism and the consequent impermanence of species assemblages and ecosystems; **[*Recommendation 3*]**
- the vital role of protected areas in any successful adaptation strategy; **[*Recommendation 4*]**
- the absolute need to render landscapes "permeable" to species as they adjust their spatial patterns of distribution. **[*Recommendation 7*]**

In order to achieve this and to be effective, adaptation strategies must incorporate:

- re-evaluation of the management goals of protected areas; **[*Recommendation 1*]**
- the need to maintain legal protection for protected areas that in future may not support the species or ecosystems that led to their initial designation; **[*Recommendation 1*]**
- a re-evaluation of the concept of a "native" species; **[*Recommendation 1*]**

- implementation of management, of protected areas and the wider landscape, that will facilitate species' potential future range changes; **[*Recommendation 1*]**
- measures designed to minimise loss of intra-specific genetic diversity, especially that component of such diversity concentrated near the "trailing edge" of species' European distributions; **[*Recommendation 2*]**
- measures designed to facilitate community and ecosystem changes; **[*Recommendation 3*]**
- management practices designed to facilitate ecosystem dynamic processes upon which realisation of community and ecosystem changes often depends; **[*Recommendation 3*]**
- continued protection and appropriate management of existing protected areas; **[*Recommendation 4*]**
- identification, using a "coarse filter" approach, of gaps in the existing network of protected areas; **[*Recommendation 4*]**
- augmentation of the existing protected areas network to maximise representation of the range of combinations of environmental conditions and physical habitats, as well as to minimise the occurrence of large spatial gaps in the network; **[*Recommendation 4*]**
- implementation of appropriate management of the wider landscape and development of a landscape structure that will facilitate species' spatial responses to climatic change; **[*Recommendation 4*]**
- exploitation of buffer zones to enhance the effectiveness of protected areas; **[*Recommendation 5*]**

- development of landscapes that provide functional networks of habitat "stepping stones" ensuring connectivity between the protected areas that will form the major nodes in these functional networks, the "stepping stones" being of varying sizes and separations and providing appropriate representation of the range of physical habitats characteristic of the landscape; **[*Recommendation 7*]**
- implementation of management of the "matrix" of the wider landscape in ways that are less intensive and that favour the maintenance or enhancement of fine-scale heterogeneity; **[*Recommendation 8*]**
- exploitation of existing, and development of new, incentive schemes for land-owners that promote the desired lower intensity land management, increased fine-scale heterogeneity and provision of habitat "stepping stones". **[*Recommendation 9*]**

In addition, adaptation strategies must recognise that continuous corridors are neither a necessary part of achieving landscape connectivity nor a viable option in most parts of Europe on the scale necessary to render them an effective response to climatic change [***Recommendation 6***]. Adaptation strategies also must recognise the scale mismatch between viable buffer zones and species' potential spatial responses to climatic change; buffer zones are valuable in enhancing the effectiveness of protected areas, but offer little or nothing specifically in relation to adaptation to climatic change.

Strategies for adaptation

In addition to the implications outlined above for the development of adaptation strategies, such strategies also must have a number of further attributes.

In relation to species' dynamic and individualistic responses to climatic change, adaptation strategies must also:

- implement management of both protected areas and "stepping stones" that accelerates community and ecosystem transformation; [***Recommendation 10***]
- implement management, especially of protected areas, that will maximise populations of rare or threatened species found therein, even in the case of sites near the "trailing edge" of a species' range where it is unlikely to persist in the longer term but where elements of the species' intra-specific genetic diversity important to its ability to adapt to climatic change elsewhere in its range are likely to be concentrated; [***Recommendation 10***]
- combine and balance the foregoing requirements; [***Recommendation 10***]
- develop a new holistic approach to the legal framework for the protection of an overall functional network of protected areas and the associated "stepping stones" required to render the landscape permeable, taking a continental scale view rather than a national focus; [***Recommendation 11***]
- adopt the concept of a "potential native" species and provide equivalent protection for all such species. [***Recommendation 12***]

In relation to the importance of maintaining and augmenting the existing protected area network, adaptation strategies must also:

- address as a matter of urgency the need to amend the legal basis for the designation of many protected areas so as to ensure continuity of protection of these sites that will be vital to any successful adaptation strategy; [***Recommendation 11***]
- take the steps necessary to increase the extent of the protected area in order that the often conflicting management practices required to facilitate change, on the one hand, and to maximise populations of rare and threatened species, on the other, can be accommodated; [***Recommendations 13 & 15***]
- target increases in the extent of the protected area such that the additional area, whether in the form of extensions to existing protected areas or of additional newly designated protected areas, offers the greatest flexibility and potential for species to adjust their distributions within the landscape in response to climatic change, for example by adding areas that extend to the highest elevations in the local landscape, that offer a high degree of topographic diversity, that maximise the range of physical habitats represented and/or that maximise the extent of the physical habitat and ecosystem that is dominant within the landscape. [***Recommendation 14***]

In relation to the requirement to ensure connectivity of the protected area network through appropriate management of the wider landscape, adaptation strategies must also:

- take the steps necessary to retain as many as possible of the remaining fragments of unaltered or semi-natural habitat in the landscape, especially of western Europe, in order that they may serve as "stepping stones" and contribute to rendering the landscape permeable; [***Recommendation 16***]
- make the necessary provisions to encourage the creation of habitat "stepping stones" in landscapes where past land management practice has led to the absence of sufficient suitable patches of unaltered or semi-natural habitat that may be managed for this purpose; [***Recommendation 9***]
- ensure that the legal protection afforded to species applies wherever in the landscape they may be present, and that the default status of species is that they are protected from disturbance or destruction wherever they may occur. [***Recommendation 17***]

Although translocations and captive-breeding programmes must not be ruled out as potential components of an adaptation strategy, they should be considered only as options of last resort and will be impractical on any large scale, being viable only principally for extremely rare or threatened species [***Recommendation 19***].

Given the potential scale of species' responses to climatic change, adaptation strategies must be international, and preferably sub-continental or continental, in scope [***Recommendation 18***].

Conclusion

Projected climatic changes are, relative to past changes, large in magnitude, at least an order of magnitude more rapid and leading to a destination without precedent in the past ten million or more years. Species' potential range shifts in response to these changes are large, range boundaries potentially shifting 500-1 000 km in many cases. Because these responses are individualistic, conservation efforts must focus upon species and upon the provision of functional networks encompassing the full range of physical habitats found within a region. Communities and ecosystems should not in themselves be a focus for conservation efforts. Maintaining and augmenting the existing protected area network will be vital to any successful strategy for biodiversity conservation in the face of climatic change. This enhanced network of protected areas must be embedded within landscapes that are managed to ensure their permeability to species making adjustments to their spatial distributions. The provision of habitat “stepping stones” is seen as the primary mechanism for rendering landscapes permeable. The challenges and opportunities that the development of such adaptation strategies presents must be addressed internationally if the resulting strategies are to be effective.

1. INTRODUCTION

This paper has been prepared for the Group of Experts on Biodiversity and Climate Change of the Bern Convention for discussion at their meeting in June 2007. The principal focus of the paper is upon the principles that ought to underpin the development of adaptation strategies that will maximise the conservation of biodiversity in the face of climatic change, and what these principles may mean in practice. These topics are dealt with in sections 6 and 7 of the paper. In order to illustrate the basis from which these underpinning principles have been developed, however, the paper begins with four sections summarising essential background material, a thorough understanding of which is essential to the development of appropriate adaptation strategies. These background sections deal in turn with: the climatic changes predicted by the end of the present century; evidence from studies of the Quaternary geological period, as well as of the more recent past, showing how species have responded to past climatic changes; a discussion of how ecosystems are affected by climatic change; and an outline of the expected responses of species to projected 21st century climatic changes. The sixth section then sums up the key implications of this background material for the development of biodiversity conservation strategies. The seventh section deals with the principles and potential practical approaches to adaptation, and is followed by the final concluding section summarising the key elements that it is proposed ought to be part of any adaptation strategy.

2. CONTEXT – PREDICTED 21ST CENTURY CLIMATIC CHANGE

Before considering potential adaptation strategies to maximise the conservation of European biodiversity in the face of predicted climatic changes, it is essential to understand how the climate of Europe is expected to have changed by the end of the present century, and the extent to which different regions of Europe may experience climatic changes that differ in important respects. It is also important to consider the predicted climatic changes in the context of past changes, because such contextual background can assist in assessing the resilience of the biosphere to predicted 21st century climatic changes.

Successive scientific reports from the Intergovernmental Panel on Climate Change (IPCC) have provided estimates of the range of potential increase in the global mean temperature by the end of the present century (IPCC, 1990, 1995, 2001, 2007). The most recent report (IPCC, 2007) considers that the most likely global mean temperature increase this century (2090-99 relative to 1980-99) is 1.8°C for the low emission B1 scenario and 4.0°C for the high emission A1FI scenario (Leggett et al., 1992; Nakicenovic & Swart, 2000), with likely ranges of 1.1-2.9°C and 2.4-6.4°C respectively. This report also estimates that there has been an increase of 0.74°C (uncertainty range 0.56-0.92°C) in global mean surface temperature during the 20th century (1906-2005) and, furthermore, the rate of warming has accelerated. In terms of biodiversity conservation and adaptation measures, the IPCC (2007) also reports that global mean temperature is expected to continue to increase at a rate of around 0.2°C per decade for the next two decades regardless of future emission levels; thereafter, the extent and rate of warming are determined by the emission levels and hence by the stringency of internationally agreed and implemented mitigation measures.

Global mean temperature, however, is to some extent a misleading value to consider. The IPCC (2007) reports that warming is expected to be greater in general over the continents than over the oceans, and greatest over the high northern latitudes. Snow cover is expected to be reduced in extent and duration, while the extent of Arctic sea ice will decline. In some scenarios late-summer sea ice in the Arctic basin has almost disappeared by the end of the century. Precipitation is very likely to increase in high latitude areas, with decreases likely in sub-tropical land areas. It is also considered very likely that a range of extreme climatic events, including heat waves and episodes of heavy precipitation, will become more frequent.

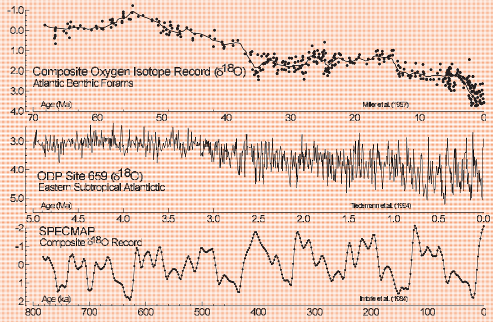
Although the full regional implications of the results presented in the IPCC Working Group 1 Fourth Assessment Report (IPCC, 2007) are not yet available at the time of writing, the results from climate projections made for the Third Assessment Report (Cubasch et al., 2001) can be used to provide a valuable guide as to what can be expected in Europe. In addition, various regional climate modelling studies (e.g. Räisänen et al., 2004) provide further insight. Overall, the results presented by Räisänen et al. (2004) indicate that Europe can be expected to experience warming of a greater magnitude than the global mean. For general circulation model (GCM) scenarios giving 21st century global mean warming of 2.3-2.6°C for the SRES B2 scenario and 3.2-3.4°C for the A2 scenario, annual mean temperatures across Europe increased by 2-4°C and 2-6°C respectively (2071-2100 relative to 1961-90). These are equivalent to mean rates of temperature increase of 0.18-0.36°C per decade and 0.18-0.55°C per decade respectively. Seasonal temperatures showed even greater increases. Simulated warming was greatest in winter in the north, where the DJF mean temperature increased by 4-6°C over much of Fennoscandia, whereas warming was greatest in summer in the south, where JJA mean temperature increased by 4-6°C over large areas in most scenarios, and by as much as 10°C in some scenarios and areas. Temperature extremes were simulated to increase to an even greater extent: annual maximum temperature increased by 6-12°C across most of Europe south of around 50° N, whilst annual minimum temperature increased by 6-18°C throughout most of Europe east of the Greenwich Meridian.

Turning to precipitation, the results presented by Räisänen et al. (2004) showed a very marked contrast between southern and northern Europe, both in terms of total annual precipitation and in terms of seasonal precipitation. Annual precipitation was consistently simulated to decrease, by 10-40%, across most of southern Europe, with slight increases in south-east Europe for only one of the scenarios examined, whereas increases of 10-40% were simulated for areas north of around 60° N. During the summer season, JJA precipitation decreased by > 40% across most of Europe south of around 40° N in most scenarios, whereas JJA precipitation increased in most areas north of around 60° N. Winter season (DJF) precipitation increased even more markedly in northern Europe, by 20-50% in most areas north of around 40° N, whilst southern Europe was simulated to have only small changes, with increases or decreases of < 10% in most areas for most scenarios. Maximum one-day precipitation increased across many parts of Europe, by > 20% in many areas, but with no clear large-scale geographical pattern.

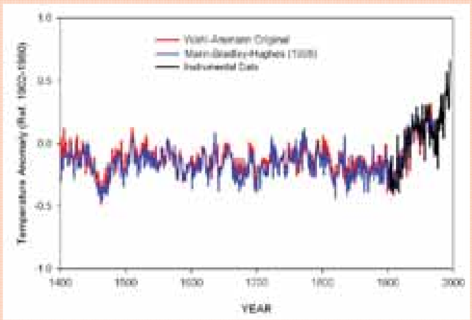
Windiness showed a general tendency to increase in north-eastern Europe, by up to 12% in some scenarios, but to decrease in the south and west, although generally by only 4-8%. Extreme wind events showed a similar pattern, being characterised by up to 15% higher extreme wind speeds in northern Europe but up to 11% lower extreme wind speeds in the south-west. This pattern relates to the more northerly position simulated for the predominant storm track by the end of the century.

One way to contextualise these simulated climatic changes is to compare them with the magnitude of the spatial gradients in the present climate of Europe. The simulated increase of 4-6°C in DJF mean temperature in Fennoscandia is equivalent to the present (1961-90) difference in DJF mean between Helsinki and Bucharest or between Copenhagen and Dublin, while the simulated increase of 4-6°C in JJA mean temperature in southern Europe is equivalent to the present difference between Bordeaux and Madrid. The simulated increases and decreases in precipitation do not generally translate into such large spatial displacements, mainly because the spatial patterns in precipitation are more regional in scale, whereas those in temperature are more clearly continental in scale. Nonetheless, the increase in DJF precipitation simulated in northern Europe equates to westward shifts of at least a few hundred kilometres in most regions, whilst the decrease in JJA precipitation simulated in the south equates generally to a similar magnitude of displacement, usually in a southward direction. In south-western Europe, however, the simulated decrease in JJA precipitation is equivalent to a spatial displacement of similar magnitude to that implied by the simulated increase in JJA mean temperature.

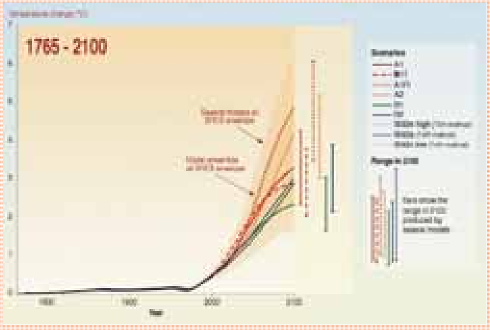
Box 1: Past and projected future global temperature changes



Three time series of $\delta^{18}O$ from marine microfossils illustrating global cooling trends and associated increase in volume of continental ice sheets during the Tertiary and Quaternary periods, and the glacial interglacial fluctuations in ice volume and global temperature during the last 800 000 years. Top: Composite record for the Cenozoic from Miller et al. (1987); Centre: Record of the past five million years from a core off the coast of West Africa (Tiedemann et al., 1994). Bottom: SPECMAP stacked and smoothed record for the past 800 000 years (Imbrie et al., 1984). (Re-drawn from Bartlein, 1997.)



Northern hemisphere temperature changes of the past 600 years as reconstructed from various proxies and as recorded in instrumental data for the last century. Most of the record is characterised by decadal and multidecadal variability with a magnitude of about 0.5°C; the century, however, was marked by a generally persistent trend of warming, temperature increasing to levels that are considered likely to be higher than at any time for at least 1 300 years (IPCC, 2007). Red line is from Wahl and Ammann (in press), blue line from Mann et al. (1998) and black line from Jones and Moberg (2003). (Figure from http://www.ucar.edu/news/releases/2005/ammann.shtml.)



Simulated global mean temperature since 1765 and projected to 2100 for a series of alternative emissions scenarios. Even for the "low" emissions B1 scenario, the rate of temperature increase is maintained at the late-20th century level for the first half of the present century, the rate of warming only slowing substantially in the final decades of the century. For the high emissions A1FI scenario warming continues rapidly throughout the century. (Figure based on Figure 9.13*b* of Cubasch et al. (2001) and taken from slide TS22 at http://www.grida.no/climate/ipcc_tar/slides/index.htm.)

An alternative and in may ways more telling way to contextualise the simulated changes is to compare their rate and magnitude, as well as the potential future climate of Europe, with evidence of past climate and past rapid climatic changes (Box 1). The Quaternary geological period spans approximately the last two million years, the transition from the preceding Tertiary period being marked by a global cooling event (Bartlein, 1997). Superimposed upon a general long-term cooling trend during the Quaternary have been a series of marked fluctuations in global climate on time scales of tens to hundreds of thousands of years. For the past approximately 800 000 years the predominant fluctuations have had a periodicity of approximately 100 000 years (EPICA community members, 2004) and have been of larger magnitude than previously. These fluctuations characterise the Quaternary "Ice Age", representing alternations between interglacial conditions, broadly similar to the present in global climatic terms, and glacial conditions, when global mean temperature is estimated to have been about 5-7°C cooler than that of the recent past (Kutzbach et al., 1998).

Even the warmest of interglacial stages, which was probably the last or Eemian interglacial, about 127-110 thousand years ago (Brauer et al., 2007), had a global mean temperature no more than 1-2°C warmer than the recent past (Overpeck et al., 2005). Thus, in terms of magnitude, the projected increase in global mean temperature this century is unlikely to exceed the magnitude of the shift in global mean temperature between the last glacial maximum, about 21 000 years ago, and the middle of the present interglacial stage, about 6 000 years ago. In terms of "destination", however, even at the lower end of the uncertainty range given by the IPCC (2007) (about 1.84°C warming between 1906 and 2090-99), the projected increase represents warming at least equivalent to the warmest part of the past two million years; an increase near the middle of the projected range, that is, about 3.6°C warming between 1906 and 2090-99, would result in global temperatures without precedent during the Quaternary and probably unparalleled also during the late-Tertiary, whilst any increase greater than this leads to a destination without an analogue during at least the past ten million years of earth history.

The most rapid large magnitude changes in global mean temperature of the recent geological past are the so-called glacial terminations, the most recent of which occurred between about 15 000 and 9 000 years ago. Although the rapidity of the increase in global mean temperature has been a subject of debate, with conflicting views expressed (see e.g. Overpeck et al., 2003; 2005), the most recent consensus is that the most rapid past large magnitude global warming events were at least an order of magnitude less rapid than the warming projected for the present century (Jansen et al., 2007). Thus both the "destination" and the rate of the changes in global climate projected for the present century are very likely to be without any precedent in recent earth history – and hence unprecedented during the "evolutionary lifetime" of most species on earth today, ourselves included.