1
Introduction

I grew up in Stocksbridge, a small town in the Yorkshire Pennines between Sheffield and Manchester. Looking down into the valley, there were massive steel works, mines, coke ovens, blast furnaces, pipe works and rolling mills that polluted the air with fumes and smoke. The local river – the Little Don or Porter – was heavily contaminated close to its source. Slag and other wastes were dumped in the woodland downstream below the works. In the 1950s, our community was not alone in suffering from the effects of industrial pollution; indeed, the problem was widespread in South Yorkshire.

However, Stocksbridge had one important advantage not shared by many other towns. Looking down the valley the prospect could be depressing, but this was not the whole picture. Beyond the valley, the hills and valleys of the Peak District National Park came into view, offering some of the finest scenery in England, with farms, rough grazing, woodlands, moorlands managed for grouse shooting, and reservoirs that provided drinking water for Sheffield.

It was here, in an area of such contrasting land use, that I first considered the historical and ecological forces at work shaping the industrial landscapes and the moorland, woodlands and farmland of the National Park. In time, the scope of these reflections widened, for while recovering from some brief teenage illness, I first read Charles Darwin's *Voyage of the Beagle* (1839). Later, I was given a battered copy of *The Origin of Species* by my grandfather (The Popular Impression, 1901, from which quotations in this book have been drawn) and began to consider environmental issues in a Darwinian context. A lifetime interest has led to the writing this book.

Human influences: implications for conservation

As McNeill (2000) has shown, human beings have wrought massive changes in our world. 'To a degree unprecedented in human history, we have refashioned the earth's air, water and soil, and the biosphere of which we are a part.' Since the nineteenth century, conservationists have been attempting to prevent the loss of natural ecosystems, and in the twentieth century particular attention was directed to securing the future of endangered species, a group that might be characterised as the 'losers' or 'potential losers' in contemporary and future

ecosystems. As a result of human-induced changes worldwide, it has been estimated that *c*. 10% of the world's plant species are in danger of extinction (May, Lawton & Stork, 1995). However, in the light of recent advances in our understanding of the likely impacts of climate change, this figure now looks very conservative. In recent IPCC reports (2007a–d), it is predicted that, if human activities continue in 'business as usual' mode (with no reduction in greenhouse gas emissions), by the end of the twenty-first century, much of the biosphere could be put at risk by an average global surface temperature rise of *c*. 4 °C (likely range 2.4–6.4 °C). The implications of this highly disturbing information are reported daily in the media, and there have been a number of important books highlighting the issues, and seeking solutions to mitigate such catastrophic changes. Here, the aim is to focus on climate change as one of many consequences of human activities impacting on plant microevolution and conservation.

A second major theme of this book is to highlight the fact that, not only are there 'losers' or 'potential losers', there are also 'winners' amongst the plant species in human-influenced ecosystems. Thus, McKinney and Lockwood (1999, 450) consider: 'emerging evidence shows that most species are declining as a result of human activities ("losers") and are being replaced by a much smaller number of expanding species that thrive in human-altered environments ("winners").' This point is also made by Morris and Heidinga (1997, 287). 'Humanity has induced pervasive negative impacts on the world's biodiversity. Earth is accumulating an ecological deficit that, when the accounting is complete, will be written off by mass global extinctions. But the evolutionary ledger has another side. Adversity for one group of species often represents opportunities for others.'

A third aim is to highlight the contemporary relevance of Charles Darwin's ideas on evolution, by showing that the notion of 'winners' and 'losers' is essentially a Darwinian concept. As we reach the 200th anniversary of Darwin's birth and the 150th anniversary of the publication of *On the Origin of Species* in 2009, it is timely to undertake such a review.

It is possible to consider evolution as something that happened in the past or is only of long-term concern (Stockwell, Hendry & Kinnison, 2003). But this would be a profound misreading of the situation, for, while Darwin emphasised the importance of gradual change over long-distant time scales, he was convinced that natural selection is always active, for he wrote (Darwin, 1901, 60, Darwin's emphasis):

> It may metaphorically be said that natural selection is daily and hourly scrutinising, throughout the world, the slightest variations; rejecting those that are bad, preserving and adding up all that are good; silently and insensibly working, *whenever and wherever opportunity offers* . . .

Post-Darwinian advances in our understanding of evolution confirm the ongoing ever-present nature of evolution by natural selection. This fact is recognised by some but not all conservationists. It is important to accept that the world's biota are 'controlled by evolution', for 'evolution is no mere curiosity of the natural world, but a potent process that we must understand' (Palumbi, 2001, 92, 94). Moreover, in addition to the climatic and environmental factors that have operated in geological time, a convincing case can be made that human activities present organisms with 'new' selection pressures. As we shall

see, there is now a great deal of evidence for anthropogenic microevolutionary changes in human-disturbed ecosystems.

I am myself passionately interested in conservation. A fourth aim, therefore, is to consider the impact of human management within conservation areas, in collections maintained for conservation in gardens (*ex situ*), and in the wider landscape. In their attempts to secure the future of endangered landscapes, ecosystems and species, it is essential that conservationists understand the full implications of their efforts in the light of Darwin's theory of evolution in its modern form – neo-Darwinism. In particular, the possibility that management will lead to some form of domestication must be confronted. Again, this is an area of microevolution where Darwin made pioneering contributions.

A fifth aim is to highlight the uncertainties that lie ahead for ecosystems and species, in relation to the combined effects of population growth, increasing exploitation of the Earth's resources and the effects of climate change. Both the increasing human domination of the biosphere and the shrinking areas of 'natural' vegetation have major implications for the direction of future ecological research. It is highly significant that the Ecological Society of America recently called for a 'shift in [its] primary focus from the study of undisturbed ecosystems to interdisciplinary studies of human-influenced ecosystems for the betterment of human societies' (Bawa *et al*., 2004). The original documents are available on the internet at http://esa.org/ecovisions/.

A stream of important questions flows from these preliminary observations, and these form the basis of the following chapters.

Outline of the chapters

Chapter 2 emphasises that our knowledge of microevolution in human-dominated ecosystems is illuminated by studies from very diverse fields – from archaeology and anthropology, from molecular genetics to ecology etc. In order to judge the veracity of this evidence, it is necessary to consider how it was obtained, and how reliable it might be. In essence, many advances have been made through the testing of hypotheses and models. Some important general principles will be considered about the scientific method, the status of 'facts', the possibility of 'proof' of propositions and concepts, and the public responses to researches.

Chapter 3 provides an outline of Darwin's theory of evolution by natural selection. Also, his views on domestication will be considered, as this topic is highly relevant to human-managed ecosystems. Then follows an account of post-Darwinian advances in our present understanding of these topics, paying particular attention to changes at the population level. In addition, some major concepts of population biology will be introduced relating to the establishment, survival and reproduction of natural populations. In later chapters, we examine how human activities and influences have changed, or subverted these natural processes.

A major theme of this book is the extent to which species have evolved, and are evolving, within human-influenced ecosystems, and Chapter 4 provides a brief historical review of

a number of key issues. When and where did *Homo sapiens* emerge as a species, and how quickly did numbers increase across the globe? Where and when did the hunter-gatherer life-style give way to settled agriculture? How has agriculture developed, and how have many of the Earth's ecosystems – both terrestrial and marine – been transformed by ever-increasing human populations?

Chapter 4 makes the case that the Earth's ecosystems have been dramatically changed by human activities, and the time frame for these changes is counted in millennia. Drawing on evidence from various sources, Chapter 5 addresses a different, but related, issue: is there any pristine natural wilderness left? In the nineteenth century, the embryonic conservation movement was born. Such was the over-harvesting of natural resources and the destruction and pollution of many ecosystems, that attempts were made to protect surviving 'wilderness' in national parks, and, later, in nature reserves and wildlife refuges. Conservationists still employ concepts of wilderness in their fund-raising and management strategies, for instance, in the protection of the ecosystems of tropical islands and rainforests. However, recent advances in archaeology and anthropology have transformed our understanding of the extent and scale of human environmental impact in prehistoric and more recent times. Thus, many ecosystems, especially in the tropics, hitherto regarded as natural, unspoilt, untouched, pristine wilderness, are now seen as areas long impacted by human occupation and exploitation. Indeed, there is a case to be heard that parks and reserves were often far from untouched pristine natural wilderness when they were first established. Another major issue is also considered. Surveying the damaging impact of past and present human activities on the biosphere, many now consider that human well-being can only be secured if unfettered exploitation is replaced by 'sustainable development'.

Chapters 4 and 5 review our present understanding of the way humans have modified the natural ecosystems of the world, and there is abundant evidence that all ecosystems on Earth are subject to some impact from human activities. The human population has reached more than 6.5 billion. If predictions about population growth and global climate change are correct, further transformations of the biosphere are inevitable, with increasing exploitation of all natural resources.

Having provided a brief account of the 'stage' on which present microevolutionary processes are taking place, the different groups of 'vegetative' players on this stage are introduced (Chapter 6). A great deal of effort has been expended in determining the number of species that are threatened with extinction worldwide. In order to assess the scale of what many regard as an impending mass extinction (Myers & Knoll, 2001), Chapter 6 considers how far taxonomists have succeeded in naming the plants and animals of the biosphere. At first sight it would seem simple to define each of these categories, but there are many difficulties. The species concept is at the heart of our understanding of evolution, and, furthermore, both the theory and the practice of conservation are to a large extent based on concerns about species. This focus on species: how they are evolving in the contemporary landscapes, and whether it is possible to prevent the extinction of those that are threatened, raises a major issue. What are species? As we shall see, there is no single universally agreed definition.

Having presented an account of the present evolutionary stage and the plant actors on this stage, the evidence for microevolutionary change in plant populations is reviewed in a number of chapters. The general thesis will be examined that by chance, unwitting action, or by intention, human activities have increased, influenced, disturbed, distorted or reduced 'natural processes' such as gene flow, seed dispersal, plant establishment and reproduction. We examine, first in Chapter 7, how microevolutionary processes are investigated. Then we consider how plants exposed to 'new' anthropogenic selection pressures have responded to grassland management (Chapter 8), cropping in agriculture and forestry (Chapter 9), environmental pollution (Chapter 10), and introduction to new territories (Chapter 11). Chapter 12 continues the microevolutionary theme in presenting an account of how human activities have resulted in the decline of populations of many species.

As many plants are threatened with extinction, it is important to consider how quickly new species might evolve to take their place. Chapter 13 examines how contemporary species hybridisation and speciation has been influenced by human-induced breakdown of the geographical and/or ecological isolation that previously existed between species 'in the wild'. Also, the relationships between cultivated plants and weeds/wild species will also be examined, including recent studies of the interrelations between wild and weedy species and transgenic crop plants.

A major strategy for securing the future of rare and endangered species is to conserve them *ex situ* – as living plants in botanic and other gardens, or as stored seed or other structures in gene banks. Chapter 14 reviews the strengths and weaknesses of such conservation in the light of microevolutionary considerations. Several major questions have to be faced. Is it possible in the long term to maintain populations of threatened plants in their 'wild' state in gardens, or is it inevitable that some species will change genetically in cultivation? Is unwitting domestication the likely fate of 'wild' plants grown in gardens?

There is another point of interest. In order to make effective public displays of threatened plant communities, and to present conserved rare and endangered species in an authentic-looking ecological context in botanic and other gardens, many 'wild areas', such as ponds, wetlands, grasslands etc., have been created. At the same time, in many areas of the world, there is a vogue for wildlife gardens, with sowings and plantings of 'wild flowers' to give 'natural-looking' areas. Also, given that reintroduction and reinforcement of 'wild' populations of plants, in parks, reserves and increasingly outside protected areas, involves sowing and/or planting of 'wild' species, is there a danger of blurring the distinction between gardens and nature reserves? Are reserves likely to become specialist gardens and *de facto* zoos? Does reserve management, in reality, treat wildlife as a specialised crop, and, as with crop plants proper, is domestication therefore a possibility? Such moves may present difficulties in the future. If 'wild' plants are deliberately cultivated, then genetic change in the direction of domestication seems a strong possibility, and, while success in conserving the species might be achieved in the short term, if close human management in garden is diminished or withdrawn, or environmental conditions change, such stocks would be vulnerable.

Conservationists have had considerable experience of maintaining and managing national parks and nature reserves, and the rare and endangered species and threatened ecosystems they contain. Despite the claims of conservation managers that 'wildness' and 'naturalness' are being maintained in protected areas, evidence suggests that such places have frequently been subject to very active management, rather than being left to function as untouched natural wilderness areas (Chapters 15 and 16). Such management may involve the implementation of formal science-based conservation plans by professional staff. However, in other parks and reserves there may be a great deal of unofficial, often illegal, alternative 'management', inimitable to the conservation, involving hunting, logging, forest clearance for agriculture, mining etc. Conservation management is concerned not only with entire ecosystems, but also with the survival and reproduction of endangered species. In Darwinian terms, the aim is to identify threats to populations of endangered species and tailor management to counter these threats. Thus, management is about identifying and nullifying the 'adverse selection pressures' impinging on rare and endangered species, so that their populations might stabilise or increase. How far have conservationists been successful in this endeavour? Has the designation and management of protected areas succeeded in its objective of securing the immediate survival of endangered species and ecosystems? There are also questions to be faced concerning the practice of management. Should it be devised to take the form of properly designed experiments, or should 'common sense' be the guide? Are there universal general principles that can guide management, or are all conservation sites uniquely different, and, therefore, require specific local management. Often swift interventions have to be devised to prevent the loss of species and ecosystems. What are the implications of this type of crisis management?

In recent decades there have been major changes in conservation practice, with elaborate interventions, including the restoration and creation of ecosystems, and reintroductions and restocking of populations of endangered species (Chapter 16). Returning to the Darwinian theme: what are the implications for microevolution of plants in areas where such creative conservation projects have been established? How far are these endeavours likely to succeed? Indeed, by what criteria is success in ecosystem restoration to be judged? Other questions must also be faced. Is it possible to recreate original ecosystems or wilderness? Moreover, is it likely that, by careful management of planting schemes, complex communities, such as forests or species-rich grasslands, will be relatively quickly recreated?

In Chapter 17, the microevolutionary implications of size, shape, distribution, connectivity or isolation of parks and reserves will be considered in relation to the wider landscape. Does the existing network of parks and reserves provide a secure arena for the continuing evolution of plant species as members of functioning ecosystems? Many reserves and parks were designed as 'fortress' areas, from which humans are excluded except as visitors. What have been the consequences of such designs, and what would be the implications for conservation if management policies were changed, allowing local people access and control over the resources of the area, in some form of sustainable development?

Conservation management often involves short-term crisis management. However, in reality, as Frankel and Soulé (1981) point out, conservation must be a long-term effort. In one of the seminal books on conservation, they made a most important distinction between preservation and conservation. Preservation 'provides for the maintenance of individuals or groups but not for their evolutionary change' (Frankel & Soulé, 1981, 4). In contrast, conservation 'is diametrically different. Its essence is for some forms of life to remain in existence in their natural state, to continue to evolve as have their ancestors before them throughout evolutionary time' (Frankel & Soulé, 1981, 6). In practical conservation the focus is often on short-term crisis management of immediate problems. But, if the views of Frankel and Soulé are accepted, we are faced with a 'for ever time scale of concern', even if this is not explicitly stated or agreed. It is against this very challenging aim, and against this time frame that conservation efforts will be judged. Given the high costs of conservation, the practical implications of management in 'perpetuity' are daunting. This is particularly the case if separate management plans are pursued for each endangered species. Would the outcome of conservation efforts be more successful and cost effective if conservation management focused under a single management plan for the entire ecosystems in a particular area? In addition, should conservation efforts be directed largely at sites considered to be closest to wilderness, or should equal attention be paid to managing the large number of endangered plant species found in human-managed forests, grasslands, wetlands, arable lands and urban areas etc.?

The book closes with three chapters (18–20) reviewing the current concerns about the impact of global climate change in relation to conservation and microevolution. It is predicted that climate change will present plants with new selection pressures. What will be the effect on those species currently rare and endangered? How far will the species presently conserved in nature reserves and parks be put at risk by climate change? Will conservationists find themselves in the invidious position of spending a great deal of time and money trying to manage populations in their protected sites 'against' the major impacts of climate change? If charismatic plants and animals are lost from reserves and parks, will such areas be abandoned, or will they continue to be maintained for whatever wildlife they come to contain?

Considering the reaction of particular species to climate change, do species have adequate reserves of genetic variability to allow for the selection of new variants *in situ* that are more in tune with climatic change and changing interrelationships with other species? For those species with insufficient genetic variability to respond to these newly developing selection pressures in their current site, what is the probability that they will be able to migrate naturally to suitable climatic zones? If natural migration in the face of climate change is impossible, should species be artificially transferred to suitable climatic zones? Many endangered species occur outside reserves and parks. How far has it proved possible to conserve such species, and what are the prospects in the future?

To complete the review of the interface between microevolution and conservation, Chapter 21 draws together issues raised in earlier chapters. Faced with climate change, will humankind successfully adapt to limit the greenhouse gas emissions and thereby

escape the most extreme impacts? Should the focus of conservation efforts be reassessed in the light of increasing anthropogenic domination of ecosystems? The concept of the 'fortress' reserve has been much criticised. Would the adoption of sustainable development management practices prove a more secure route to the successful conservation of endangered species and ecosystems? Finally, if conservation efforts falter, and there is a major extinction spasm in the coming decades, what will be the long-term effect of human domination of the biosphere on the future evolution of plants?

2

Studying change

In order to undertake a critical review of the interface between plant microevolution and conservation, it is necessary to examine published information on a very wide range of topics. Current microevolution is illuminated by ecological studies, common garden and other types of experiment, and a variety of cytological and genetic investigations that increasingly employ molecular markers. Concerning the environmental and conservation context of the success or failure of species, there are many peer-reviewed papers in academic journals and books, together with official documents and statistics produced by national governments, international agencies, interest groups and professional conservationists etc. There is also a great deal of what is called grey literature, which, for reasons of confidentiality, is not publicly available. This includes, for example, consultants' reports, on which far-reaching conservation decisions are made. There is also a great deal of information on the Internet. In total there is a substantial body of knowledge about the conservation of communities and endangered species, based not only on the experience of habitat management, but also on experiments, field observations, mapping and surveys.

Technical advances in many fields have greatly enlarged our understanding of wider environmental issues. With the increasing use of aerial photography, satellite imagery and remote sensing, it has been possible to investigate land use in a way hitherto impossible from fieldwork alone. Google Earth – http://earth.google.com – provides an unrivalled opportunity to examine in great detail the impact of human activities on ecosystems (Biever, 2005). Moreover, important advances have been made in the precise measurement of key physical and chemical properties of the air, water, soil and sea, including estimates of minute but significant concentrations of pollutants etc.

Our understanding of these complex issues has been revolutionised by investigating environmental and ecosystem change in its historical context, by examining archaeological findings, historic documents, maps, old photographs, explorers' accounts, herbarium specimens and field notes etc.

Drawing on a wide variety of historical and other sources, there are now many wide-ranging studies of environmental history (Detwyler, 1971; Goudie, 1981; Worster, 1988; Nisbet, 1991; Pontin, 1993; McNeill, 2000). Williams (2006) has studied the history of deforestation worldwide. Others have examined regional changes. For example, Whitney (1994) charts the history of change in temperate North America from 1500 to the present

day; Worster (1992) reviews the ecological history of the western USA in relation to cattle ranching, irrigation and water resources; and Kirch and Hunt (1997) survey the historical ecology of Pacific islands. Major studies of historical ecology have now been carried out across the Mediterranean (Rackham & Moody, 1996; Grove & Rackham, 2001). The environmental history of the British countryside has been particularly carefully examined in the pioneer work of Hoskin (1977) *The Making of the English Landscape*, and the seminal studies of Rackham (1980, 1986). A group of other historians have investigated changes following a significant historic event. For instance, Melville (1994) has examined the changes in the Mexican landscape in the sixteenth century. Intensive sheep production was imposed by the Spanish invaders in the sixteenth century in the Valle del Mezquital region of Mexico. A densely populated region with a mosaic of different land uses, based on intensive irrigation agriculture, was converted by overgrazing to a sparsely populated mesquite desert. Major insights have also been achieved by studying small areas in detail. For example, Rackham (1975) examined the history of Hayley Wood Nature Reserve, Cambridgeshire, while Preston and Sheail (2007) have recently highlighted the transformation of the famous commons that line the riverbanks through the city in Cambridge. While these areas have a timeless quality reflecting their past use, in reality they have evolved from undrained pasture land, grazed by cattle, to areas of mixed use, especially recreation. This change has been brought about by drainage, digging out minerals and gravel, and the dumping of domestic rubbish and dredgings from the river. Widespread levelling of the ground has been accompanied by much reseeding and tree planting.

These accounts provide information into change in rural and agricultural landscapes. By examining a wide range of evidence, supplemented by careful measurement of pollutants, it has proved possible to examine the environmental impact of cities and urban industrial areas. McNeill (2000) provides a very important review of the history of air and water pollution, with reference to many case histories. For instance, the chronic pollution of Lake Michigan by the city sewage of Chicago (which included offal from the largest stockyards on the planet) was remedied by reversing the flow of two rivers, so that the pollution was diverted into the catchment of the Mississippi (Changnon & Changnon, 1996). McNeill (2000) also provides details of the revival of many European river systems, such as the Thames and the Rhine, after remedial action was taken to control pollution. He also examines, in a historical context, the growing pollution of the rivers in countries, such as India and China, that are undergoing dramatic industrial development.

Defining terms and questioning assumptions

While information from many sources provides a sound basis for judgement on questions concerning environmental history, conservation and microevolution, it is important to stress that evidence must be carefully and critically assessed. Firstly, there are differences of opinion about concepts and the definition of terms. Thus, there is much debate about ‘species’, ‘wilderness’ and ‘habitat degradation’ etc. For example, Barrow (1991) examines the concept of land degradation, while Grove and Rackham (2001) discuss the use of