Conservation of Exploited Species

The use of wildlife for food and other human needs poses one of the greatest threats to the conservation of biodiversity. Wildlife exploitation is also critically important for subsistence and commerce to many people from a variety of cultures. This book brings together international experts to examine interactions between the biology of wildlife and the divergent goals of people involved in hunting, fishing, gathering and culling wildlife. Reviews of theory show how sustainable exploitation is tied to the study of population dynamics, with direct links to reproductive rates, life histories, behaviour, and ecology. This information is used to predict the impacts of exploitation on population conservation. As such theory is rarely put into effective practice to achieve sustainable use and successful conservation, *Conservation of Exploited Species* explores the many reasons for failure and considers remedies to tackle them, including scientific issues such as how to incorporate uncertainty into estimations, as well as social and political problems that stem from conflicting goals in exploitation.

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Conservation Biology

Conservation biology is a flourishing field, but there is still enormous potential for making further use of the science that underpins it. This series aims to present internationally significant contributions from leading researchers in particularly active areas of conservation biology. It focuses on topics where basic theory is strong and where there are pressing problems for practical conservation. The series includes both single-authored and edited volumes and adopts a direct and accessible style targeted at interested undergraduates, postgraduates, researchers and university teachers. Books and chapters will be rounded, authoritative accounts of particular areas with the emphasis on review rather than original data papers. The series is the result of a collaboration between the Zoological Society of London and Cambridge University Press. The series editor is Professor Morris Gosling, Professor of Animal Behaviour at the University of Newcastle upon Tyne. The series ethos is that there are unexploited areas of basic science that can help define conservation biology and bring a radical new agenda to the solution of pressing conservation problems.

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Foreword

We do not know, to within 10%, how many distinct species of eukaryotic species (broadly, plants, animals and fungi) have been named and recorded. The total is roughly 1.5 million, but problems with synonyms, and other problems associated with the lack of a synoptic database, prevent an exact answer. The total number of eukaryotic species alive on Earth today is much less well known, with reasonable estimates ranging from 5 million to 15 million, and numbers as low as 3 million or as high as 100 million or more being defensible. Given these lamentable uncertainties, it is not surprising that we have very little idea of exactly how many species – mainly small invertebrates – became extinct last year.

We do know, however, that for some well-studied groups, particularly birds and mammals, rates of documented extinction over the past century ran roughly 100 to 1000 times faster than the average background rates of extinction over the half-billion year sweep of the fossil record. And four different methods of projecting extinction rates over the coming centuries – all four beset with approximations and extrapolations – suggest a further acceleration by a factor of 10 or more. This puts us clearly on the breaking tip of a sixth great wave of extinctions, fully comparable with the Big Five mass extinctions in the fossil record.

What are the causes of the loss of those species who enjoy the dubious honour of a tombstone of certified extinction over the past 100 years or so? Three main causes are usually identified: excessive exploitation by humans, loss of habitat, and effects of the introduction of alien species (including infectious diseases). Often two, or all three, of these factors are implicated.

This brings us to the present book. It derives from a meeting focused on the conservation of species which are imperilled by 'overexploitation' or 'overharvesting'.

The question immediately arises (see Ludwig, Chapter 2): under what circumstances is it possible, with good management, to exploit a species for

human purposes without endangering it? I think that, as for so much else in biology, Darwin had the essentials of the answer. Three fundamental observations underpin *The Origin of Species*. The first is that there is heritable (genetically based) variation within all natural populations. The second is that all natural populations have the inherent reproductive capacity to increase, generation to generation, were resources not limiting. But various factors do limit population growth, leading to a 'struggle for existence' among progeny. Thirdly, when external conditions change, those offspring who – within the population's variability – are best adapted to the changed environment are more likely to survive. This, over time, leads to changes in the gene pool and eventually to new species.

Darwin's second point says yes, it is in principle possible to substitute human exploitation for other mortality factors, harvesting a potential surplus. Such a harvest is, of course, only sustainable if it is not so high that death rates exceed the inherent, resource-unlimited birth rate.

But such harvesting represents, for the species in question, an environmental change. So Darwin's third point suggests that exploitation, even when at sustainable levels, is likely to result in genetic changes in the population. A colourful example, widely cited in Darwin's day but rarely found in today's texts, is the high incidence of crabs with a striking skull-like pattern on their shells, found in a bay in Japan. Fishermen's superstitious discarding of such ill-omened individuals from their catch appears to have produced this phenomenon, which might even have helped the crab population to persist. More commonly, however, such exploitation-induced changes can threaten the species' persistence. Several better-documented cases of significant changes in exploited species' gene pools are discussed in the present volume.

These questions are pursued in diverse ways – some theoretically, others through detailed examples – in this book. There is much devilment in the details. For a start, although most would agree that all natural populations have birth and/or death rates that depend, to some extent, on population density, we rarely have a precise understanding of these density-dependent factors. Yet simple ideas about maximising sustainable yields tacitly assume we indeed know how birth and death rates change as population numbers are lowered by harvesting.

Even if techniques – no matter how heuristic – can be developed to assess maximum levels of harvesting that are sustainable, further complications arise and are important. For one thing, environmental stochasticity causes population fluctuations. Sustainable harvesting in such fluctuating environments presents complications that undercut simple ideas about

'maximum sustainable yield' (MSY); precautionary approaches are necessary. For another thing, heterogeneity in the spatial distribution of the exploited population – sometimes in the form of protected areas – offers other kinds of complication. Yet again, the species under discussion may be embedded in a complex web of interactions among species, so that harvesting a particular species not only can endanger other species, but can even threaten the target species in a way that conventional single-species methods would not anticipate. All these difficulties are exemplified in this volume.

These biological questions about conserving exploited species are only a beginning. Economic, political and social questions usually pose more serious barriers to sustainable management.

For starters, it is too often assumed that overexploitation of a potentially sustainable resource is always a 'tragedy of the commons'. Were there a single owner of the resource, rationality would indicate maximising the *sustainable* yield, or some appropriately sophisticated latter-day variant. But in a 'commons', it is in each exploiter's interest to take as much as possible, until the resource is either extinguished or dwindles to the point where the yield is not worth its cost; any exploiter exercising restraint, in the cause of sustainability, will be disadvantaged, and the Gadarene – but remorselessly logical – rush to collective collapse will continue. This is indeed the case for exploitation based on natural populations – such as most fish populations, or many softwoods – that have an intrinsic growth rate, r (per capita birth rate minus death rate, at low density) exceeding the inflation-corrected economic discount rate, δ (usually taken to be around 5–7%). In this event, the solution is to construct an effective political mechanism such that there is a sole owner/manager. In principle, examples are the International Whaling Commission or the many fisheries consortia such as the International Council for the Exploration of the Sea (ICES). In practice, even for $r > \delta$, things go wrong either because short-term social and political considerations override the regulatory authorities' advice, or because the regulatory mechanisms (aimed at controlling the harvesting via quotas, licences or other means) are badly designed or not enforced, or both.

But all this is irrelevant for resources where intrinsic population growth rates are simply less than the discount rate, $r < \delta$; this applies, for example, to most whale species, and to many hardwoods such as mahogany. Here economic realities conflict with sustainability even when there is a truly effective sole owner. If the sustainable return is below the economic discount rate, accountancy suggests liquidating the biological stock, and reinvesting the consequent money elsewhere. There is still much unhelpful

confusion in the conservation movement about this distinction between $r > \delta$ and $r < \delta$. In the latter case, the conflict is really about an appropriate long-term definition of δ. Should it be set purely by economic considerations, or should ethical or other arguments (possible preservation of ecological services which are not counted in conventional economic balance sheets) require us not to discount the future, thus putting $\delta = 0$?

Ultimately, however, it is the social and political pressures from growing populations that constrain essentially all choices about conservation. In developing countries, these pressures are compounded by legitimate aspirations to the material comforts of the developed world, vividly conveyed by global media in a shrinking world. In the developed world itself, ever more prodigal patterns of consumption counterbalance lower levels of population growth (one rough calculation suggests that, in terms of environmental impact, one newborn in the USA equals 30–40 newborns in many developing countries). So, as many chapters in this book make clear, any effective plan for the conservation of an endangered species must be based not only on sound understanding of its ecology but even more on untidy social and political realities.

A critic could dismiss much of this book as 'touchy-feely' sentiment. Maybe we can grievously simplify the marvellously diverse ecological systems whose function we do not yet understand, and which built the biosphere as a place where life can flourish, without extinguishing ourselves as an unintended consequence. Maybe the world of the cult movie *Bladerunner* is sustainable. Maybe fears of disasters – new plagues from careless exploitation of other animals (HIV from hunting our cousins, the chimpanzees, is a forewarning), loss of various amenities from carelessly introduced aliens (waterweeds, from the equator to the Norfolk Broads), climate change and all its many consequences – can be magicked away by our technological cleverness. So long as the motivation for conservation is pinned primarily on our human interests, on preservation of endangered species for our sustainable use or aesthetic pleasure, I think the basis is shaky. I prefer a motivation that endows biological diversity, and its constituent species, with their own inherent rights: a motivation based on our role as the uniquely self-conscious species that is causing the problems, and accepts the responsibilities of stewardship. But this motivation has its own shakiness, not least because it is more easily sustained from the privileged luxuries of a developed-world life.

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Preface

Exploitation poses special problems for conservation. Individuals are usually removed directly from populations and this is intentional, rather than a by-product of other human activities. Although 'exploitation' is often used synonymously with 'harvesting', the comfort implied by the latter term is belied by the fact that many species have become extinct as a result of commercial and non-commercial activities. Whatever term one uses, many species are threatened by this activity and many populations have been reduced to a fraction of their former size.

In theory, the intensity of some forms of exploitation is manageable. In practice, however, controlling exploitation usually proves difficult. Conservation of exploited populations thus raises particular biological and social questions. For example, because the response of populations may be directly tied to one factor – elevated mortality – there are direct links to the study of population dynamics, reproductive rates, life histories and ecology. Furthermore, 'conservation' in the context of exploitation clearly means different things to different people. Some people wish to conserve their ability to profit from animal 'resources', with little concern about long-term declines in populations or impacts on ecosystems. Other people are more interested in minimising risks of extinctions of targeted species and minimising impacts on ecosystem function. While these goals may come into conflict with one another, there may also be pragmatic reasons for them to reinforce one another, as in the case of populations that may not survive unless they are exploited for some economic benefit.

This book has arisen from a meeting that we organised in London on 9 and 10 December 1999. The speakers who contributed these chapters focused primarily on biological issues in conservation of exploited species, but many also explored various social dimensions.

In Part I of this book two chapters set the scene of exploitation as a conservation issue. First, Georgina Mace and John Reynolds consider

differing goals of exploitation, ranging from preservation to sustainable use to 'hit-and-run'. Donald Ludwig then examines biological and social dimensions that answer the question of whether we can exploit sustainably. His review of the basic biological principles that underlie the theory of sustainable exploitation provides a foundation for the more detailed treatments that appear elsewhere in the book, as does his discussion of the 'tragedy of the commons' and important economic principles such as discounting.

Part II explores various population-based approaches to sustainable exploitation. André Punt and Anthony Smith review the death and reincarnation of the classical concept of maximum sustainable yield. This review is concerned with fisheries, but the concepts are general, concerning targets for populations and yields, reference points and the precautionary principle. Russ Lande, Bernt-Erik Sæther and Steinar Engen examine the particular problems faced by exploitation of fluctuating populations. They aim for a target different from most models of exploitation – maximum yields prior to extinction – and suggest how this might be achieved. E. J. Milner-Gulland examines the importance of spatial structure in the conservation of exploited species, including the spatial behaviour of the hunters as well as the hunted. In the final chapter in this section, Paul Wade reviews novel quantitative methods for dealing with uncertainty in population assessments of exploited populations. First, he raises serious concerns about the fundamental methods of statistical inference that the editors of this volume and most of our readers were taught and still use! Then he explores exciting new ways of incorporating uncertainty into parameter estimation and decision theory.

Part III examines taxonomic differences in responses of populations to exploitation. John Reynolds, Simon Jennings and Nicholas Dulvy consider how life histories affect population trends of exploited fish species. These questions are becoming increasingly relevant as conservationists express concern about impacts of fisheries. Andy Purvis reviews similar issues with mammals, including a comparative analysis of relationships between life histories and threatened status of a wide variety of species. Steven Beissinger reviews the importance of international trade for bird conservation. This exemplifies problems faced by many species threatened by exploitation for use as pets, rather than being killed outright as sources of food. Beissinger presents a sophisticated model for calculating sustainable yields, as well as recommendations to guide the international trade. In the fourth chapter in this section, John Fa and Carlos Peres then review how tropical hunting compares between Africa and South America. Hunting for

bushmeat is the number one threat to many species in Africa, and the projections based on human population growth make for sobering reading. In the final chapter in this section, Charles Peters offers lessons from the plant kingdom. Of course, plants deserve far more than one chapter, but the subject matter has a strong bias towards animals, and indeed, towards vertebrates, as the content of this book suggests. In this chapter, Charles draws interesting comparisons between plants and animals.

In Part IV we have six topics that range from individuals to communities. William Sutherland and Jennifer Gill examine the role of animal behaviour in determining responses of populations to exploitation. Christopher Petersen and Don Levitan then focus on one particular process that is usually driven by behaviour, the Allee effect, whereby inverse density dependence can cause populations to decline sharply once they reach a low density. Hanna Kokko, Jan Lindström and Esa Ranta examine the role of life histories within populations in determining yields and population changes. They include a consideration of which age classes and sexes should be taken, in terms of reducing impacts on populations and yields. Nearly all forms of exploitation are selective within populations. Richard Law considers how such selectivity, combined with heritability estimates for specific traits, can cause evolutionary changes within species. The final two chapters of this section scale up from population changes to community impacts. Michel Kaiser and Simon Jennings examine the evidence for changes in marine, freshwater and terrestrial communities due to trophic interactions. Kent Redford and Peter Feinsinger then consider more subtle processes that can affect communities due to disruptions in symbioses, such as plant–pollinator interactions.

Part V brings us more squarely into the realm of human social considerations that are encountered when conservation meets sustainable use. Gordon Grigg and Anthony Pople's review of management of Australian kangaroos shows how the largest sustainable hunting programme in the world is governed by conflicting goals ranging from pest control to resource exploitation. Anne Gunn's review of conservation and resource use in Arctic ecosystems shows how a range of difficult issues are tackled, from biological uncertainty to distrust of administrators by aboriginal peoples. Local concerns also feature prominently in Jon Hutton and Barney Dickson's review of conservation through resource use in Africa. These authors scoff at the idea of being able to find parameters for many of the biological models discussed elsewhere in this book as they search for pragmatic solutions to local problems. This brings us to Steven Sanderson's

discussion of the politics involved in conserving exploited species. The political advice he offers demands to be taken seriously by any biologist who wishes to translate research into action.

In Part VI John Robinson offers some final thoughts on the goals of conservation. We need to understand that different people have different objectives if we are to make progress in improving the conservation of exploited species.

Readers of this book will thus see some divergent viewpoints over these issues, amid a heavy dose of biological considerations. We hope that this airing of the biological and social dimensions of exploitation will help lead towards an appreciation of alternative attitudes to the use of wildlife, and ways of solving conservation problems.

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