Preface

Importance of the topic

One of the greatest unmet issues in conservation biology is the genetic management of fragmented animal and plant populations. Most species across the planet now have fragmented distributions, with many small isolated populations potentially suffering from inbreeding, loss of genetic diversity, and elevated extinction risk. Fortunately, these effects can usually be remedied by initiating gene flow (crossing populations within species), but this is rarely conducted. Disturbingly, evidence of genetic differentiation among populations often is taken to mean that the populations should be kept isolated, thereby dooming many to eventual extinction. We are particularly concerned with populations fragmented by human actions in the last 500 years.

A **paradigm shift** is urgently needed whereby the existence of genetic differentiation among populations acts as a trigger to ask if any populations are suffering from genetic problems (Ralls et al. 2018). If so, as conservation managers we should ask if there are populations to which they can be crossed to reduce inbreeding and increase genetic diversity, and whether this gene flow would be more beneficial than harmful.

Whether to maintain genetic isolation is a major issue for managers of wild animal and plant populations. It is critical that managers, and those who advise them, become aware of the issues relating to restoration of genetic diversity and reversal of genetic deterioration associated with small population size.

Why did we write *A Practical Guide for Genetic Management of Fragmented Animal and Plant Populations*?

We have previously written an advanced textbook (Frankham et al. 2017 *Genetic Management of Fragmented Animal and Plant Populations*) detailing the relevant concepts and supporting evidence. The current *Practical Guide* is shorter, simpler, and more practical than the previous textbook, and is designed for conservation managers and others seeking a briefer and more applied treatment of the topics.

This book provides a concise background to the genetic issues in fragmented wild animal and plant populations and offers means for making practical decisions on genetic management of population fragments. We focus particularly on the harmful consequences of mating among relatives on offspring fitness (inbreeding depression) that are ubiquitous in sexually reproducing animals and plants. A second major focus is on maintenance of genetic diversity, so that species and populations can adapt evolutionarily to changing environments.

Intended audience

This *Practical Guide* is designed for wildlife conservation managers who might have limited familiarity with conservation genetics (conservation ecologists, land and wildlife managers, etc.) and as a concise introduction to the topic for students of conservation biology and wildlife management. To make the book accessible to a wide audience, we have assumed knowledge only of Mendelian genetics and basic statistics. Readers wishing for a simple concise introduction to conservation genetics are referred to *A Primer of Conservation Genetics* (Frankham et al. 2004) or its translations.

Précis of contents

The first five chapters consist of background material and concepts, and the subsequent four chapters are concerned with genetic management (including objectives, questions, and decision trees). The "Take home messages" in the following section summarize the book's messages. This book deals predominantly with outbreeding diploid species, with brief consideration of self-fertilizing and polyploid species. Bold is used for emphasis where necessary.

Historical perspective

A conservation manager we consulted pointed out they previously had avoided implementing genetic rescues on the advice of conservation geneticists, and so sought a historical perspective. Why are we now advising a greater use of genetic rescue? Much of the science we present is recent, especially our recommendations about using genetic rescues. Prior to 2011, outbreeding depression was not considered predictable, so very conservative advice about crossing populations was given (e.g. Edmands 2007). However, Frankham et al. (2011) developed a method for predicting the risk of outbreeding depression (see also Frankham 2015). Further, meta-analyses showed that if there was a low risk of outbreeding depression, genetic rescues led to large fitness benefits that persisted over generations if inbred populations of natural outbreeders were being rescued (Frankham 2015, 2016, 2018). Finally, updated management recommendations were given by Frankham (2015) to reflect these new insights and evidence.

The extent of the fragmentation problem has become ever more serious due to ongoing habitat destruction and fragmentation (IUCN 2018). In earlier times, many remnant populations may have been sufficiently large and genetically diverse, or connected to other populations, to persist. However, this has become increasingly unlikely as populations have continued to decline and become more isolated.

Minimizing mean kinship is widely used for genetically managing fragmented captive populations based on the classic work of Ballou & Lacy (1995). The extension of minimizing kinship to genetic management of fragmented populations in natural habitats has been made possible by recent advances in molecular genetics and genomics that allow estimation of kinship from DNA markers rather than pedigrees. Further, several new insights and results from Ballou and Lacy were presented in Frankham et al. (2017).

Sub-species and species were once regarded as fixed entities, but they are now known to be constantly evolving (Thompson 2013). Further, we now know that hybridization between populations, sub-species, and even species is a normal occurrence in both animals and plants (Coates et al. 2018). Frankham et al. (2012) addressed the conservation implications of different species concepts.

Understanding of the role of climate change in impacting biodiversity has grown markedly, from little mention prior to 2000, to its recognition as one of the most important factors threatening populations and exacerbating genetic problems (Hoffmann & Sgrò 2011; Weeks et al. 2011; Hughes et al. 2017, 2018). Global environmental change makes the need for genetic management of fragmented populations even more pressing (Frankham et al. 2017).

All these insights were reviewed and presented along with genetic management recommendations for fragmented populations in Frankham et al. (2017). The current book presents updated management recommendations that reflect these scientific advances and altered realities faced by conservation managers.

Format

To make the book easy to read and skim, we use a textbook format similar to that of Frankham et al. (2017) *Genetic Management of Fragmented Animal and Plant Populations* and the Frankham, Ballou, & Briscoe textbooks *Introduction to Conservation Genetics* (2002, 2010) and *A Primer of Conservation Genetics* (2004).

Genetic management often involves the use of equations. However, the conservation managers we consulted about this book advised against presenting equations. As a compromise, we have restricted equations to boxes, so they can easily be skipped if preferred. Useful software packages for implementing our recommendations are listed at the end of the chapters.

Referencing

As detailed references were given in our *Genetic Management of Fragmented Animal and Plant Populations*, and due to the length constraints for this guide, we cite only references not given in that book, apart from ones required for copyright purposes. However, the remaining references common to both books are available online http://www.oup.co.uk/companion/FrankhamPG, where they are arranged in chapter groupings for this book. Further, each chapter in this book has about six key sources of **Further reading**, while source references for figures and tables plus new references and Further reading are listed after the Glossary.

New items in the *Practical Guide*

In addition to extensively re-writing the text, re-formulating the headings, making minor changes in structure, incorporating feedback on *Genetic Management of Fragmented Animal Plant Populations*, and drawing on the recommendations of conservation practitioners, we have added the following items not found in the previous book:

- an "Historical perspective" on genetic management of fragmented animal and plant populations (Preface)
- a revised decision tree on genetic management of fragmented populations (Fig. 1.4)
- advice on how to find someone to assist with studying the genetic diversity or the chromosomal constitution of your species (Chapters 2 and 5)
- Box 2.4 on means to obtain an estimate of effective population size (N_e), and Appendix 2 with estimates of N_e/N ratios for a diversity of taxa that can be used to estimate N_e for your population or species
- depiction of genetic differentiation among vertebrate populations that walk, swim, or fly in relation to geographical distances between them (Fig. 4.3)
- explanation of how genetic drift generates random, non-adaptive morphological, behavioral, physiological, and disease resistance variation among populations (Chapter 4)
- potential use of evolutionary rescue to minimize the impact of invasive species (Box 5.3)
- a section on "What not to do in genetic management" (Section II, Table SII.1), added on the recommendation of conservation practitioners
- an unfolding case study "Should isolated, declining populations of Blanding's turtles in central North America be managed as separate populations?" (Box 7.1)
- recommendation that expert opinion should be elicited using recent guidelines that minimize biases in human perception (Chapter 7)
- corrected prediction of benefits of gene flow from lethal equivalents and reduction in inbreeding (Example 7.3)
- prediction of fitness increase due to gene flow when the level of inbreeding depression is known (Example 7.4)
- a revised section on choice of donor population(s) for genetic rescue when there is limited genetic information (Chapter 8)
- a method to estimate the approximate number of generations required until a further round of gene flow into completely isolated population fragments (Example 8.2)
- a section on "Should we manage to conserve rare alleles?" (Chapter 8)
- major revisions of the decision tree for assessing genetic management options to improve the ability of populations and species to cope with global climate change (Fig. 9.2)

- information on a heat-tolerant allele from wild rice (*Oryza australiensis*) that has the potential to be used to improve the heat tolerance of plant species to cope with global climate change (Chapter 9)
- updated information on CRISPR-Cas9 gene editing (Chapter 9)
- six new illustrations of animals and plants by Karina McInnes and one re-used from *Introduction to Conservation Genetics*, 2nd edition
- more than a hundred new references.