PREFACE

# Applied raptor ecology in a quantitative age: how to use this book

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## Introduction

The science of applied ecology is becoming increasingly quantitative (Hastings et al. 2005, Jones et al. 2006, Barraquand et al. 2014, Touchon and McCoy 2016). Complex and large-scale issues such as climate change, overharvesting, and invasive species often require sophisticated modeling to make predictions effectively and guide management (Green et al. 2005). Indeed, conservation decisions should be made using the best available scientific evidence (Pullin and Knight 2003, Sutherland et al. 2004), requiring the use of statistics to confront hypotheses with data (Williams et al. 2002). Quantitative methods are therefore important skills for the applied ecologist, not only for the analysis of data but also in the design of experiments and monitoring programs.

As proficiency—or, at least conversancy—in sophisticated statistical techniques becomes more important, many ecologists are feeling underprepared by their graduate education. In a survey of early-career ecologists, Barraquand et al. (2014) found that 75% were unsatisfied with their understanding of mathematics and statistics and 95% thought more statistics courses should be available. Touchon and McCoy (2016) reviewed course listings for 154 US doctoral programs in ecology and found that only 25% required students to take a biostatistics course and one-third did not even list a statistics course in their catalog. The paucity of available statistics courses, coupled with the often steep learning curve associated with computer programs needed for analysis, has led to the publication of many books targeted at ecologists looking to gain quantitative skills and navigate complicated statistical software (e.g., Piegorsch and Bailer 2005, Cooch and White 2006, Hector 2015).

Many ecologists are using open-source software like R (R Core Team 2016) for analysis (Barraquand et al. 2014, Touchon and McCoy 2016). R is a software environment for statistics and graphics and is cited in more than three times the number of ecological articles than the next most-popular statistical software (SAS, Touchon and McCoy 2016). The popularity of R is likely because it is free, runs on all major platforms (Windows, Mac, Unix), and is open-source—meaning it can be extended and modified by users. The functions implemented by R are all stored in packages. R's open-source framework allows users to develop their own packages and make them available online. There are currently more than 10,000 contributed packages available (https://cran.r-project.org/web/packages/), many of which were specifically developed for ecological analyses (e.g., Laake and Rexstad 2008, Fiske and Chandler 2011, Oksanen et al. 2017).

This book presents many of the statistical analyses commonly used by applied ecologists and provides step-by-step instruction for implementation using R. Particularly, the analyses presented in this book are meant to inform the study of raptors. Their trophic level, life history, large home-range, and unique physiology present distinct challenges to those tasked with the study and management of raptors (Bird and Bildstein 2007). This book specifically focuses on the Gyrfalcon, a species considered both under-studied and under threat (see Chapter 1, this volume). Although we highlight one raptor in particular, the techniques and analyses presented are useful for the applied ecology of raptors in general and many other vertebrates.

## How to use this book

In addition to the wealth of information regarding Gyrfalcons contained within these pages, this book is a resource when designing studies, storing data, and performing analyses relevant to raptor ecology. Several chapters mention important elements of study design and, of course, it is best to understand appropriate analyses before data are collected. There are also chapters and appendixes that are helpful in developing field methods for studying Gyrfalcons and other raptors. For additional information on the study and management of raptors, see Bird and Bildstein (2007).

This book is not intended to be an in-depth treatise on statistical theory, but rather a practical guide to using statistics in applied raptor ecology. For more information regarding the background of analyses presented, we encourage the reader to seek out the studies cited in individual chapters. Further, analyses presented in each chapter represent choices made by the individual authors regarding data analysis. The field of ecological statistics is not as formulaic as often assumed and there might be several 'right' ways to analyze a given dataset. Readers should therefore not only consider how to conduct an analysis, but also why a given analysis was chosen over other options.

We assume that the reader has already downloaded and installed R, has a basic familiarity with the syntax of the R language, can download and load packages, and can load and run scripts. For those new to R, there are many resources available online at the Comprehensive R Archive Network (CRAN) website (https://cran.r-project.org/) under the manuals tab. There are also many excellent books available for help with ecological analyses in R (e.g., Bolker 2008, Zuur et al. 2009, Kéry 2010, Kéry and Schaub 2012, Hector 2015, Kéry and Royle 2016). The authors of the chapters in this book have provided step-by-step instructions to run the analyses they present. The R code presented in the book is available as Online Appendixes on the companion website (http://science.peregrinefund.org/applied-raptor-ecology) along with the example datasets. Within the text, R functions are identified using Courier font, unless otherwise noted.

## Conclusion

Of course, results from analyses presented in this book are only as reliable as the data from which they are derived. Chapter 4 of this book reviews the importance of proper database construction and management. As ecology grows more quantitative, methods and tools for data storage and access are becoming paramount. Open databases such as the Avian Knowledge Network (www.avianknowledge.net, Iliff et al. 2008) are increasing the scope and scale of ecological analyses while providing researchers with secure places to store their data (e.g., Reichman et al. 2011, Hampton et al. 2014, Michener 2015).

The field of raptor ecology is also embracing the trend toward open data. For example, the Hawk Migration Association of North America's database of migration counts (www.hawkcount.org) is connected to the Avian Knowledge Network. The Peregrine Fund created and maintains the American Kestrel Partnership (www.kestrel.peregrinefund.org) and supports the African Raptor Databank (www.habitatinfo.com/ardb_resources/) and Polar Raptor Databank (see sections 1.3.2 and 4.4.2 in this volume, gis.habitatinfo.com/tpf/) to provide for the storage, download, analysis, and dissemination of data collected in the study of raptors. The Polar Raptor Databank will soon be a valuable tool in the applied study of Gyrfalcons and other Arctic raptors—allowing users to store and download data consistent with the analyses presented in this book. Eventually, the Polar Raptor Databank should be incorporated into the Avian Knowledge

Network and expanded into a global effort so that raptor researchers around the world can store and share data at a global scale.

Ecologists increasingly feel their statistical training is inadequate or outdated, and large, secure, open databases are increasing in importance. Therefore, opportunities for ecologists to gain quantitative skills will likely be improved if developed with applicable databases in mind. Our hope is that this book will be a resource for raptor biologists as applied ecology grows more quantitative and open databases become convention. With an uncertain future and need for research, the Gyrfalcon provides a great example of the expanding challenges faced by applied raptor ecologists.

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