## Contents

# About the Companion Website Page xiii

Molecular Genetics in Ecology 1
What is Molecular Ecology? 1
DNA, RNA, and Protein 2
Allozymes 5
DNA: An Unlimited Source of Data
Mutation and Recombination 8
Epigenetic Marks 10
Genomes 12
Mitochondrial DNA (mtDNA) 13
Chloroplast DNA (cpDNA) 13
Haploid Chromosomes 16
Polymerase Chain Reaction 16
Quantitative PCR 19
Sources of DNA 21
Getting Data from PCR 22
Fragment Sizes 22
DNA Sequencing 25
High Throughput Sequencing 26
Overview 28
Chapter Summary 29
References 29

# Molecular Markers in Ecology 35 Understanding Molecular Markers 35 Neutral Versus Adaptive Markers 35 Genomes 36 Animal Mitochondrial DNA (mtDNA) 36 Plant Mitochondrial DNA (mtDNA) 39 Chloroplast DNA (cpDNA) 39 Haploid Chromosomes 42 Uniparental Markers: Some Final Considerations 43 Molecular Markers 44

Early Developments in Molecular Markers 45 Allozymes 46 PCR-RFLPs 46 Random Amplified Polymorphic DNA (RAPDs) 47 Inter Simple Sequence Repeats (ISSRs) 48 Amplified Length Fragment Polymorphisms (AFLPs) Modified AFLPs: Methylation-Sensitive Amplified Polymorphisms (MSAPs) 50 Microsatellites 51 DNA Sequencing 56 Sequencing a Single Region of DNA 56 Single Nucleotide Polymorphisms (SNPs) 59 High Throughput Sequencing (HTS) 61 RAD Sequencing Genotyping-by-Sequencing (GBS) 63 Targeted Sequence Capture 63

Whole-Genome Sequencing
Overview 65
Chapter Summary 65
References 66

# 3 Species 71

Species Concepts 71

DNA Barcoding 73

Barcoding Applications 76

Barcoding Limitations 79

Metabarcoding 81

Metagenomics 84

Barcoding and Metabarcoding Environmental DNA (eDNA) 87

Overview 91

Chapter Summary 91

References 92

### 4 Phylogeography 101

What is Phylogeography? 101
The Evolution of Phylogeographic Data Sets 102
Molecular Clocks 104
Bifurcating Trees 109
The Coalescent 115
Networks 117
Model-Based Phylogeographic Inference 120
Long-Term Climatic Fluctuations 121
Glacial—Interglacial Cycles 121
Marine Refugia 123
Far-Reaching Effects of Glaciation 125
Dispersal and Vicariance 125
Lineage Sorting 127

Hybridization 130
Applied Phylogeography: Biological Invasions 133
Overview 136
Chapter Summary 136
References 137

**Genetic Analysis of Single Populations** Why Study Single Populations? 149 What is a Population? 149 Quantifying Genetic Diversity 151 Hardy-Weinberg Equilibrium 152 Estimates of Genetic Diversity 157 Haploid Diversity 160 Choice of Marker and Genome What Influences Genetic Diversity? Genetic Drift 163 What is Effective Population Size? 164 Census Population Size (N<sub>c</sub>) 165 Effective Number of Breeders (Nb) Estimating N<sub>e</sub> from Demographic Data 165 Estimating N<sub>e</sub> from Genetic Data 166 Estimating N<sub>e</sub>: A Cautionary Note 170 Ne, Genetic Drift, and Genetic Diversity 173 Population Bottlenecks and Founder Effects Population Size and Decline 176 Natural Selection 178 Reproduction 180 Inbreeding 182 Ecology and Life History 186 Overview 188 Chapter Summary 188 References 189

Dispersal, Gene Flow, and Landscape Genetics 197
Why Study Multiple Populations? 197
What is Gene Flow? 197
Why Do We Want to Quantify Gene Flow? 199
Quantifying Gene Flow Among Discrete Populations 200
F-Statistics 201
Assignment Tests 204
Relatedness and Parentage Analysis 206
Non-a Priori Identification of Populations 207
Landscape Genetics and Genomics 209
Data Analysis in Landscape Genetics 214
Isolation by Distance 216
Isolation by Resistance 217
Genotype—Environment Associations 218

Contemporary Versus Historical Influences on Gene Flow 221 Population Differentiation: Gene Flow, Genetic Drift, and Natural Selection Gene Flow and Genetic Drift 223 Local Adaptation and Gene Flow 223 Drift Versus Selection 225  $Q_{\rm ST}$  and  $F_{\rm ST}$  226 Overview 228 Chapter Summary 228 References 229 **Behavioral Ecology** 237 How Do Genetic Data Help Us Understand Behavior? 237 Mating Systems 238 Monogamy 239 Polygamy 239 Parentage Analysis 241 Extra-Pair Fertilizations 244 EPFs and Male Fitness 244 EPFs from the Female Perspective: Adaptive Explanations 245 EPFs from the Female Perspective: Non-adaptive Explanations 247

Social Breeding Cooperative Breeding – Indirect Benefits 253 Cooperative Breeding – Direct Benefits 257

Eusociality 257

Sex-Biased Dispersal

Sex-Biased Dispersal: Population-Level Analyses Male Versus Female Genetic Differentiation 262 Markers with Different Modes of Inheritance 263 Relatedness 264

Sex-Biased Dispersal: Individual-Level Analyses 266

Assignment Indices 266 Spatial Autocorrelation Parentage Analysis

Concordant Results 270

Foraging Ecology 271

Overview 276

Chapter Summary 276

References 277

### **Conservation Genetics**

Taxonomy 292 Subspecies 294 Taxa Below Subspecies Conservation Units and Adaptation Genetic Diversity 300

Genetic Diversity and Evolutionary Potential 301 Transcriptomics and Epigenetics 303

299

Genetic Diversity and Inbreeding 307 Inbreeding Depression 310 Purging and Balancing Selection 312 Measuring and Inferring Inbreeding Depression 315 Genetic Differentiation and Genetic Rescue 317 Outbreeding Depression 320 Reintroductions 321 Hybridization 324 Community Genetics 326 Overview 330 Chapter Summary 330 References 331

Glossary Index 359