Contents

Introduction xiii

1 Introducing insect conservation **1**
1.1 The challenge: the relevance of sampling insects 1
1.2 An historical perspective 2
1.3 Ethics of insect conservation 3
1.4 Ethics of collecting insects 6
1.5 Ecological and evolutionary timescales 10
1.6 The taxonomic challenge 13
1.7 Summary 15

2 Taxonomy and curation of insects **17**
2.1 Introduction: essential planning 17
2.2 Selection of insect groups for study 19
2.3 Taxonomic knowledge 21
2.4 Taxonomic resolution 25
2.5 Morphospecies and parataxonomists 27
2.5.1 The morphospecies approach *27*
2.5.2 Parataxonomists *29*
2.5.3 Voucher collections *30*
2.6 Bioinformatics 31
2.6.1 Virtual voucher collections *33*
2.6.2 Sample tracking *33*
2.6.3 Taxonomy using barcoding *34*
2.7 Specimen treatment 35
2.7.1 Sequence of steps for treating insect samples *38*
2.7.1.1 Preservation 38
2.7.1.2 Mounting 46
2.7.1.3 Storage 53
2.8 Summary 57

3 Designing sampling protocols for insect conservation **59**
3.1 Introduction 59
3.2 Defining the conservation question 60
3.2.1 Broad objectives in insect conservation *61*
3.2.2 Refining the objective *63*
3.2.3 Hypothesis formulation *64*
3.3 Designing a sampling protocol 65
3.3.1 Sample grain *66*

3.3.2 Sample extent *67*
3.3.3 Sample number *68*
3.3.4 Sample independence *70*
3.3.5 Spatial autocorrelation *73*
3.3.6 Sample placement *76*
3.3.7 Sampling coverage and intensity *79*
3.3.8 Controls *79*
3.4 Pilot studies 80
3.5 Coping with the unexpected 81
3.6 Data management 82
3.7 Summary 82

4 Collecting and recording insects 85
4.1 Introduction: What do you really need to collect? 85
4.2 Named and nameless approaches to data portrayal 87
4.3 High-canopy insects 92
4.4 Low-canopy insects 96
4.5 Grass/herbaceous layer 99
4.6 Sampling flying insects 101
4.7 Sampling insects on the ground 116
4.8 Sampling insects in the leaf litter and soil 121
4.9 Sampling aquatic insects 124
4.10 Sound recording 127
4.11 Summary 129

5 Measuring environmental variables 131
5.1 Introduction: selection of variables 131
5.2 Conceptualizing environmental variable data 134
5.3 Choosing the environmental variables 135
5.4 Measuring air and soil environmental variables 146
5.5 Measuring vegetation characteristics 153
5.6 Aquatic environmental variables 156
5.7 Summary 159

6 Estimating population size and condition 161
6.1 Introduction: the relevance of populations 161
6.2 Assessing changes in population levels 163
6.3 Significance of surveys 166
6.4 Evaluating population structure 168
6.5 Measuring population size 171
6.5.1 Some underlying principles *171*
6.5.2 Temporal considerations *173*
6.5.3 Spatial considerations and differences between sexes *177*
6.5.4 Accuracy of estimates relative to feasibility *177*

6.5.5 Special considerations for threatened species 178
6.5.6 Direct counts 179
6.5.7 Transect counts 183
6.5.7.1 Line transects 183
6.5.7.2 Point transects 187
6.5.7.3 Belt transects 187
6.5.8 Quadrat counts 188
6.6 Populations and conservation status 189
6.6.1 Conservation status 189
6.6.2 Level of threat 191
6.7 Population distinctiveness 202
6.8 Population condition 204
6.9 Population modelling 205
6.10 Summary 206

7 The population and the landscape 209
7.1 Introduction: the relevance of landscapes 209
7.2 Effects of landscape structure 211
7.3 Resources and landscape geometry: the insect's habitat 217
7.4 Insect movements and MRR methods 218
7.4.1 MRR process 226
7.4.2 Capture 228
7.4.3 Marking 229
7.4.4 Release 232
7.4.5 Recapture 232
7.4.6 Outcomes from MRR studies 233
7.5 Landscape geometry and insect populations 235
7.6 Dispersal and dispersion (aggregation) 240
7.6.1 Activity patterns 243
7.6.2 Recording activity and abundance 244
7.7 Summary 245

8 *Ex-situ* conservation: captive rearing and reintroduction programmes 247
8.1 Introduction: conservation objectives 247
8.2 Farming or ranching insects for conservation 252
8.3 Process 253
8.3.1 Capture 257
8.3.2 Transport 258
8.3.3 Maintenance 259
8.3.4 Breeding 260
8.3.5 Release 264
8.4 Practical outcomes 268
8.5 Summary 271

9 Biodiversity and assemblage studies 273
9.1 Introduction: defining biodiversity in space and time 273
9.2 The assemblage matrix 275
9.3 The relational matrix 278
9.4 Estimating sampling adequacy 278
9.4.1 Taxon sampling (accumulation and rarefaction) curves 280
9.5 Species richness 282
9.5.1 Comparisons of species richness 282
9.5.2 Estimating species richness 282
9.5.3 Chosing a richness estimator 283
9.6 Species abundance and density 284
9.7 Species range and distribution 287
9.7.1 Biodiversity mapping 288
9.8 Diversity indices 292
9.8.1 Species richness, evenness and dominance 292
9.8.2 Beta diversity 295
9.8.3 Functional diversity 298
9.8.4 Taxonomic diversity 300
9.9 Phylogenetic comparative methods 302
9.10 Summary 303

10 Studying insects in the changing environment 305
10.1 Introduction: drivers and methodology 305
10.2 Environmental change in context 305
10.3 Approaches to studying environmental change 306
10.3.1 Methodological approaches 306
10.3.2 Modelling 307
10.4 Bioindicators 310
10.4.1 Bioindication terminology and development 311
10.4.2 Taxa that make good bioindicators 312
10.4.3 Quantifying the indicator value of a species 318
10.4.4 Testing the proposed bioindicator and developing the bioindicator system 321
10.5 Biodiversity assessment 322
10.6 Biodiversity mapping 325
10.7 Summary 331

11 Key questions for insect conservation in an era of global change 333
11.1 Forms of environmental change 333
11.1.1 Habitat loss, fragmentation, and isolation 333
11.1.2 Disturbance, decline in habitat quality and the loss of critical resources 335
11.1.3 Impact of invasive alien species 336

11.1.4 Climate change 337
11.1.5 Biotechnology, biological control, and sustainable harvesting 346
11.1.5.1 *Biotechnology* 346
11.1.5.2 *Biological control* 351
11.1.5.3 *Sustainable harvesting* 352
11.1.6 Aquatic and terrestrial systems contamination 353
11.2 Consequences of species loss for ecosystem function 354
11.2.1 Importance of diversity 354
11.2.2 Temporal perspectives, adverse synergisms and discontinuities 354
11.2.3 Species numbers, rarity and ecosystem function 355
11.2.4 The importance of food web connectance 357
11.2.5 Rare and threatened species as flagships 358
11.3 Lessons learned from diversity value: towards a synthetic management approach 359
11.4 Triage and restoration 364
11.5 Ecological monitoring 365
11.6 Engaging citizen scientists in insect conservation 368
11.7 Summary 371

Software 373
References 375
Glossary 405
Index 425