

# Contents

Part I Regression Analysis for a Single Response Variable	
<b>1 “Stats 101” Revision</b>	3
1.1 Regression, Predictors, and Responses	4
1.2 Study Design Is Critical	4
1.3 When Do You Use a Given Method?	11
1.4 Statistical Inference	17
1.5 Mind Your Ps and Qs—Assumptions	22
1.6 Transformations	35
<b>2 An Important Equivalence Result</b>	43
2.1 The Two-Sample $t$ -Test	43
2.2 Simple Linear Regression	47
2.3 Equivalence of $t$ -Test and Linear Regression	57
<b>3 Regression with Multiple Predictor Variables</b>	63
3.1 Multiple Regression	63
3.2 ANOVA	73
<b>4 Linear Models—Anything Goes</b>	81
4.1 Paired and Blocked Designs	81
4.2 Analysis of Covariance	86
4.3 Factorial Experiments	90
4.4 Interactions in Regression	99
4.5 Robustness of Linear Models—What Could Go Wrong?	102
<b>5 Model Selection</b>	107
5.1 Understanding Model Selection	108
5.2 Validation	114
5.3 $K$ -fold Cross-Validation	117
5.4 Information Criteria	119

5.5	Ways to Do Subset Selection . . . . .	121
5.6	Penalised Estimation . . . . .	124
5.7	Variable Importance . . . . .	126
5.8	Summary . . . . .	131
<b>6</b>	<b>Mixed Effects Models . . . . .</b>	<b>133</b>
6.1	Fitting Models with Random Effects . . . . .	135
6.2	Linear Mixed Effects Model . . . . .	136
6.3	Likelihood Functions . . . . .	139
6.4	Inference from Mixed Effects Models . . . . .	142
6.5	What If I Want More Accurate Inferences? . . . . .	145
6.6	Design Considerations . . . . .	146
6.7	Situations Where Random Effects Are and Aren't Used . . . . .	148
<b>7</b>	<b>Correlated Samples in Time, Space, Phylogeny... . . . . .</b>	<b>151</b>
7.1	Longitudinal Analysis of Repeated Measures Data . . . . .	155
7.2	Spatially Structured Data . . . . .	163
7.3	Phylogenetically Structured Data . . . . .	170
7.4	Confounding—Where Is the Fixed Effect You Love? . . . . .	177
7.5	Further Reading . . . . .	179
<b>8</b>	<b>Wiggly Models . . . . .</b>	<b>181</b>
8.1	Spline Smoothers . . . . .	182
8.2	Smoothers with Interactions . . . . .	189
8.3	A Smoother as a Diagnostic Tool in Residual Plots . . . . .	192
8.4	Cyclical Variables . . . . .	193
<b>9</b>	<b>Design-Based Inference . . . . .</b>	<b>205</b>
9.1	Permutation Tests . . . . .	206
9.2	Bootstrapping . . . . .	211
9.3	Do I Use the Bootstrap or a Permutation Test? . . . . .	214
9.4	Mind Your Ps and Qs! . . . . .	215
9.5	Resampling Residuals . . . . .	217
9.6	Limitations of Resampling: Still Mind Your Ps and Qs! . . . . .	221
9.7	Design-Based Inference for Dependent Data . . . . .	223
<b>10</b>	<b>Analysing Discrete Data . . . . .</b>	<b>231</b>
10.1	GLMs: Relaxing Linear Modelling Assumptions . . . . .	236
10.2	Fitting a GLM . . . . .	240
10.3	Checking GLM Assumptions . . . . .	244
10.4	Inference from Generalised Linear Models . . . . .	251
10.5	Don't Standardise Counts, Use Offsets! . . . . .	259
10.6	Extensions . . . . .	261

**Part II Regression Analysis for Multiple Response Variables**

<b>11 Multivariate Analysis</b> .....	267
11.1 Do You Really Need to Go Multivariate? Really? .....	268
11.2 MANOVA and Multivariate Linear Models .....	270
11.3 Hierarchical Generalised Linear Models .....	279
11.4 Other Approaches to Multivariate Analysis .....	293
<b>12 Visualising Many Responses</b> .....	295
12.1 One at a Time: Visualising Marginal Response .....	296
12.2 Ordination for Multivariate Normal Data .....	297
12.3 Generalised Latent Variable Models .....	308
12.4 Multi-Dimensional Scaling and Algorithms Using Pairwise Dissimilarities .....	312
12.5 Make Sure You Plot the Raw Data! .....	314
<b>13 Allometric Line Fitting</b> .....	317
13.1 Why Not Just Use a Linear Model? .....	319
13.2 The (Standardised) Major Axis .....	320
13.3 Controversies in the Allometry Literature .....	327

**Part III Regression Analysis for Multivariate Abundances**

<b>14 Multivariate Abundances and Environmental Association</b> .....	331
14.1 Generalised Estimating Equations .....	334
14.2 Design-Based Inference Using GEEs .....	336
14.3 Compositional Change and Diversity Partitioning .....	344
14.4 In Which Taxa Is There an Effect? .....	349
14.5 Random Factors .....	351
14.6 Modelling Frameworks for Multivariate Abundances .....	351
<b>15 Predicting Multivariate Abundances</b> .....	357
15.1 Special Considerations for Multivariate Abundances .....	358
15.2 Borrowing Strength Across Taxa .....	360
15.3 Non-Linearity of Environmental Response and Interactions .....	365
15.4 Relative Importance of Predictors .....	366
<b>16 Explaining Variation in Responses Across Taxa</b> .....	369
16.1 Classifying Species by Environmental Response .....	369
16.2 Fourth Corner Models .....	378
<b>17 Studying Co-occurrence Patterns</b> .....	387
17.1 Copula Frameworks for Modelling Co-occurrence .....	389
17.2 Inferring Co-occurrence Using Latent Variables .....	392
17.3 Co-occurrence Induced by Environmental Variables .....	394
17.4 Co-occurrence Induced by Mediator Taxa .....	398

17.5 The Graphical LASSO for Multivariate Abundances .....	400
17.6 Other Models for Co-occurrence .....	403
<b>18 Closing Advice .....</b>	<b>405</b>
18.1 A Framework for Data Analysis—Mind Your Ps and Qs .....	405
18.2 Beyond the Methods Discussed in This Book .....	410
<b>References .....</b>	<b>415</b>
<b>Index .....</b>	<b>429</b>