

Contents

Contents.....	ix
Contributors	xvii
1 Introduction	1
1.1 What is in the book?	1
1.2 Software	5
1.3 How to use this book if you are an instructor	6
1.4 What we did not do and why	7
1.5 How to cite R and associated packages	7
1.6 Our R programming style	8
1.7 Getting data into R.....	9
2 Limitations of linear regression applied on ecological data.....	11
2.1 Data exploration.....	12
2.2 The linear regression model.....	17
2.3 Violating the assumptions; exception or rule?	19
2.3.1 Introduction	19
2.3.2 Normality	20
2.3.3 Heterogeneity	20
2.3.4 Fixed X.....	21
2.3.5 Independence.....	21
2.3.6 Example 1; Wedge clam data	22
2.3.7 Example 2; Moby's teeth	26
2.3.8 Example 3; Nereis	29
2.3.9 Example 4; Pelagic bioluminescence	30
2.4 Where to go from here	32
3 Things are not always linear; additive modelling	35
3.1 Introduction.....	35
3.2 Additive modelling	36
3.2.1 GAM in gam and GAM in mgcv	37
3.2.2 GAM in gam with LOESS	38
3.2.3 GAM in mgcv with cubic regression splines.....	43
3.3 Technical details of GAM in mgcv*	45
3.4 GAM example 1; bioluminescent data for two stations.....	56

3.5 GAM example 2: Dealing with collinearity.....	64
3.6 Inference*	68
3.7 Summary and where to go from here?	69
4 Dealing with heterogeneity	71
4.1 Dealing with heterogeneity	72
4.1.1 Linear regression applied on squid.....	72
4.1.2 The fixed variance structure	74
4.1.3 The varIdent variance structure	75
4.1.4 The varPower variance structure	78
4.1.5 The varExp variance structure.....	80
4.1.6 The varConstPower variance structure.....	80
4.1.7 The varComb variance structure	81
4.1.8 Overview of all variance structures	82
4.1.9 Graphical validation of the optimal model	84
4.2 Benthic biodiversity experiment	86
4.2.1 Linear regression applied on the benthic biodiversity data	86
4.2.2 GLS applied on the benthic biodiversity data	89
4.2.3 A protocol.....	90
4.2.4 Application of the protocol on the benthic biodiversity data	91
5 Mixed effects modelling for nested data	101
5.1 Introduction	101
5.2 2-stage analysis method	103
5.3 The linear mixed effects model.....	105
5.3.1 Introduction	105
5.3.2 The random intercept model.....	106
5.3.3 The random intercept and slope model	109
5.3.4 Random effects model.....	111
5.4 Induced correlations.....	112
5.5 The marginal model	114
5.6 Maximum likelihood and REML estimation*	116
5.7 Model selection in (additive) mixed effects modelling.....	120
5.8 RIKZ data: Good versus bad model selection	122
5.8.1 The wrong approach.....	122
5.8.2 The good approach.....	127
5.9 Model validation	128
5.10 Begging behaviour of nestling barn owls	129
6 Violation of independence – Part I.....	143
6.1 Temporal correlation and linear regression	143
6.2 Linear regression model and multivariate time series.....	152
6.3 Owl sibling negotiation data	157
7 Violation of independence – Part II	161
7.1 Tools to detect violation of independence	161

7.2 Adding spatial correlation structures to the model.....	166
7.3 Revisiting the Hawaiian birds	171
7.4 Nitrogen isotope ratios in whales	172
7.4.1 Moby	172
7.4.2 All whales.....	174
7.5 Spatial correlation due to a missing covariate.....	177
7.6 Short godwits time series	182
7.6.1 Description of the data	182
7.6.2 Data exploration	183
7.6.3 Linear regression	185
7.6.4 Protocol time	186
7.6.5 Why all the fuss?	191
8 Meet the exponential family	193
8.1 Introduction.....	193
8.2 The Normal distribution.....	194
8.3 The Poisson distribution	196
8.4 The negative binomial distribution	199
8.5 The gamma distribution	201
8.6 The Bernoulli and binomial distributions	202
8.7 The natural exponential family	204
8.8 Zero truncated distributions for count data	207
9 GLM and GAM for count data	209
9.1 Introduction.....	209
9.2 Gaussian linear regression as a GLM	210
9.3 Introducing Poisson GLM with an artificial example	211
9.4 Likelihood criterion	213
9.5 Introducing the Poisson GLM with a real example	215
9.5.1 Introduction	215
9.5.2 R code and results	217
9.5.3 Deviance.....	218
9.5.4 Sketching the fitted values	218
9.6 Model selection in a GLM	220
9.6.1 Introduction	220
9.6.2 R code and output.....	221
9.6.3 Options for finding the optimal model	221
9.6.4 The drop1 command.....	222
9.6.5 Two ways of using the anova command	223
9.6.6 Results	224
9.7 Overdispersion	224
9.7.1 Introduction	224
9.7.2 Causes and solutions for overdispersion	225
9.7.3 Quick fix: Dealing with overdispersion in a Poisson GLM.....	225
9.7.4 R code and numerical output.....	226
9.7.5 Model selection in quasi-Poisson	227

9.8 Model validation in a Poisson GLM.....	229
9.9 Illustration of model validation in quasi-Poisson GLM.....	231
9.10 Negative binomial GLM.....	233
9.10.1 Introduction.....	233
9.10.2 Results.....	236
9.11 GAM.....	239
10 GLM and GAM for presence-absence and proportional data	245
10.1 Introduction	245
10.2 GLM for presence – absence data	246
10.2.1 Tuberculosis in wild boar.....	246
10.2.2 Parasites in cod.....	252
10.3 GLM for proportional data	255
10.4 GAM for presence-absence data.....	258
10.5 Where to go from here?	260
11 Zero truncated and zero inflated models for count data	261
11.1 Introduction	261
11.2 Zero truncated data	263
11.2.1 The underlying mathematics for truncated models	263
11.2.2 Illustration of Poisson and NB truncated models	266
11.3 Too many zeros.....	269
11.4 ZIP and ZINB models.....	274
11.4.1 Mathematics of the ZIP and ZINB	274
11.4.2 Example of ZIP and ZINB models.....	278
11.5 ZAP and ZANB models, alias hurdle models.....	287
11.5.1 Mathematics of the ZAP and ZANB	288
11.5.2 Example of ZAP and ZANB	289
11.6 Comparing Poisson, quasi-Poisson, NB, ZIP, ZINB, ZAP and ZANB GLMs.....	291
11.7 Flowchart and where to go from here	293
12 Generalised Estimation Equations.....	295
12.1 GLM: Ignoring the dependence structure	295
12.1.1 The California bird data	295
12.1.2 The owl data.....	298
12.1.3 The deer data.....	300
12.2 Specifying the GEE	302
12.2.1 Introduction.....	302
12.2.2 Step 1 of the GEE: Systematic component and link function.....	303
12.2.3 Step 2 of the GEE: The variance	303
12.2.4 Step 3 of the GEE: The association structure	304
12.3 Why all the fuss?	309
12.4 Association for binary data	313
12.5 Examples of GEE	314
12.5.1 A GEE for the California birds.....	314

12.5.2 A GEE for the owls	316
12.5.3 A GEE for the deer data	319
12.6 Concluding remarks	320
13 GLMM and GAMM.....	321
13.1 Setting the scene for binomial GLMM	322
13.2 GLMM and GAMM for binomial and Poisson data	325
13.2.1 Deer data	325
13.2.2 The owl data revisited	331
13.2.3 A word of warning	337
13.3 The underlying mathematics in GLMM	338
14 Estimating trends for Antarctic birds in relation to climate change	341
14.1 Introduction.....	341
14.2 Data exploration.....	343
14.3 Trends and auto-correlation	349
14.4 Using ice extent as an explanatory variable	350
14.5 SOI and differences between arrival and laying dates	353
14.6 Discussion.....	358
14.7 What to report in a paper	360
15 Large-scale impacts of land-use change in a Scottish farming catchment.....	361
15.1 Introduction.....	361
15.2 Data exploration.....	363
15.3 Estimation of trends for the bird data.....	365
15.4 Dealing with independence.....	372
15.5 To transform or not to transform.....	376
15.6 Birds and explanatory variables	377
15.7 Conclusions.....	378
15.8 What to write in a paper.....	379
16 Negative binomial GAM and GAMM to analyse amphibian roadkills ...	381
16.1 Introduction.....	381
16.2 Data exploration.....	383
16.3 GAM.....	388
16.4 Understanding what the negative binomial is doing	392
16.5 GAMM: Adding spatial correlation.....	395
16.6 Discussion.....	396
16.7 What to write in a paper.....	396
17 Additive mixed modelling applied on deep-sea pelagic bioluminescent organisms	397
17.1 Biological introduction	397
17.2 The data and underlying questions.....	399
17.3 Construction of multi-panel plots for grouped data	400
17.4 Estimating common patterns using additive mixed modelling	408

17.5 Choosing the best model	418
17.6 Discussion.....	418
17.7 What to write in a paper.....	420
18 Additive mixed modelling applied on phytoplankton time series data....	421
18.1 Introduction	421
18.2 Data exploration.....	425
18.3 A statistical data analysis strategy for DIN.....	428
18.4 Results for temperature	438
18.5 Results for DIAT1	440
18.6 Comparing phytoplankton and environmental trends	443
18.7 Conclusions	446
18.8 What to write in a paper.....	446
19 Mixed effects modelling applied on American Foulbrood affecting honey bees larvae.....	447
19.1 Introduction	447
19.2 Data exploration.....	448
19.3 Analysis of the data	450
19.4 Discussion.....	458
19.5 What to write in a paper.....	458
20 Three-way nested data for age determination techniques applied to cetaceans.....	459
20.1 Introduction	459
20.2 Data exploration.....	460
20.3 Data analysis	462
20.4 Discussion.....	467
20.5 What to write in a paper.....	468
21 GLMM applied on the spatial distribution of koalas in a fragmented landscape.....	469
21.1 Introduction	469
21.2 The data	471
21.3 Data exploration and preliminary analysis.....	473
Collinearity.....	474
21.4 Generalised linear mixed-effects modelling	481
21.5 Discussion.....	490
21.6 What to write in a paper.....	492
22 A comparison of GLM, GEE and GLMM applied on Badger activity data	493
22.1 Introduction	493
22.2 Data exploration.....	495
22.3 GLM results assuming independence	497
22.4 GEE results	499
22.5 GLMM results	500

22.6 Discussion.....	501
22.7 What to write in a paper.....	502
23 Incorporating temporal correlation in seal abundance data with MCMC	503
23.1 Introduction.....	503
23.2 Preliminary results	505
23.3 GLM	508
23.4 What is Bayesian statistics?	510
23.5 Fitting the Poisson model in BRugs.....	513
23.6 Poisson model with random effects	520
23.7 Poisson model with random effects and auto-correlation	523
23.8 Negative binomial distribution with auto-correlated random effects.....	525
23.9 Conclusions.....	529
A. Required pre-knowledge: A linear regression and additive modelling	
example.....	531
A.1 The data.....	531
A.2 Data exploration.....	532
A.3 Linear regression.....	536
A.4 Additive modelling	545
A.5 Further extensions.....	549
A.6 Information Theory and Multi-Model Inference.....	550
A.7 Maximum likelihood estimation in linear regression context.....	551
References	553

