

Contents

PREFACE	V
CONTENTS	VIII
1 INTRODUCTION TO BAYESIAN STATISTICS, MCMC TECHNIQUES, AND WINBUGS	1
1.1 PROBABILITIES AND BAYES' THEOREM	1
1.2 LIKELIHOOD FUNCTIONS	3
1.3 CONJUGATE PRIOR DISTRIBUTIONS	6
1.4 MCMC.....	9
1.4.1 Markov Chain.....	9
1.4.2 Transition rules*	10
1.5 USING WINBUGS.....	16
1.6 SUMMARY	21
2 ZERO INFLATED GLMM APPLIED TO BARN OWL DATA	25
2.1 INTRODUCTION	25
2.1.1 Vocal begging behaviour of nestling barn owls	25
2.1.2 Previous analyses of the owl data.....	26
2.1.3 Prerequisite knowledge for this chapter	28
2.2 IMPORTING AND CODING THE DATA.....	28
2.3 DATA EXPLORATION	29
2.4 OVERDISPERSION IN THE POISSON GLMM	34
2.4.1 Assessing overdispersion using Pearson residuals	34
2.4.2 Assessing overdispersion using an observation level random effect term.....	35
2.4.3 Simulation study demonstrating observation level random effect	35
2.4.4 A GLMM with observation level random effect	40
2.5 WHY ZERO INFLATED MODELS?	41
2.6 IMPLEMENTING A POISSON GLM IN WINBUGS.....	43
2.6.1 Converting vectors to matrices	43
2.6.2 Data for WinBUGS.....	45
2.6.3 Modelling code for WinBUGS.....	45
2.6.4 Initialising the chains	46
2.6.5 Parameters, thinning rate and length of the chains	47
2.6.6 Starting WinBUGS from within R	47
2.6.7 Assessing convergence of the chains	48
2.6.8 Summarising the posterior distributions.....	49
2.6.9 Pearson residuals	51
2.6.10 WinBUGS versus GLM results.....	53
2.7 IMPLEMENTING A POISSON GLMM IN WINBUGS	54
2.8 IMPLEMENTING A ZERO INFLATED POISSON GLM IN WINBUGS USING ARTIFICIAL DATA	56
2.9 APPLICATION OF ZIP GLMM IN WINBUGS USING THE OWL DATA	62
2.10 USING DIC TO FIND THE OPTIMAL ZIP GLMM FOR THE OWL DATA	64
2.11 ZIP GAMM FOR 1-WAY NESTED DATA.....	66
2.12 WHAT TO PRESENT IN A PAPER?	66
3 A ROADMAP FOR ANALYSIS OF OVERDISPERSED SANDEEL COUNTS IN SEAL SCAT	67
3.1 SANDEEL OTOLITHS AND SEAL SCAT	67

3.2 DATA EXPLORATION	68
3.3 GLM WITH A POISSON DISTRIBUTION	71
3.4 GLM WITH A NEGATIVE BINOMIAL DISTRIBUTION	73
3.5 GAM WITH A POISSON DISTRIBUTION	75
3.6 GAM WITH A NEGATIVE BINOMIAL DISTRIBUTION	76
3.6.1 <i>Model and R code</i>	76
3.6.2 <i>Model validation of the negative binomial GAM</i>	77
3.6.3 <i>Model interpretation</i>	78
3.7 ZERO INFLATED GAM WITH A POISSON DISTRIBUTION	80
3.7.1 <i>True and false zeros</i>	81
3.7.2 <i>The ZIP model</i>	81
3.7.3 <i>Result for the ZIP GAM</i>	83
3.7.4 <i>Result for the ZINB GAM</i>	84
3.8 FINAL REMARKS	87
3.9 DISCUSSION	88
3.10 WHAT TO PRESENT IN A PAPER?	89
4 GLMM AND ZERO INFLATED POISSON GLMM APPLIED TO 2-WAY NESTED MARMOT DATA	91
4.1 INTRODUCTION	91
4.2 DATA EXPLORATION AND VISUALISATION	93
4.2.1 <i>Import the data and get a first impression</i>	93
4.2.2 <i>Zero inflation in the response variable</i>	94
4.2.3 <i>Number of missing values</i>	95
4.2.4 <i>Outliers</i>	96
4.2.5 <i>Collinearity</i>	96
4.2.6 <i>Visualisation of relationships between number of young and the covariates</i>	98
4.3 WHAT MAKES THIS A DIFFICULT ANALYSIS?	101
4.4 WHICH STATISTICAL TECHNIQUES AND SOFTWARE TO APPLY?	102
4.5 SHORT DESCRIPTION OF THE STATISTICAL METHODOLOGY	103
4.5.1 <i>Viewing it (wrongly) as a Gaussian linear mixed effects model</i>	103
4.5.2 <i>Viewing the data (potentially wrongly) as a Poisson GLM or GLMM</i>	106
4.5.3 <i>Viewing the data (potentially wrong) as a zero inflated Poisson GLM</i>	107
4.5.4 <i>Viewing the data (possibly correct) as a 2-way nested ZIP GLMM</i>	108
4.6 DEALING WITH 25 COVARIATES IN A 2-WAY NESTED ZIP GLMM	109
4.7 WINBUGS AND R CODE FOR POISSON GLM, GLMM, AND ZIP MODELS	112
4.7.1 <i>WinBUGS code for a Poisson GLM</i>	112
4.7.2 <i>WinBUGS code for 1-way and 2-way nested Poisson GLMMs</i>	116
4.7.3 <i>WinBUGS code for ZIP GLM</i>	121
4.7.4 <i>WinBUGS code for 2-way nested ZIP Poisson GLMMs</i>	126
4.8 VALIDATING THE 2-WAY NESTED ZIP GLMM	128
4.9 INTERPRETATION OF THE 2-WAY NESTED ZIP GLMM MODEL	133
4.10 DISCUSSION	134
4.11 WHAT TO PRESENT IN A PAPER?	136
APPENDIX A: CORRELATION BETWEEN OBSERVATIONS IN GLMMs*	137
A.1 <i>Correlations in a Poisson GLMM for 1-way nested data*</i>	137
A.2 <i>Correlations in a Poisson GLMM for 2-way nested data*</i>	138
A.3 <i>Correlations in a binomial GLMM for 1-way nested data*</i>	140
A.4 <i>Correlations in a GLMM binomial model for 2-way nested data*</i>	142
A.5 <i>Correlations in a ZIP model for 1-way nested data*</i>	144
A.6 <i>Correlations in a ZIP model for 2-way nested data*</i>	145
A.7 <i>Non-technical summary of the appendix</i>	145
A.8 <i>Example of correlations for the 2-way nested ZIP GLMM*</i>	146
5 TWO-STAGE GAMM APPLIED TO ZERO INFLATED COMMON MURRE DENSITY DATA	149
5.1 INTRODUCTION	149
5.2 SAMPLING	149
5.3 COVARIATES	153

5.4 DATA EXPLORATION	154
5.4.1 <i>Potential outliers in the bird data</i>	154
5.4.2 <i>Zero inflation of the bird data</i>	154
5.4.3 <i>Outliers in the covariates</i>	155
5.4.4 <i>Collinearity of the covariates</i>	156
5.4.5 <i>Visualisation of relationships between birds and covariates</i>	159
5.4.6 <i>Cruise and transect effects</i>	161
5.4.7 <i>Summary of the data exploration</i>	162
5.5 GAMM FOR ZERO INFLATED AND CORRELATED DENSITIES	163
5.5.1 <i>Brainstorming</i>	164
5.5.2 <i>Four model selection approaches</i>	165
5.6 RESULTS OF THE FULL MODEL APPROACH	165
5.6.1 <i>Results of the presence/absence GAMM</i>	165
5.6.2 <i>More detailed output for the binomial GAMM</i>	167
5.6.3 <i>Post-hoc testing</i>	168
5.6.4 <i>Validation of the binomial GAMM</i>	170
5.6.5 <i>Analysis of the presence-only data using a gamma GAMM</i>	172
5.7 FITTING A GAMMA GAMM WITH CAR CORRELATION IN WINBUGS**	173
5.7.1 <i>Fitting a Gamma GLM in WinBUGS**</i>	174
5.7.2 <i>Fitting a ZIP GAM on the Common Murre counts in WinBUGS**</i>	176
5.7.3 <i>Fitting a ZIP GAM with residual CAR in WinBUGS**</i>	180
5.8 DISCUSSION	181
5.9 WHAT TO PRESENT IN A PAPER?	182
6 ZERO INFLATED SPATIALLY CORRELATED COASTAL SKATE DATA	183
6.1 INTRODUCTION	183
6.2 IMPORTING THE DATA AND DATA CODING	183
6.3 DATA EXPLORATION	184
6.3.1 <i>Outliers</i>	184
6.3.2 <i>Collinearity</i>	185
6.3.3 <i>Relationships</i>	187
6.3.4 <i>Geographical position of the sites</i>	188
6.3.5 <i>Zero inflation in the species data</i>	189
6.3.6 <i>What makes this a difficult analysis?</i>	190
6.4 ZERO INFLATED GLM APPLIED TO R. AGASSIZI DATA	191
6.4.1 <i>What is the starting point?</i>	191
6.4.2 <i>Poisson GLM applied to R. agassizi data</i>	191
6.4.3 <i>NB GLM applied to R. agassizi data</i>	192
6.4.4 <i>Zero inflated Poisson GLM applied to R. agassizi data</i>	193
6.4.5 <i>Zero inflated negative binomial GLM applied to R. agassizi data</i>	196
6.4.6 <i>Model validation of the ZIP GLM applied to R. agassizi data</i>	201
6.5 ZERO INFLATED GLM APPLIED TO A. CASTELNAUI DATA	203
6.6 ADDING SPATIAL CORRELATION TO A GLM MODEL	206
6.6.1 <i>Who are the neighbours?</i>	206
6.6.2 <i>Neighbouring sites</i>	210
6.6.3 <i>The CAR model*</i>	210
6.6.4 <i>Applying CAR to simulated spatially correlated data</i>	212
6.7 ANALYSIS OF SPECIES 3: SYMPTELYGIA BONAPARTII	218
6.7.1 <i>Poisson or negative binomial distribution?</i>	218
6.7.2 <i>Adding spatial correlation to the zero inflated Poisson GLM</i>	218
6.7.3 <i>Stetting up the required matrices for car.proper</i>	219
6.7.4 <i>Preparing MCMC code for a ZIP with residual CAR correlation</i>	222
6.7.5 <i>MCMC results for ZIP with residual CAR structure</i>	225
6.8 DISCUSSION	229
6.9 WHAT TO PRESENT IN A PAPER?	230

7 ZERO INFLATED GLMS WITH SPATIAL CORRELATION– ANALYSIS OF PARROTFISH ABUNDANCE.....	231
7.1 INTRODUCTION	231
7.2 THE DATA	232
7.2.1 <i>Surveying</i>	232
7.2.2 <i>Response variable</i>	234
7.2.3 <i>Covariates</i>	234
7.3 ANALYSIS OF THE ZERO INFLATED DATA IGNORING THE CORRELATION	238
7.3.1 <i>Poisson and NB GLMs</i>	238
7.3.2 <i>ZIP and ZINB GLMs</i>	239
7.3.3 <i>Model selection for ZINB</i>	243
7.3.4 <i>Independence</i>	244
7.3.5 <i>Independence – model misspecification</i>	245
7.3.6 <i>Adding year to the ZINB?</i>	245
7.3.7 <i>Dive effect on the residuals</i>	246
7.3.8 <i>Adjusting the sample variogram for land between transects</i>	246
7.3.9 <i>Which model to choose?</i>	249
7.4 ZERO INFLATED MODELS WITH A RANDOM INTERCEPT FOR DIVE	250
7.5 ZERO INFLATED MODELS WITH SPATIAL CORRELATION	250
7.5.1 <i>Adding a residual correlation structure to the ZINB</i>	250
7.5.2 <i>ZINB with a residual CAR correlation in R</i>	251
7.5.3 <i>MCMC results</i>	253
7.6 PREDICTIONS	254
7.7 DISCUSSION.....	255
7.8 WHAT TO WRITE IN A PAPER	255
8 ANALYSIS OF ZERO INFLATED CLICK-BEETLE DATA.....	257
8.1 INTRODUCTION	257
8.2 THE SETUP OF THE EXPERIMENT	257
8.3 IMPORTING DATA AND CODING	258
8.4 DATA EXPLORATION	259
8.4.1 <i>Spatial position of the sites</i>	259
8.4.2 <i>Response and explanatory variables</i>	260
8.4.3 <i>Viewing the data as time series</i>	261
8.4.4 <i>Spatial and temporal patterns</i>	262
8.4.5 <i>Big trouble</i>	263
8.4.6 <i>Effects and interactions for the species data</i>	265
8.4.7 <i>Zero inflation</i>	267
8.4.8 <i>Direction</i>	267
8.4.9 <i>Where to go from here; zero inflated models?</i>	268
8.5. ZIP GLM.....	268
8.6 ZIP GLM WITHOUT CORRELATION FOR THE SPECIES DATA	269
8.7 RESULTS FOR THE FEMALE – MALE DATA.....	274
8.8 DISCUSSION.....	276
8.9 WHAT TO WRITE IN A PAPER?	276
9 ZERO INFLATED GAM FOR TEMPORAL CORRELATED SPERM WHALE STRANDINGS TIME SERIES	277
9.1 INTRODUCTION	277
9.2 WHAT MAKES THIS A DIFFICULT ANALYSIS?	277
9.3 IMPORTING AND DATA CODING	278
9.4 DATA EXPLORATION	278
9.5 POISSON GAM WITH A SINGLE SMOOTHER IN WINBUGS.....	280
9.5.1 <i>Fitting a Poisson GAM using gam from mgcv</i>	280
9.5.2 <i>Fitting the binomial GAM from Pierce et al. (2007)</i>	282
9.5.3 <i>Knots</i>	283
9.5.4 <i>Low rank thin plate splines</i>	284
9.5.5 <i>Mathematics for low rank thin plate splines</i>	286

9.5.6 <i>Bypassing the mathematics</i>	288
9.5.7 <i>WinBUGS code for GAM</i>	289
9.5.8 <i>Results</i>	290
9.6 POISSON GAM WITH TWO SMOOTHERS IN WINBUGS	293
9.7 ZERO INFLATED POISSON GAM IN WINBUGS	296
9.7.1 <i>Justification for zero inflated models</i>	296
9.7.2 <i>Underlying equations for the ZIP GAM</i>	297
9.7.3 <i>R code for a ZIP GAM</i>	298
9.7.4 <i>Results for the ZIP GAM</i>	299
9.7.5 <i>Model validation of the ZIP GAM</i>	301
9.8 ZERO INFLATED POISSON GAM WITH TEMPORAL CORRELATION IN WINBUGS	302
9.8.1 <i>CAR residual correlation in the ZIP GAM</i>	303
9.8.2 <i>Auto-regressive residual correlation in the ZIP GAM</i>	306
9.9 DISCUSSION	308
9.10 WHAT TO WRITE IN A PAPER?	308
REFERENCES	309
CONTRIBUTORS	XIV