Index

Page numbers followed by f indicate figure, t indicate table

A	parameterizations for one-way, 78
Abundance, 253–255	types of, 115
in binomial mixture model, 256–257,	ANOVA (one-way), 76-78
271–273, 271f	fixed-effects, Bayesian analysis using
distribution and, 260-261	WinBUGS, 120–122
naïve analysis and, 272, 273f	fixed-effects, data generation, 119-120
for species distribution, 260	fixed-effects, ML analysis using R, 120
vegetation and, 257–262	fixed-effects compared to random-effects,
AD model builder (program), 277	116–118
Adder, 219–228, 220f	parameterization of, 116
ADMB (program), 277	random-effects, Bayesian analysis using
ADMB foundation, 277	WinBUGS, 125–127
AIC. See Akaike's information criterion	random-effects, data generation,
Akaike's information criterion (AIC), 25,	122–123, 123f
124, 156, 159, 207, 233	random-effects, REML using R, 124
Algorithm	Swiss hare data, 127
computing, 18	ANOVA (two-way), 78–82
Metropolis-Hastings, 20	bias assessment, 133-134
Newton-Raphson, 9	data generation, 131-133
Alps, 220	fixed-effects, 129-139
Analysis of Covariance. See ANCOVA	interaction-effects, R analysis, 134-135
Analysis of Variance. See ANOVA	interaction-effects using WinBUGS, 137-138
ANCOVA. See also Binomial ANCOVA;	main-effects, R analysis, 134
Poisson ANCOVA	main-effects using WinBUGS, 135-137
analysis of, 82–89	parameterization, 130
ANOVA converted to, 127	predictions, 138-139, 139f
ANOVA distinguished from, 141-142	Swiss hare data, 139
data generation for, 143-144	Apparent occurrence, 240
effects parameterization and, 143	Arable, grasslands and, 101, 167-177
interaction-effects, 84, 88f	Asp viper, 142, 142f, 152, 152f
main-effects, 85-86, 87f	Assumption violations, 101
R analysis, 145	Asymptotic, 2
Swiss hare data, 150	Autocorrelation, 42, 204
WinBUGS analysis, 145-149	Axioms, of probability, 4, 16-17
ANOVA, 41, 66	_
ANCOVA converted from, 127	В
ANCOVA distinguished from, 141-142	Backwards compatibility, 32
continuous covariate, 141-142	Balanced data, 240
main-effects, 79	Bayes rule, 16–17
means parameterization for one-way, 76–77	Bayesian (approach to statistics)

Bayesian (approach to statistics) (Cont.)	in WinBUGS, 63-64
advantages of, 2–4	Binomial mixed-effects model, 229
asymptotics and, 2	data generation, 230-231
classical statistics compared to, 6, 15–19	Poisson GLMM compared to, 230
combining information, 3	random-coefficients model, 229-230,
computers aiding, 19	231–235
definition, 1–2	Binomial mixture model, 253
error propagation, 2–3	abundance, 256-257, 271-273, 271f
inference, 8–9, 16–17	assumptions, 255–256
intuitive appeal, 3–4	convergence, 265–266
literature on, 9–10	data generation, 257–262
modern algorithms, 19	naïve analysis and, 261f, 262
numerical tractability, 2	posterior predictive check, 268f
probability, interpretation in, 3-4, 15	site-occupancy model compared to,
resistance to, 4	256, 259
summary of, 53–54	Swiss hare data, 274
vague prior and, 55–56, 275	WinBUGS analysis, 262–273
Bayesian <i>p</i> -value, 104, 227	Biological distribution, 265
linear regression and, 107–109	Biological process, 241, 243–244,
Belief	255–256, 259
degree-of-, 20	Biometrics (journal), 18
prior, 17–18	Biometrika (journal), 18
Bell-shaped cloud, 260	Bird. See specific species
Bernoulli (distribution), 63–64	Bivariate Normal (distribution), 161–162
presence-absence data and, 238	Black adder, 219–228, 220f
Between-chain variance, 22	Black Forest, 220
BGR statistic	Block, experimental, 117
convergence monitoring and, 54-55	BOA, 48
Bias, 101	Boosted regression tree, 240
detection probability and, 251	Boxplot, 98f, 132f
Maximum likelihood and, 2	Brooks-Gelman-Rubin (BGR). See BGR
two-way ANOVA, assessing,	statistic
133–134	Brown hare, 168–169, 169f
un-, 2, 133	BRugs, 47
Binomial	BUGS, 8. See also WinBUGS
counts, 211	Bugs(), 31–32, 51, 95
distribution, 211–213	Burn-in, 9, 22
noise, 222, 231	nonzero, 42
regression, multiple, 228	specifying, 39
sampling variation, 233f	Butterflies, 130, 130f
t-test, 213–216	population data for, 131–133
Binomial ANCOVA, 219	r vr
data generation, 221–223	С
Pearson residual, 224	C++, 4, 277
R analysis, 223	Calcareous, 239–240
Swiss hare data, 228	Cambridge, 29
WinBUGS analysis, 224–228	Canned routine, 190, 203
Binomial distribution, 16, 58, 60	Capture-recapture, 256
inbuilt variance, 63	Catalonia, 230
picture, 64f	Categorical variables, 59, 67
sampling situation, 62	Centering, 149
uses, 168	Chain(s). See also Markov chain Monte Carlo
•	. ,

requesting, 47–48	Poisson distribution, 169, 211
variance, 22	replicate, 255, 260
Chiltern gentian, 212-216, 216f,	ZIP, 185
239–252, 239f	Courier font, 31
Chi-squared, 167, 268f	Covariate, 24
CI. See Confidence interval	design matrix and values of, 75-76
Click-point, 5	of mixed-model, 151
Closed population, 242	normalize, 154
CODA, 48	offset and, 188-189
Coherence, 4	of Poisson ANCOVA, 193
Coin-flip, 211–212	site, 252
Colonization, 242	site-occupancy model and, 241-242
Complementary log-log, 220	survey, 252, 273–274
Conditional distribution, 20	time, 239
Condor, 3	transformation, 149
Confidence interval (CI), 111–113	uniform, 231
Confound, occurrence/detection, 240,	WinBUGS and standardization of,
254, 260	147–149
Continuous	Crash, in WinBUGS, 45, 263–264
discrete compared to, 60	Creativity
index, 242	statistics and, 275
response and explanatory variable,	in WinBUGS, 30–31
73–76	Credible interval (CRI), 23
uniform distribution, 62	Bayesian CRI v. frequentist CI, 43
wetness index, 221, 222f	creating, 42
Continuous covariate, 82, 193, 219	Hypothesis testing, 24–25
ANOVA, 141–142	for linear regression, 110–111, 111f
Contrast	CRI. See Credible interval
custom, 122	Cross-classification, 81, 131
estimate, 177	Cross-leaved gentian, 212–216, 212f, 216f
Converged MCMC, 21–22, 41,	Cross-validation, 24
173–174	Curvilinear graphs, 66
Convergence	Custom
in binomial mixture model, 265–266	contrast, 122
non-, 26t, 27, 31	hypothesis test, 121
of Poisson GLMM, 208–209	tests, 146
Rhat and, 173	CV, 56
Convergence diagnostics, 148	D
Convergence monitoring, 21–23 BGR statistic and, 54–55	
•	Data sets
Copy-pasting, 32 Cordulegaster bidentata, 194f	actual, 8 assemble, 105, 123, 194–195, 229–230
Coronella austriaca, 116f	bundle, 50
Correlation, 43–44	generation of, 48–49
Counting window, 65	ideal, 8
consistency of, 188	loading, 36
Counts	simulated, 7–8
binomial, 211	Debug
land use, 170	false, 51
mite, 195	true, 52
naïve analysis, 238–239	Decision tree, 275
overdispersion in, 180	Decline

Decline (Cont.)	Dynamic, site-occupancy model, 22, 242
population in, 15, 103	
probability of, 105–106	Е
Degree-of-belief, 20	Ecology, 253
Delta method, 23	Ectoparasite, 193, 196f
Density, 39, 42, 56	Effective number of parameters (pD) , 25
of land use, 169	Effects parameterization, 72, 77
Derived quantity, 56, 95, 99, 146, 177	ANCOVA, 143
Design matrix	interaction-effects, 83, 86
covariate values, 75–76	t-test, 92–93
without intercept, 154	Equal variances, 92–97
linear predictor and, 67, 71–72, 144	Equation. See specific types
parameterizations associated with, 77	Equilibrium distribution, 21–22
R function for, 68–69	Error propagation, 216
specification of, 58–59	Bayesian approach and, 2–3
Detection	false-positive, 244
imperfect, 251-252, 254-257	Estimable. See also Maximum likelihood
occurrence confounded with, 240, 254, 260	estimate
Detection probability, 238, 240	contrast, 177
bias and, 251	fixed-effects, 118
importance of, 251	Exchangeable, 117
in site-occupancy model, 241,	Experimental block, 117
250–251, 250f	Explanatory variable, 242
Detection-nondetection data, 212, 215	combining effects of multiple, 78–82
Deterministic systems, 29, 277	continuous response and continuous,
stochastic systems compared to, 58	73–76
Deviance, 68–69	discrete, 68
Deviance information criterion (DIC), 25	Exponential family distributions, 5
Df, 94, 98, 145, 180, 182–183	Extinction, 242
DIC. See Deviance information criterion	Extra-binomial, 180
Diffuse prior, 18	Extra-Poisson, 180
Discrepancy measure, 172, 248	Eye-opener, WinBUGS as, 275
Discrete	Eye opener, Whibe do us, 270
continuous compared to, 60	F
explanatory variables, 68	Factor. See also fixed-effects; mixed-effect;
Disease, 27	two-factor ANOVA
Dispersal, 256	levels, 18
Dispersion, 101, 194, 223. See also	scale reduction, 199
overdispersion	two-level, 152
Distance sampling, 256	unrecognized, 59
Distribution, 204, 220. See also specific	Falco peregrinus, 34f
distribution types	False-positive, 244
abundance and, 260–261	Fixed-effects
binomial, 211–213	one-way ANOVA, Bayesian analysis
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	using WinBUGS, 120–122
choosing type of, 60 conditional, 20	one-way ANOVA, data generation,
equilibrium, 21–22	119–120
exponential family, 5	one-way ANOVA, ML analysis
gamma, 65 Double-indexing, 120, 198	using R, 120
Double-indexing, 120, 198 Dragonfly, 193–194, 194f	one-way ANOVA, random-effects compared to, 116–118
Dummy variable, 70, 92	two-way ANOVA, 129–139
Daning variable, 10, 12	1110 Way 11110 VA, 127-107

in WinBUGS, 166	(HPDI), 23
Flat prior, 18	obtaining, 43
Fortran, 4, 277	History button, 38-39, 42, 51
Frog, 113	Homogeneous slopes, 275
F-test, 117	Homogeneous variance, 101
,	Homoscedasticity, 97, 107
G	HPDI. See Highest-posterior density
GAM, 240	interval
	Hurdle model, 185
Gamma (distribution), 65	
Gaussian bell curve, 61	Hyperparameter, 122–123, 152, 162
Gelman-Rubin, 22	Hyperprior, 125, 164
Generalized linear mixed model (GLMM),	Hypothesis testing, 24
5, 5t. See also Binomial GLMM and	CRI for, 24–25
Poisson GLMM. See also Mixed model.	custom, 121
See also Non-standard (GLMM).	*
Generalized linear model (GLM), 5, 5t,	I
8, 24, 67. See also ANCOVA;	Identifiability, parameter, 24
Binomial ANCOVA; Poisson	assessing, 26–27
ANCOVA	definition of, 26
components, 168	simulation for, 27
recognition of, 141–142	Identity (link function), 168
unification of models under, 167-168	Ignorance, 18
General-purpose software, 1, 4, 11, 275	specifying, 3, 61
GenStat (program), 5	Imperfect detection, 251–252, 254–257
Gentiana cruciata, 212f	Implicit assumption, 170, 205, 220
Gentianella germanica, 239–252, 239f	Impute (data), 45
Gibbs sampling, 9, 100	Inbuilt variance (in Poisson and Binomial
basis of, 20	distributions), 63, 65
starting, 40–41	Poisson ANCOVA and, 194
GLM. See Generalized linear model	
	Indicator variable, 71, 143
Glm(), 6, 66–67, 174, 180	Inference. See also Scope (of inference)
Glmer(), 6, 235	Bayesian, 8–9, 16–17
GLMM. See Generalized linear mixed	summarizing, 39
model	Informative prior, 19, 277
Goodness-of-fit	posterior distribution and, 56
code assessing, 265	Initial value, 22
linear regression and, 106–109	defining, 51
measuring, 24	loading, 37
Graphical check, 107, 267	for MCMC, 35
Grassland, 242	Intensity (Poisson), 169, 180
arable sites and, 101, 167–177	Interaction-effects
Greenfinch, 64	ANCOVA, 84, 88f
	effects parameterization, 83, 86
Н	main-effects compared to, 129-130
Habitat suitability, 68, 127	means parameterization, 81, 83, 86
Hare. See Swiss hare data	specifying, 82–83
Heterogeneous variance, 97, 98f	two-way ANOVA, R analysis, 134-135
Hierarchical model, 241, 276–277	two-way ANOVA, WinBUGS, 137-138
non-, 25	Intercept, 72, 75, 84
High-dimensional integrals, 19	design matrix without, 154
Higher-order interactions, 142	random-coefficients mixed-model
Highest-posterior density interval	ANCOVA, with correlation of
inglest posterior delisity interval	Anveova, with correlation of

slope and, 161–165	R analysis, 105
random-coefficients mixed-model	residual plot, 107, 107f
ANCOVA, without correlation of	simple, 73–76
slope and, 158–161	Swiss hare data, 113
Inventory, plant, 212, 239–240, 242	WinBUGS analysis, 105-113
Iteratively reweighted least squares, 9	Link function, 204, 213, 220
	identity, 168
J	LM. See Linear model
JAGS (program), 277	Lm(), 6, 66–67
Jura, 193–194, 212, 221, 240, 242	Lme4, 31
	Lmer(), 165, 235
K	LMM. See Linear mixed model
Kruskal-Wallis test, 275	Log (link function), 168
	Logistic regression, 104, 167, 251
L	Logit (link function), 168, 220
Lacerta agilis, 254f	Logit-linear regression, 242-243
Land use, 139, 180-181, 209, 228	Log-linear model, 167, 197–199
counts and, 170	Log-normal, 61, 95, 183, 225
density of, 169	Log-transformation, 169
Lanius collurio, 204f	Low-information prior, 18
Lanius senator, 230f	LRT. See likelihood ratio test
Latent effect, 184	
Latent state, 187–188, 251	M
Lattice, 31, 205, 206f	Main-effects
Least-squares	ANCOVA, 85–86, 87f
in classical analysis, 138	ANOVA, 79
iteratively reweighted, 9	interaction-effects compared to, 129-130
method of, 71	means parameterization, 80, 84–85
Lepus europaeus, 169f	two-way ANOVA, R analysis, 134
Likelihood, 16, 95, 99	two-way ANOVA, WinBUGS, 135-137
Likelihood ratio test (LRT), 171	MARK (program), 67, 246, 262
Linear mixed model (LMM). See Mixed	Markov chain Monte Carlo (MCMC), 9, 18
model	compiling, 36–37
Linear model (LM), 5, 5t, 24	converged, 21–22, 41, 173–174
explanatory variable specified, 66, 75	definition of, 19–20
normal distribution, 70	history, 20
of t-test compared to linear regression, 103	initial values, 35
usefulness of, 58–59	posterior distribution, 20
in WinBUGS, 66–67	reversible-jump, 25
Linear predictor, 168, 204, 213, 220	sampling error, 250
design matrix and, 67, 71–72, 144	time-series plot, 22f
residuals and, 70	MASS, 31, 162
Linear regression	Massif Central, 193–194
Bayesian <i>p</i> -value, 107–109	Matlab (program), 10
CI v. CRI, 111–113	Matrix, 53, 71, 74
data generation, 104–105	multiplication, 123, 132, 144
goodness of fit, 106–109	variance-covariance, 162
LM of t-test compared to, 103	X, 71
model adequacy, 105–106	Maximum likelihood (ML). See also
posterior predictive distributions PPD,	Restricted maximum likelihood
107–109	bias and, 2
predictions, 109–111, 110–111f	Maximum likelihood estimate (MLE), 16

MC error, 43 MCMC. See Markov chain Monte Carlo Means parameterization, 73 ANOVA, one-way, 76–77 of interaction-effects, 81, 83, 86 of main-effects, 80, 84–85 t-test, 92 Metapopulation, 240, 253, 257 Metropolis-Hastings algorithm, 20 Minimally informative prior, 18 Missing data, 113 Missing value, 257 Mite, 193–194 counts, 195 load, 199–201	"Model of the mean," 33–34, 68–69 result summary, 41–44 setting up, 34–40 Model selection, 24 challenge, 26 DIC, 25 Monitoring, convergence, 21–23 Morph, zigzag, 219–220 Motorbike, 8 Motorcycle, 48 Mourning cloak, 130, 130f Multiple binomial regression, 228 Multi-way ANOVA, 115. See also ANOVA (two-way) MVN, 161
Mixed-effect. See mixed model; Binomial	
mixed-effects model; See Poisson	N
mixed-effects model	Naïve analysis
Mixed-model. See also Binomial mixed-	abundance and, 272, 273f
effects model; Generalized linear	binomial mixture model, 261f, 262
mixed model	counts, 238–239
benefits, 152	for site-occupancy model, 246, 246f
covariates, 151	Negative-binomial (distribution), 65
data generation for, 154–156 linear, 5, 5t, 151–166	Neighboring model, 270
non-linear, 277	Netherlands, The, 254–274
random-coefficients model, with slope/	Newton-Raphson algorithm, 9
intercept correlation, 161–165	N-mixture model. See Binomial mixture
random-coefficients model, without	model
slope/intercept correlation,	Node, 38, 42
158–161	Non-Bayesian, 6, 19
random-coefficients model, 153	Nonconvergence, 26t, 27, 31 Nondetection. See detection-nondetection
random-intercepts model, Bayesian	data
analysis with WinBUGS, 156-158	Nonhierarchical, 25
random-intercepts model, REML analysis	Nonidentifiable parameter, 139
with R, 156	Non-linear mixed models, 277
random-intercepts model, 153, 156–158	Non-normal, 229
REML, 154	Non-standard (GLMM). See Binomial
REML analysis using R, 156	mixture model; Site-occupancy model
Mixture model. See Binomial mixture model	Normal distribution, 34, 58
ML. See Maximum likelihood MLE. See Maximum likelihood estimate	mathematical description, 61
	picture, 61f
Model adequacy	uses, 168
checking, 24 for linear regression, 105–106	in WinBUGS, 61–62
posterior predictive check, 108–109,	Normalize covariate, 154
109f, 248	Nymphalis antiopa, 130f
posterior predictive distributions, 108	
for t-test, 96	Ο
Model averaging, 25	Observation process, 265
Model criticism, 24	modeling, 244
Model matrix, 69–70, 143	Occupancy, 215-216, 216f

Occurrence	wingspan, 92
apparent, 240	Poisson ANCOVA
detection confounded with, 240,	covariates, 193
254, 260	data generation, 194-196
probability of, 238, 240, 242, 243f	inbuilt variance, 194
OD. See overdispersion	predictions, 199-201
ODC format, 34	R analysis, 196–197
Offset, 179	Swiss hare data, 202
analysis methods for, 189-190	WinBUGS analysis, 197-201
covariates and, 188-189	Poisson distribution, 60
OpenBUGS (program), 47, 277	for counts, 169, 211
Optimization, 30	data generation, 170
Outlier, 108	inbuilt variance, 65
Overdispersion (OD)	posterior distribution, 175
correcting, 180	predictions, 175
data generation, 180–181	R analysis, 171
in counts, 180	R code, 65, 66f
R analysis, 181–183	Swiss hare data, 177
Swiss hare data, 191	t-test, 168–169
WinBUGS analysis, 183–184	in WinBUGS, 65
zero-inflation as, 179	WinBUGS analysis, 171–177
Overparameterization, 79	zero-truncated, 185
o verparameterization, , ,	Poisson GLMM, 203
P	binomial mixed-effects model
Pachyderm, 17	compared to, 230
Parameter estimability, 7, 21, 27	convergence, 208–209
Parameter identifiability, 24	data generation, 205
assessing, 26–27	R analysis, 207
definition of, 26	random-coefficients model, 206–209
simulation for, 27	Swiss hare data, 209
Parameter vector, 71, 144,	WinBUGS analysis, 207–209
	· · · · · · · · · · · · · · · · · · ·
195, 222 Parameterization 7, 67, 72, See also	Poisson regression, 202
Parameterization, 7, 67, 72. See also	Poisson-gamma (mixture), 65
effects parameterization;	Poisson-log-normal (distribution), 183
means parameterization	Polynomial, 24, 109, 242
ANOVA, one-way, and, 78	Poisson regression, 202
design matrices, 77	Population, 10
of one-way ANOVA, 116	closed, 242
over-, 79	covariate, 257
re-, 72	in decline, 15, 103
for two-way ANOVA, 130	density, 10
Parametric statistical modeling, 59	trends, 109, 112–113, 119, 203
Parasite data sets, 195, 196f	Postcondition violated, 251
Parsimony, 18, 145, 196, 223	Posterior distribution, 16–17, 19
PD, 25	graphical summaries for, 55
Pearson residual, 171, 173, 174f	informative prior and, 56
for Binomial ANCOVA, 224	numerical summaries, 55
posterior predictive check and, 175f,	samples from, 19
225, 226f	summarizing, 23
Peregrine falcon, 34f, 48	Posterior draws, 51
body mass, 33	Posterior predictive check (PPC),
summary of results, 41-44	104–105, 171

for binomial mixture model, 268f for model adequacy, 108–109, 109f,	Pyrenees, 142–145, 193, 195–196
225, 226f, 248	Q
Pearson residuals and, 175f, 225,	Quadratic effect, 257
226f	Quasibinomial, 180
for residuals, 173-174	Quasi-likelihood, 180
for site-occupancy model, 246	Quasipoisson, 182
Posterior predictive distributions (PPD), 106	R
linear regression and, 107-109	R (program), 5–6, 8
model adequacy and, 108	basic knowledge of, 10
PPC. See Posterior predictive check	Poisson distribution code in, 65, 66f
PPD. See Posterior predictive distributions	in R2WinBUGS used with WinBUGS,
Predation, size-dependent, 131	49–55
Prediction(s), 236	WinBUGS integrated with, 6
forming, 24	WinBUGS run from, 30
for linear regression, 109–111,	working directory set for, 49-51
110–111f	workspace, 51–52, 55
for Poisson ANCOVA, 199–201	R function. See also specific types
for Poisson distribution, 175	common, 6
for two-way ANOVA, 138-139, 139f	defining types of, 51, 53
Prediction interval, 110	for design matrix, 68–69
PRESENCE (program), 246, 262	R2WinBUGS, 22, 30, 47
Presence-absence data, 212, 244	WinBUGS with R program used
Bernoulli distribution and, 238	through, 49–55
Prevalence, 27	Random variables
Prior(s), 135. See also specific types	Poisson, 211
belief, 17–18	probability distributions and, 59
inference affected by change in, 270	Random-coefficients model
uniform, 267	for binomial mixed-effects model,
Prior distribution, 16–17	229–230, 231–235
problems with, 17–18	for mixed-model ANCOVA, 153
Prior sensitivity, 251, 274	for mixed-model ANCOVA with slope/
analysis for, 252	intercept correlation, 161–165
Probability	for mixed-model ANCOVA without
axioms of, 4, 16–17	slope/intercept correlation,
Bayesian approach and interpretation of,	158–161
3–4, 15	for Poisson GLMM, 206-209
classical interpretation of, 15	for Poisson mixed-effects model,
of decline, 105–106	See for Poisson GLMM
degree-of-belief, 20	Swiss hare data, 166
detection, 238, 240-241	Random-effects
of occurrence, 238, 240, 242, 243f	in Bayesian analysis, 235
theory, 14	definition of, 115
Probability distributions, 20	ZIP, 185
parameters of, 59–60	Random-intercepts model
random variables and, 59	for mixed-model ANCOVA,
Prussian soldiers, 65	Bayesian analysis with
Pscl, 186	WinBUGS, 156-158
Pseudo-code, 31	for mixed-model ANCOVA,
P-value. See Bayesian p-value	REML analysis with R, 156
PyMC (program), 277	Raptor, 177

Red-backed shrike, 203–204, 204f,	Simulation, 27. See also specific simulations
229–236, 230f Refresh setting, 40	Site-covariate, 252 Site-occupancy model, 104, 237, 239
Regression. See also Linear regression	binomial mixture model compared to,
linear, 73–76	256, 259
logistic, 104, 167, 251	confusions with, 238–239
logit-linear, 242–243	covariates, 241–242
multinomial, 167	data generation, 242–246
multiple binomial, 228	detection probability, 241, 250–251, 250f
Poisson, 202	dynamic, 22, 242
ZIP, 184	naïve analysis, 246, 246f
REML. See restricted maximum likelihood	posterior predictive check, 246
Reparameterization, 72	probability of occurrence, 240
Repeated measurement, 240, 257	starting values, 263
Replicate counts, 255, 260	Swiss hare data, 252
Reptiles, 254	truth, 251–252
Residual(s), 24. See also Pearson residual	WinBUGS analysis, 246–251
assumptions, 69–70	Slope
linear predictor and, 70	random-coefficients mixed-model
PPC for, 173–174	ANCOVA, with correlation of
raw, 224	intercept and, 161–165
t-test, checking, 97	random-coefficients mixed-model
Residual plot, of linear regression, 107, 107f	ANCOVA, without correlation of
Residual standard error, 49	intercept and, 158–161
Restricted maximum likelihood (REML), 5	Slovenia, 239
mixed model, 154	Smooth snake, 116, 116f
mixed model ANCOVA analysis using R and, 156	Snake, 142, 142f, 219–228, 220f data set for, 67–68, 68t
random-effects one-way ANOVA	smooth, 116, 116f
using R and, 124	Snout-vent length (SVL), 115–116
Reversible-jump (MCMC), 25	Software. See specific software
Rhat, 22, 54, 148	Sombre goldenring, 193–194, 194f
convergence and, 173	Splines, 242
R-squared, 94, 145	Standard deviation (SD), 7, 42, 49
•	for Bernoulli distribution, 64
S	residual, 123
Sample Monitor Tool, 37, 41	Standard error, 7
Sampling error	Standardization, covariate, 147–149
exercise, 93	Starting value
MCMC, 250	random, 51
statistics and understanding, 48–49	for site-occupancy model, 263
understanding, 7	State-space (model), 241
Sampling variance. See Sampling error	Statistical analysis, 5, 5t
Sand lizard, 254–274, 254f	Statisticians, 275–276
SAS (program), 5, 10 Scale reduction factor, 199	Statistics. See also Bayesian (approach to
Scope (of inference), 152	statistics) Bayesian v. classical, 6, 15–19
SD. See Standard deviation	creativity and, 275
Sex, 59, 92	definition/use of, 14
Shrinkage estimators, 118	sampling error and, 48–49
fixed/random, 236	Stochastic systems, 7
Simulated data sets, 7–8	binomial mixture model and, 255

1-111	II-1: 1 2 122
deterministic systems compared to, 58	Unbiased, 2, 133
in life, 14	Uncertainty interval, 110
Straight-line relationships, 66, 156	Unequal variances, 97–100
Structural	Uniform distribution, 58
model parameters, 152, 266	continuous, 62
model parts, 25	picture, 63f
model problems, 43	Uninformative prior, 18
Survey-covariate, 252, 273–274	
Survival, 10, 59, 211–212	V
SVL. See Snout-vent length	Vague prior, 18–19, 158, 277
Swiss hare data, 56	Bayesian approach with,
ANCOVA, 150	55–56, 275
Binomial ANCOVA, 228	Variance(s). See also specific variances
binomial mixture model, 274	Bayesian compared to
linear regression, 113	frequentist, 96
one-way ANOVA, 127	chain, 22
overdispersion, 191	comparing, 101
Poisson ANCOVA, 202	modeling, 100–101
Poisson distribution, 177	t-test and equal, 92–97
Poisson GLMM, 209	t-test and unequal, 97–100
random-coefficients model, 166	Variance component, 51
	Variance-components model, 152
site-occupancy model, 252	
t-test, 101	Variance-covariance matrix, 162
two-way ANOVA, 139	Vegetation, 257–262
Т	covariable, 261
_	Vipera aspis, 142f, 152f
Tichodroma muraria, 104f	Vipera berus, 220f
Transect, 254	W/
Transformation, covariate, 149	W
Treatment contrasts, 71	Wallcreeper, 103–104, 104f
Trellis plot, 206f, 232–233f	Website
constructing, 155, 155f	for book, 31–32, 34, 49, 250
Trends, population, 109, 112–113, 119, 203	for WinBUGS, 10
True state, 242–244, 253	Welch test, 98
partially observed, 247	WinBUGS
T-test, 69–73	advantages, 4–5
binomial, 213–216	ANCOVA, 145–149
data generation, 92-93, 97-98	Binomial ANCOVA, 224-228
effects parameterization, 92-93	binomial distribution, 63-64
with equal variances, 92-97	binomial mixture model, 262-273
as LM, 91	1 1: .: 147 140
LM of linear regression compared to, 103	covariate standardization, 147–149
	crash, 45, 263–264
means parameterization, 92	crash, 45, 263–264
means parameterization, 92 model adequacy, 96	crash, 45, 263–264 creativity, 30–31
model adequacy, 96	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275
model adequacy, 96 Poisson distribution, 168–169	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166
model adequacy, 96 Poisson distribution, 168–169 residuals, 97	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA,
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101 with unequal variances, 97–100	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122 freedom of, 30–31
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122 freedom of, 30–31 Gibbs sampling, 21
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101 with unequal variances, 97–100	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122 freedom of, 30–31 Gibbs sampling, 21 interaction-effects two-way ANOVA,
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101 with unequal variances, 97–100 Tutorial, WinBUGS, 11 U	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122 freedom of, 30–31 Gibbs sampling, 21 interaction-effects two-way ANOVA, 137–138
model adequacy, 96 Poisson distribution, 168–169 residuals, 97 Swiss hare data, 101 with unequal variances, 97–100 Tutorial, WinBUGS, 11	crash, 45, 263–264 creativity, 30–31 as eye-opener, 275 fixed-effects, 166 fixed-effects one-way ANOVA, 120–122 freedom of, 30–31 Gibbs sampling, 21 interaction-effects two-way ANOVA,

WinBUGS (Cont.)	tutorial, 11
literature on, 9–10	website for, 10
main-effects two-way ANOVA,	ZIP model, 187–188
135–137	Within-chain variance, 22
mixed-model ANCOVA, 156-158	Woodchat shrike, 229-236, 230f
normal distribution, 61-62	Working directory, 31–32
overdispersion, 183-184	setting R, 49–51
Poisson ANCOVA, 197–201	Workspace, R, 51–52, 55
Poisson distribution, 171-177	1
Poisson distribution, 65	X
Poisson GLMM, 207-209	X matrix, 71
power of, 29	,
practical implementation of complex	Z
models in, 263-264, 270-271	Zeroes, 177
R integrated with, 6	avoiding, 263
R2WinBUGS, 49–55	Zeroinfl(), 186
random-effects in, 166	Zero-inflated binomial (ZIB), 184
random-effects one-way ANOVA,	Zero-inflated Poisson (ZIP)
125–127	counts, 185
site-occupancy model, 246-251	data generation, 185-186
technicalities, 31–32	hurdle model compared to, 185
t-test analysis, 94–97	R analysis, 186–187