Index

A	В
Abundance, estimation, 17	Basic capture-recapture method, 530
Abundance model	Bayesian analyses, 33, 50, 434, 509, 532
multinomial, 367	Bayes' rule, 50–51, 434
Poisson, 367	BUGS language for, 60–61
Acoustic sampling, 7, 270, 288	confidence intervals, 54, 68
BUGS implementation, 273	inference principles, 51
secr implementation, 273	in JAGS , 200
signal strength model, 272	MCMC methods, 63
Activity center, 129	model checking in, 80
binomial point process model, 129	model selection in, 80, 83-84
in BUGS, 145	posterior inference, 54
concept, 16	prior distributions, 53
conditional intensity and, 135	random variables in, 50
direct linkage to density, 17	selection, 80
in distance sampling, 133	small sample inference, 55
initial values of, 142	Bayesian inference, 434
in MCMC, 162	sampling variance, 148
in state space, 131, 139, 158	Bayesian p-value, 82–83
posterior prediction of, 166	Behavioral response, 101
non-uniformity of, 158	in animal studies, 101
two-dimensional spatial coordinate, 127	BUGS code for, 208
uniform distribution, 163	covariate effect, 203
unobserved random variable, 128-129	encounter probability, 205
in WinBUGS, 157, 159	local or global, 207, 215
Acoustic sampling, 7, 270–273	to trapping, 101, 207
in <i>secr</i> , 273	Bernoulli distributions, 29, 450
in BUGS , 273-274	encounter probability, 245
Adaptive rejection sampling, 448	M_0 model, 104
AIC, 181, 195, 210	observation model, 250
ArcGIS, 463	prior distribution, 83
Akaike Information Criterion (AIC), 55, 181	probability distributions, 29
likelihood methods, 219	Probability mass function (PMF), 29
model selection in, 198, 213, 220	SCR0, 167
secr package, 202, 216, 222	Binomial distributions, 450
Alternative movement model, 394	definition of
American shad	M_0 model, 102
Cormack-Jolly-Seber (CJS) models,	notation, 27
416, 420	probability mass function (PMF), 23, 28-29, 37
SCR issues, 424	Binomial GLMs, 49, 77-79
stream flow, 427	in WinBUGS , 80
Animal movement, 283	parameter estimation, 77
see also Trap spacing, Movement models	Binomial integrated likelihood, 193
Area search, 383, 389–390	Binomial observation model, 126
Availability	Binomial point process model, 129-130
Avian mist-netting example, 260	Binomial probability mass function, 23

Binomial regression	Cormack-Jolly-Seber (CJS) models, 415
waterfowl banding data, 79	Cost-weighted distance, 331
Bivariate normal distribution, 33, 136	Cost-weighted paths
Bivariate normal model of space usage, 517–518	calculation, 334
Black bears	computation, 333-334
SCR + RSF model, study on, 355	defined, 331, 336
space usage, 358	R code, 334
convex hell, 9	in SCR model, 332
standard approach, 12	Count data
BUGS implementation	Count detector model (in secr), 253
Stratified populations, 368	see Poisson observation model
Buffering, 9, 12	Counter detector, in secr package, 253
Burn-in, 65, 75, 439, 444, 457, 460	Covariate effects
BUGS language, 434	in density, 307
	in encounter probability models, 203, 246
	landscape structure, 349
C	in standard GLM or GLMM, 203
	see also Individual covariate model
Camera trapping, 5	
historical overview, 5	
encounter probability, 8	D
for sampling methods, 13	_
Capture-recapture methods, 527	Data augmentation, (DA), 92
Categorical distributions, 30	in closed population models, 92–93
Closed population models, 14	heuristic motivation, 94
assumptions, 90	joint likelihood using, 109
binomial observation model, 88	model-based analysis, 109
data augmentation (DA), 92–93	M_h model, 104
$model M_h, 102$	in M_0 model, 95
$\operatorname{model} M_0, 95$	occupancy parameter, 94
Closed capture-recapture model M_h , 449	in WinBugs , 145
Clustered detectors, 287-288	zero-inflated model, 95, 109
Optimal design, 298-299	Data format
Collared individuals, 519	three-dimensional, 153
C++, 468–470	two-dimensional, 140
coda, 457	Data structure
Computational speed, 465, 468, 470	formatting, 140
Conditional distribution, 37, 50–51, 57–59,	manipulating, 140
437, 445, 450, 453, 455	sampling design and, 126
constructing rules, 59	Density estimation, 8-13, 17, 149, 162, 195
M_0 model, 91	covariate, using, 299, 307
Markov chain Monte Carlo (MCMC), 59	data simulation, 314
Metropolis-Hastings algorithm, 59	intensity parameter, 323
Conditional likelihood, 91, 180	in M ₀ model, 100
in closed population model, 91	parameter estimation, 317
full likelihood, 180	SCR definition of, 308
SCR model, 296	Density maps, 162, 196
Convergence, 65-66, 439, 457	effective sample area, 178
Conjugacy, 435, 446, 453	individual prediction, 166
Convex hull	Wolverine analysis, 164
buffering, 9	DENSITY, 171, 186
density estimation, 9	DENSITY (software), 186
trapping array, 13	Derived parameters, 68
11 0	1 / ***

Design criterion, 290, 294, 296, 298 Optimal, 293, 296, 298 For SCR, 293–294, 296 Variance-based, 293 Density covariate models, 299 Detection function behavioral response, 250 conditional probability, 247 in covariate influence, 108 in distance sampling, 116 models, 188 signal strength, 272	trapping interval, 267 trap-specific covariate, 206 Euclidean distance in activity centers, 329 cost-weight distance, 334 encounter probability and, 330 least-cost path model, 332, 338 mis-specified model, 339, 341, 344 in SCR model, 336 shortcomings, 330 Exchange algorithm, 292, 298 Expected population size, 148
Detection probability models, 128	Explicit movement models, 534
Detector dogs, 398 DIC model selection, 225	
Discrete habitat mask, 158	F
coarseness, evaluation, 159	
Discrete state-space, see habitat mask	Fitness model
Dispersal, 397	components, 233
Dispersal dynamics, see Movement models	in encounter probability, 214
Distance function, <i>see</i> detection probability models	individual trap frequencies, 237 occupancy dynamics, 241
Distance sampling, 30, 41, 44, 116, 381, 384, 390	Fixed search path
desert tortoise example, 118	alternative movement models, 394
in hierarchical model, 118, 120	encounter probability, 383
in SCR model, 116, 118, 121	intensity model, 393
DNA sampling, 6	Focal population, 280
Distribution of individuals, 529	Fort Drum black bear study, 8, 98, 106, 110
Dummy variables, 79	, , , , , , , , , , , , , , , , , , ,
Dummy variables, 79	•
·	G
Dummy variables, 79	G
·	•
E	G Gaussian distribution (<i>see</i> Normal Distribution)
E Ecological distance	G Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338	Gaussian distribution (see Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178	Gaussian distribution (see Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458	Gaussian distribution (see Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15	Gaussian distribution (see Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188	Gaussian distribution (see Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57
Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248 covariate model, 203, 246	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445 Normal regression model, 57–58
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248 covariate model, 203, 246 Gaussian model, 198, 249, 255	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445 Normal regression model, 57–58 Gompertz hazard, 385
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248 covariate model, 203, 246 Gaussian model, 198, 249, 255 individual covariate, 208	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445 Normal regression model, 57–58 Gompertz hazard, 385 Goodness-of fit, 55, 80–82, 232–241
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248 covariate model, 203, 246 Gaussian model, 198, 249, 255 individual covariate, 208 multinomial model, 267	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445 Normal regression model, 57–58 Gompertz hazard, 385 Goodness-of fit, 55, 80–82, 232–241 evaluation, 232
E Ecological distance Bayesian analysis, 339 density covariate, 345 likelihood analysis, 338 SCR simulation, 335 Effective sample area, 167, 195 density mapping, 178 Effective sample size, 67, 458 Efford, M.G., 15 Encounter data file, 151 Encounter device types, 188 Encounter probability Bayesian analysis, 200 Bernoulli process, 245 binary observation, 248 covariate model, 203, 246 Gaussian model, 198, 249, 255 individual covariate, 208	Gaussian distribution (<i>see</i> Normal Distribution) Gaussian kernel, 517 Gelman-Rubin stastistic, 65–66, 461, 467 Generalized linear (mixed) models (GL(M)Ms), 48 binomial, 84 in Bayesian framework, 63 Generalized linear models (GLMs) binomial, 49, 77, 79 components, 48 in exponential family, 48 in SCR, 48 Poisson, 69, 71, 75 random effects, 49 Gibbs sampling, 57, 59, 436–439 in MCMC methods, 57 MH sampling <i>vs.</i> , 441, 445 Normal regression model, 57–58 Gompertz hazard, 385 Goodness-of fit, 55, 80–82, 232–241

Gregarious species, 533	see also M_h model
Group structure, see also Multi-session model	Inhomogeneous point-process, 521, 523
in data augmentation, 372	density model, 322
multi-catch model, 365	discrete space, 320
single parameter, 370	in SCR model, 310
single parameter, 370	in spatial mark-resight, 503, 520
	intensity parameters, 311
Н	Poisson model, 308
	spatial variation, 307, 315
Habitat mask, 158, 184, 186–187, 196	Integrated likelihood, 172
Habitat selection	construction, 175
space usage, 350	data augmentation for, 180
landscape simulation, 359, 363	marginal distribution, 172
non-uniform distribution, 307	MLE estimators, 171–172
spatial variation, 312	numerical calculations of, 179
Hard plot boundaries, 389	Poisson integrated likelihood, 192
Heterogeneity	in SCR models, 176, 178
in detection probability, 281–282	under data augmentation, 180
model, 103, 106	Invariance of density to state-space, 115, 132,
Hierarchical modeling	183, 194
defined, 40	Irregular patches, 341
examples of, 41	
random variables, 21	
statistical analysis, 37	J
statistical inference and, 40	
Home range area, 137, 147, 157	JAGS, 60, 433, 465, 506
Home range center, 129	Bayesian analysis in, 60
definition, 129	ecological introduction to, 60
implied model, 147	summary command for, 68
space usage model, 134	Joint distribution, 37
see also Activity center	Joint likelihood, 91 Jolly-Seber model, 404, 411
Homogeneous point process, 521	•
in a subset of the state-space, 521	data augmentation, 407
spatial randomness, 308	spatial, 411
Huggins-Alho model, 108	
	L
1	Lack-of-fit, 241
Imperfect identification, 532	Landscape connectivity
Index of dispersion, 234	geographical analysis, 341
Indicator variable	in SCR models, 329–330, 335
detection function, 231	Landscape structure
wolverine data, 229	covariate model, 349
Individual covariate mode, 108	resource selection, 359
capture location, 109	simulated example, 352, 359
data augmentation, 92	space configuration, 350, 363
distance sampling, 87	Langevin algorithm, 442
in SCR, 108, 115	Latent encounter histories, 506
Individual heterogeneity	Least-cost distance, 331–332
defined, 197	Least-cost distance, 331–332 Least-cost distance, likelihood analysis
detection probability, 211	of, 338–339
for home range size, 198	Least cost distance, Bayesian analysis
incorporation methods, 216	of, 339
mesiporation methods, 210	01, 00)

Least cost distance, habitat corridor, 341	M_b model
Least-cost path, see least-cost distance	global trap response, 215
in BUGS , 339	in non-spatial capture-recapture, 197
computation, 343	MCMC Diagnostics
covariate matrix, 336	Mean maximum distance moved (MMDM),
encounter probability, 330	282, 287
SCR example, 338	home range radius, 100
Lincoln-Petersen estimator, 500	Metropolis-Hastings algorithm
of abundance, 532	Acceptance rate, 443–444, 447, 461
Link function, 49	Acceptance ratio, 60, 73, 441–442
Cloglog, 78	Adaptive phase, 444
Log, 49	Candidate distribution, 59, 441, 443
Logit, 49, 77–78	Independent, 442
Logistic regression, 49, 77	Langevin, 442
Live-trapping study, 498	Parameters with bounded support, 441
Logit-normal model, 442–443	Proposal distribution, <i>see</i> candidate
	distribution
	Random walk, 73, 441–442
M	Tuning, 442–444, 457, 461
	Metropolis-Hastings (MH) sampling,
Marginal distribution, 37, 52, 60, 434	58–60, 441
Marginal likelihood, 172	vs. Gibbs sampling, 443
binomial form, 192	Metropolis-within-Gibbs, 444–445, 449
calculation, 184	M_h model,
point process density, 192	m_h model analysis, 104
Marginal probability of encounter, 293, 295	MCMC for, 449
MARK, 501	
Markov chain Monte Carlo (MCMC), 56, 65,	random effect, 212
433, 435	SCR, relevance to, 211
algorithm, 59, 72, 82, 506	Misidentification, 532
in Bayesian analysis, 60, 63	in capture-recapture, 500
building own algorithm, 433	in mark-resight, 500
closed capture-recapture model M_h , 449	Mist-netting, 260
convergence analysis, 65	MLE with known N, 171
manipulating state-space, 462	MLE with unknown N, 177
posterior distributions, 56, 434	MMDM, 13
in SCR models, 57, 452	$M_h $ model, 102
in WinBUGS , 64, 67	relevance to SCR, 133
Marked individuals	M_0 model, 95
homogeneous point process, 521	binomial observation, 102
imperfect identification of, 512	N-mixture model
inhomogeneous point processes, 523	in black bear study, 98
known number of, 499	in Bernoulli, 104
unknown number of, 500	in BUGS , 95
Markov random fields, 531	capture-recapture assumptions, 90
Mark-resight models, 497	closed population model, 88
data types, 499–500	conditional distribution, 91
Known number of marks, 500	occupancy type, 97
techniques, 499	Modeling territoriality, 531
Unknown marked status, 500	Model selection
Unknown number of marks, 500	using AIC, 213, 216
Maximum likelihood, 35	Bayesian, 83
in R , 36	issues, 80

in SCR model, 84	relationship to Poisson model, 263
indicator variables, 65	Multinomial model
Model output	density estimators, 267
commands, 461	encounter devices, 254
posterior density plots, 457	in Gaussian methods, 255
rejection and slice sampling, 448	in single-catch trap, 267
serial autocorrelation and effective	resource selection, 256
sample size, 458	in WinBugs, 256
summary results, 460	Multivariate normal distribution
time series plots, 457	M_{χ} model
Model SCR0	density invariance, 115
data structure, 126, 141, 151	y
binomial observation model, 126	
assumptions, 150	N
Model selection	
classical, see AIC	N-mixture model, 78
Bayesian, 224-232	Non-spatial capture-recapture, 87, 532
indicator variables, 227	Non-spatial mark-resight models, 501, 505, 512
Kuo and Mallick, 231	NOREMARK, 501
Monte Carlo error, 67–68, 460	Normal distribution, 434
Mountain lions, 391	Numerical integration
Movement model, 17–18, 386–387, 394–395	integration grid spacing, 183
alternatives, 394	R code, 179
auto-regression, 395	
data simulation, 394	
dispersal, 404, 426–429	0
encounter frequency, 381	Objective function, 290
open population, 397	Observation model
outcomes, 386	alternative methods, 245
transients, 403–404, 429	in Bernoulli, 250
transition matrix, 419–420	in Poisson, 245
	JAGS, using, 245
Moving activity centers, 524	multinomial distribution, 245, 267
Multi-catch traps, 254,	single catch trap, 266
see multinomial observation model	Observed point processes, 314
Multi-catch device, 245–254, 275	OpenBUGS, 433
Multi-catch independent multinomial	Open populations
model, 534	apparent survival, 403
Multi-session models, 193, 261, 372–373	Cormack Jolly Seber models, 415–426
BUGS language, 378	Jolly Seber models, 404–415
data augmentation, 365	movements, see Movement models
landscape variation, 379	recruitment, 406
multi-catch observation, 373	Optimal design, 289–290
other approaches, 372	detector configuration, 289
secr analysis, 373	in SCR model, 283, 293
sex effects in, 215, 365	swapping algorithm, 297
Multi-state model	trap spacing, 285, 299, 303
spatial states, 401, 422	Ordinary capture-recapture models
transition matrix, 419–420	N estimation, 18
Multinomial abundance models	non-spatial aspect, 11–12
stratified populations, 367	technical problems, 17
Multinomial distributions, 30	Ovenbird data, 260–266, 374–376
Multinomial observation model, 254–259,	Ovenbird mist-netting study, 408, 412
373–374	Oventing mist-netting study, 400, 412

P	mass of, 75
	MCMC simulation, 56, 65, 68, 434
Parallel computing, 465–467	parameter estimation, 54, 83
Parallel processing	Posterior inference, 54
Parameter estimation	Prior distribution, 52–53
in maximum likelihood estimates (MLEs), 36	choices, 63-64
statistical inference, 34	conjugate, 58
Partial information designs, 398	diffuse, 53, 61, 63
Point process aggregation, 15	flat, 53
Point process model, 15	improper, 53, 63, 453
binomial, 129	Lack of invariance to transformation, 54, 64
in spatial mark-resight, 521, 524	non-informative, 53, 63-64, 453
state-space, 131	Prior information, 53-54
for homogeneous point process, 521	Prior sensitivity
for inhomogeneous point processes, 523	Probability density function, 22
Poisson cluster process, 16	resource selection, 25
Poisson distribution, 31, 69	see also Probability mass function (PMF)
Poisson GLMs, 69	Probability distributions
in WinBugs , 71, 76	common distributions, 27–34
MCMC algorithm for, 73–74, 447	conditional,
Log-Normal mixture, 75–76	definition, 22
random effects, 75–76	ioint,
Poisson integrated likelihood	marginal,
binomial form of, 192	notation,
development, 192	Bernoulli, 29
Poison Model	binomial, 27
in BUGS , 250	different notations for, 22
data simulation, 251	hierarchical model, 40
encounter probability, 245, 505, 513	properties, 24–25
GLMM, 447	random variable, 21–22
multinomial relationship, 259	Probability mass function (PMF)
regression, 450	Bernoulli distribution and, 29
in SCR, 245	binomial, 23, 28–29, 37
in <i>secr</i> , 261	issues, 22
space usage, 247	parameters, 22, 37
zero-inflated, 250	properties, 24
Poisson observation model, 245–247	random variable values, 23
relationship to Bernoulli model, 248	Proposal distribution, 441
relationship to multinomial model, 249	random walk, 441
Population closure, 300	Proximity detector
violation of, 300–301	density estimators, 245
Test of, 301	in signal strength, 270
Population dynamics	in signar strength, 270
animal movement, 403	
Possum data, 268–272	R
Posterior density plot, 457	
Posterior distribution, 52, 54, 436, 439–441	Radio-tagged individuals, 500
Bayesian inference, 52	Random effect
Characterization of, 56	in Bayesian analysis, 84
discrepancy measures, 82	in GLMMs, 47, 49
inference, 54–55	in hierarchical models, 83
joint, 439, 450	in MCMC, 47
marginal 439	in Poisson GLMM 75

in WinBUGS model, 61, 84	spatial, 288
Random sample assumption, 497, 502	Sampling duration, 300
demographic, 498	Sampling methods
spatial, 498, 502-504, 521-522	non-invasive, 13
Random variable	Sampling techniques, 527
definition of, 22	Scenario analysis, 277–278, 283
examples	SCR0
Random walk proposal distribution, 441	Bayesian analysis of, 131
Realized population size, 148	Bernoulli model, 167
Recruitment	BUGS analysis, 125, 146
data augmentation, 407	fitting model, 141, 154–155
JS model, 404, 410, 414	home range area, 147
time dependent, 409	MCMC for, 452, 455
Regular capture-recapture models, 500	statistical assumptions, 150
Rejection sampling, 315, 448	SCR models
Resighting techniques, 499	activity center, 294
Resource selection	Bayesian analysis, 148
bivariate normal space usage, 136, 256,	binomial encounter process, 455
350–351	characterization, 41
multinomial resource selection model, 256,	construct full conditionals, 453
350–351	core assumption, 150
Poisson model of space usage, 247, 353	data simulation, 257–258
SCR as a model of, 134, 354	distance sampling, 133
encounter probability, 350, 355	effective sample area, 167
in Poisson model, 353	encounter probability, 292
in SCR model, 349	independence assumption, 361
mis-specification, 359	$\operatorname{model} M_h$, 133
population estimate, 350	optimal design criteria for, 293
second-order scale, 357	Poisson observation model, 295
telemetry data, 359, 361	population closure, 301
Resource selection function (RSF)	sex-specific encounter, 286
independence assumption, 361	study design, 281
R-hat statistic, see Gelman-Rubin statistic	Search-encounter designs
Rotating traps, 287–288, 300	fixed search path, 382–383
	total hazard, 384
	uniform intensity, 383
\$	Search-encounter sampling, 7
Sample size	fixed search path, 382
encounter probability, 287	area-search, 383
estimation parameters, 285, 303	uniform search intensity, 383, 392 Search encounter models
generation techniques, 281	
in conditional probability, 293	secr package, 186–187, 262
in SCR model, 288	additional capabilities, 194
spatial problems, 277	analysis, 189
trap clusters, 298	covariate models, 195
Sampling design, 126	density mapping, 195 encounter device, 188
design-based, 278	
	in likelihood analysis, 191, 213
focal population vs. state-space, 280 for capture-recapture, 281	multi-session model, 193
	ovenbird data, 262
for SCR, 282–283	population closure test, 195
model based, 278, 289	sex specificity, 262
population closure, 300	state-space buffer, 194

0 1 4 14 450 450	C .: 1 1 207 200
Serial autocorrelation, 458–459	Spatial randomness, 307–308
Sex specificity	homogeneous point process and, 308
effects, 215	observation model, 237
uncaptured individuals, 181	uniform distribution, 234
multi-session models, 365	Spatial randomness, testing, 233
secr package, 262	sensitivity to bin size, 235
shapefile, in least-cost distance, 345	sensitivity to state-space extent, 236
Sierra National Forest fisher study, 392	Spatial recaptures, 283, 285, 288
Single-catch trap, 266–268, 533–534	Spatial sampling
multiple sample session, 261	in SCR model, 279
observation model, 266	issues, 277, 299
Slice sampling, 448	trap location, 279
Small sample inference	State-space, 16
Bayesian analysis, 55	in spatial mark-resight, 503
SMR model. See Spatial mark-resight model	manipulating, 463–464
Sonoran desert tortoise data, 118	shapefile, 464
Southwest New York Black Bear Study, 355	size sensitivity, 236
Space-filling designs, 297	State-space model
Space usage, see resource selection	invariance, 132
Space usage model, 350	point process, 131
empirical analysis, 136	prescribing, 131
home range center, 134	state space (of point process), 16, 131
Poisson distribution, 353	Stationary distribution, 439
Spatial capture-recapture (SCR) methods	Statistical inference
in animal population, 5	fundamentals of, 21
construction of, 14	hierarchical models and, 40
defined, 4	parameter estimation and, 34
density estimation, 5	role in probability laws, 22
ecological theories and, 18	Stratified populations, see also multi-session
historical context, 12	models
non-spatial aspects, 8, 11	BUGS implementation, 368
technical problems, resolving, 3	data simulation, 371
Spatial correlation	hierarchical model, 367
Spatial design	multinomial abundance models, 367
construction, 303	in SCR model, 365
formal analysis, 277	Strauss model, 530
issues, 278, 290, 296	Study area, 280
model-based, 289	Survival
optimization criteria, 296	American shad, 416, 424
temporal aspects, 299	Cormack-Jolly-Seber (CJS) models,
Spatial distribution, 498	415, 418
Spatial mark-resight (SMR) model, 498	demographic parameters, 410
data simulation, 506	vs emigration, 403
imperfect identification of marked	in spatial model, 402
individuals, 512–514	Jolly Seber (JS) models, 404
implementation, 505–506, 508	in open population, 406
inhomogeneous point processes, 523	in open population, 100
known number of marks, 504-505	
precision of estimates, 521	T
random sample assumption, 502	
resighting techniques, 499	Telemetry data
telemetry data, incorporating, 516–519	activity centers, 351
Unknown number of marks, 508–509	in spatial mark-resight, 516–519

578 Index

Uniform distribution, 32

resource selection model, 349	Uniform search intensity
RSF model, 361	design 2, 392
SCR model, 350, 361	search-encounter designs, 383
space sampling, 354	Unmarked individuals
Temporal dependence	estimated number of, 505
multi-session formulation, 377	information, 514
Temporary emigration, 13, 103, 379, 403-404	Unstructured spatial surveys, 390
Thinning, 67	
Time series plots, 65, 439–440, 457	
Total hazard,	W
encounter model, 384–385, 390	Weibull hazard, 386
Trap arrangement, 288	WinBUGS, 60, 433-434, 460-461, 465
Trap array, 281	fitting model, 154
holes in the, 281–282 size, 282–283, 285–286	in linear regression, 60
Trap spacing	in markov chain Monte Carlo (MCMC), 64, 67
and home range size, 281–282	in random effect, 61, 84
movement estimates, 282, 285	Wolverine analysis
Relative to animal movement, 283–285	camera trapping, 161, 182
study design, 281, 287	density map, 164
Trap-specific covariate	space usage, 157
encounter probability models, 206, 513	wolverine camera trapping data,
encounter probability models, 200, 515	151, 182, 221
U	7
Unequal probability sampling, 284	L

Zero-inflated, Poisson model, 250