## HANDBOOK OF CAPTURE-RECAPTURE ANALYSIS

Edited by

Steven C. Amstrup, Trent L. McDonald, and Bryan F. J. Manly

PRINCETON UNIVERSITY PRESS PRINCETON AND OXFORD

## Contents\_\_\_\_\_

List of Illustrations	ix
List of Tables	xi
Preface	xvii
One	1
Introduction to the Handbook	
Bryan F. J. Manly, Trent L. McDonald, and Steven C. Amstrup	
1.1 Introduction	1
1.2 Overview of Chapters 2 to 8	3
1.3 Maximum Likelihood with Capture–Recapture Methods	9
1.4 Model Selection Procedures	17
1.5 Notation	19
Two	22
Classical Closed-population Capture–Recapture Models Anne Chao and Richard M. Huggins	
2.1 Introduction	22
2.2 Structure of Capture–Recapture Experiments and Data	23
2.3 Early Models and Estimators	26
2.4 Limitations of Early Models and the Motivation for	
More General Models	34
2.5 Chapter Summary	35
Three	36
Classical Open-population Capture–Recapture Models Kenneth H. Pollock and Russell Alpizar-Jara	
3.1 Introduction	36
3.2 The Original Jolly-Seber Model	38
3.3 The Jolly-Seber Likelihood Components	44
3.4 Restrictions and Generalizations of the Jolly-Seber Model	45
3.5 Age-dependent Models	46
3.6 Goodness-of-Fit and Model Selection Issues	47
3.7 Examples	48
3.8 Conclusions	55
3.9 Chapter Summary	55

	С	0	Ν	Т	E	N	Т	S
--	---	---	---	---	---	---	---	---

Four	58
Modern Closed-population Capture–Recapture Models Anne Chao and Richard M. Huggins	
4.1 Introduction	58
4.2 Discrete-time Models with Unequal Catchabilities	58
4.3 Continuous-time Models	78
4.4 Computing Considerations	85
4.5 Chapter Summary	86
Five	88
Modern Open-population Capture–Recapture Models James D. Nichols	
5.1 Introduction	88
5.2 Conditional Single-age Models	89
5.3 Conditional Multiple-age Models	102
5.4 Reverse-time Models	107
5.5 Unconditional Models	109
5.6 The Robust Design	116
5.7 Discussion	120
5.8 Chapter Summary	121
Six	124
Tag-recovery Models	
John M. Hoenig, Kenneth H. Pollock, and William Hearn	
6.1 Introduction	124
6.2 Assumptions of Brownie Models	128
6.3 Interpretation of the Tag-recovery Rate Parameter	128
6.4 Functional Linkage Between the Exploitation Rate and	
the Survival Rate	131
- 6.5 Instantaneous Rate Models for Estimating Harvest and	
Natural Mortality	131
6.6 Diagnostics and Tests of Assumptions	132
6.7 Preventing and Dealing with Failures of Assumptions	134
6.8 Chapter Summary	140
Seven .	142
Joint Modeling of Tag-recovery and Live-resighting Data Richard J. Barker	
7.1 Introduction	142
7.2 Data Structure	144
7.3 Simple Models	145
7.4 More General Models	156
7.5 Model Fitting and Assessment	157

vi

7.6 Tag Misreads and Tag Loss	161
7.7 Computing Considerations	161
7.8 Chapter Summary	163
Eight	165
Multistate Models	
Carl J. Schwarz	
8.1 Introduction	165
8.2 The Arnason-Schwarz Model	166
8.3 The Jolly-Seber Approach	177
8.4 Multisample Stratified Closed Populations	187
8.5 Multisample Stratified Open Populations	192
8.6 Chapter Summary	194
Nine	196
Examples	
Trent L. McDonald, Steven C. Amstrup, Eric V. Regehr, and	
Bryan F. J. Manly	
9.1 Introduction	196
9.2 Open-population Analyses of Data on the	
European Dipper	198
9.3 The Huggins Closed-population Model Applied to the	224
European Dipper Data	231
9.4 Assessing Goodness-of-Fit	236
9.5 Horvitz-Thompson Open-population Size Estimates	241
9.6 A Multistate (Multistrata) Model	243
9.7 Foldt Beats in the Southern Beaujort Sea	24/
9.0 Dead Recoveries of Manara Ducks	234
y.y Chapter Summary	205
Ten	266
Capture–Recapture Methods in Practice	
Bryan F. J. Manly, Steven C. Amstrup, and Irent L. McDonald	
10.1 Introduction	266
10.2 Closed-population Models	266
10.3 Open-population Models	267
10.4 Tag-recovery Models	269
10.5 Other Models	270
10.6 Model Selection	271
10.7 Known Ages	272
Appendix	275
A.1 Capability Matrix for Common Capture–Recapture	
Software Packages	275

A.2 General and Contact Information for Common Capture–Recapture Software Packages Listed in Table A.1	277
References	281
Contributor's Notes	301
Index	303