

Contents

Preface	vii
Glossary	xvii
About the Authors	xx
1 Introduction	1
1.1 Objectives of the Book	1
1.2 Background Material	4
1.2.1 Inference, Given a Model	4
1.2.2 The Critical Issue: “What Model To Use?”	5
1.2.3 Science Inputs—Formulation of the Set of Candidate Models	7
1.2.4 Models Versus Full Reality	11
1.2.5 A “Best Approximating Model”	13
1.3 Overview of Models in the Biological Sciences	13
1.3.1 Types of Models Commonly Used in the Biological Sciences	14
1.3.2 Likelihood and Least Squares Theory	15
1.3.3 Data Dredging	17
1.3.4 Some Trends	20
1.4 Inference and the Principle of Parsimony	21
1.4.1 Over-fitting to Achieve a Good Model Fit	21
1.4.2 The Principle of Parsimony	23
1.4.3 Model Selection Methods	27

1.5	Model Selection Uncertainty	29
1.6	Summary	30
2	Information Theory and Log-Likelihood Models: A Basis for Model Selection and Inference	32
2.1	The Distance or Discrepancy Between Two Models	33
2.1.1	f , Truth, Full Reality, and “True Models”	36
2.1.2	g , Approximating Models	36
2.1.3	The Kullback–Liebler Distance (or Information)	37
2.1.4	Truth, f , Drops Out as a Constant	41
2.2	Akaike’s Information Criterion	43
2.3	Akaike’s Predictive Expected Log-Likelihood	49
2.4	Important Refinements to AIC	51
2.4.1	A Second-Order AIC	51
2.4.2	Modification to AIC for Overdispersed Count Data	52
2.5	A Useful Analogy	54
2.6	Some History	56
2.6.1	The G-Statistic and K-L Information	56
2.6.2	Further Insights	57
2.6.3	Entropy	58
2.6.4	A Summary	59
2.7	Further Comments	59
2.7.1	A Heuristic Interpretation	60
2.7.2	Interpreting Differences Among AIC Values	60
2.7.3	Nonnested Models	63
2.7.4	Model Selection Uncertainty	64
2.7.5	AIC When Different Data Sets Are to Be Compared	64
2.7.6	Order Not Important in Computing AIC Values	64
2.7.7	Hypothesis Testing Is Still Important	65
2.8	Comparisons with Other Criteria	66
2.8.1	Information Criteria That Are Estimates of K-L Information	66
2.8.2	Criteria That Are Consistent for K	68
2.8.3	Contrasts	70
2.9	Return to Flather’s Models	71
2.10	Summary	72
3	Practical Use of the Information-Theoretic Approach	75
3.1	Computation and Interpretation of AIC Values	76
3.2	Example 1—Cement Hardening Data	78
3.2.1	Set of Candidate Models	79
3.2.2	Some Results and Comparisons	79
3.2.3	A Summary	82
3.3	Example 2—Time Distribution of an Insecticide Added to a Simulated Ecosystem	83

3.3.1	Set of Candidate Models	84
3.3.2	Some Results	86
3.4	Example 3—Nestling Starlings	87
3.4.1	Experimental Scenario	87
3.4.2	Monte Carlo Data	88
3.4.3	Set of Candidate Models	88
3.4.4	Data Analysis Results	92
3.4.5	Further Insights into the First 14 Nested Models	94
3.4.6	Hypothesis Testing and Information-Theoretic Approaches Have Different Selection Frequencies	96
3.4.7	Further Insights Following Final Model Selection	99
3.4.8	Why Not Always Use the Global Model for Inference? . .	100
3.5	Example 4—Sage Grouse Survival	101
3.5.1	Introduction	101
3.5.2	Set of Candidate Models	102
3.5.3	Model Selection	104
3.5.4	Hypothesis Tests for Year-Dependent Survival Probabilities	106
3.5.5	Hypothesis Testing Versus AIC in Model Selection . .	106
3.5.6	A Class of Intermediate Models	110
3.6	Example 5—Resource Utilization of <i>Anolis</i> Lizards	110
3.6.1	Set of Candidate Models	111
3.6.2	Comments on Analytic Method	112
3.6.3	Some Tentative Results	112
3.7	Summary	114
4	Model-Selection Uncertainty with Examples	118
4.1	Introduction	118
4.2	Methods for Assessing Model-Selection Uncertainty	120
4.2.1	AIC Differences and a Confidence Set on the K-L Best Model	122
4.2.2	Likelihood of a Model and Akaike Weights	123
4.2.3	More Options for a Confidence Set for the K-L Best Model	127
4.2.4	Δ_i , Model-Selection Probabilities and the Bootstrap . .	129
4.2.5	Concepts of Parameter-Estimation and Model-Selection Uncertainty	130
4.2.6	Including Model-Selection Uncertainty in Estimator Sampling Variance	133
4.2.7	Unconditional Confidence Intervals	137
4.2.8	Uncertainty of Variable Selection	140
4.2.9	Model Redundancy	141
4.2.10	Recommendations	144
4.3	Examples	145
4.3.1	Cement Data	145

4.3.2	<i>Anolis</i> Lizards in Jamaica	151
4.3.3	Simulated Starling Experiment	151
4.3.4	Sage Grouse in North Park	152
4.3.5	Sakamoto et al.'s (1986) Simulated Data	152
4.3.6	Pine Wood Data	153
4.4	Summary	157
5	Monte Carlo and Example-Based Insights	159
5.1	Introduction	159
5.2	Survival Models	160
5.2.1	A Chain Binomial Survival Model	160
5.2.2	An Example	163
5.2.3	An Extended Survival Model	168
5.2.4	Model Selection If Sample Size Is Huge, or Truth Known	171
5.2.5	A Further Chain Binomial Model	173
5.3	Examples and Ideas Illustrated with Linear Regression	176
5.3.1	All-Subsets Selection: A GPA Example	177
5.3.2	A Monte Carlo Extension of the GPA Example	182
5.3.3	An Improved Set of GPA Prediction Models	186
5.3.4	More Monte Carlo Results	189
5.3.5	Linear Regression and Variable Selection	195
5.3.6	Discussion	199
5.4	Estimation of Density from Line Transect Sampling	205
5.4.1	Density Estimation Background	205
5.4.2	Line Transect Sampling of Kangaroos at Wallaby Creek	206
5.4.3	Analysis of Wallaby Creek Data	206
5.4.4	Bootstrap Analysis	208
5.4.5	Confidence interval on D	208
5.4.6	Bootstrap Reps: 1,000 vs. 10,000.	210
5.4.7	Bootstrap vs. Akaike Weights: A lesson on $QAIC_c$	211
5.5	An Extended Binomial Example	213
5.5.1	The Durban Storm Data	213
5.5.2	Models Considered	214
5.5.3	Consideration of Model Fit	216
5.5.4	Confidence Intervals on Predicted Storm Probability	217
5.5.5	Precision Comparisons of Estimators	219
5.6	Lessons from the Literature and Other Matters	221
5.6.1	Use AIC_c , Not AIC , with Small Sample Sizes	221
5.6.2	Use AIC_c , Not AIC , When K Is Large	222
5.6.3	Inference from a Less Than Best Model	224
5.6.4	Are Parameters Real?	226
5.7	Summary	227

6	Statistical Theory	230
6.1	Useful Preliminaries	230
6.2	A General Derivation of AIC	239
6.3	General K-L–Based Model Selection: TIC	248
	6.3.1 Analytical Computation of TIC	248
	6.3.2 Bootstrap Estimation of TIC	249
6.4	AIC _c : A Second-Order Improvement	251
	6.4.1 Derivation of AIC _c	251
	6.4.2 Lack of Uniqueness of AIC _c	255
6.5	Derivation of AIC for the Exponential Family of Distributions	257
6.6	Evaluation of $\text{tr}(J(\underline{\theta}_o)[I(\underline{\theta}_o)]^{-1})$ and Its Estimator	261
	6.6.1 Comparison of AIC vs. TIC in a Very Simple Setting	261
	6.6.2 Evaluation Under Logistic Regression	266
	6.6.3 Evaluation Under Multinomially Distributed Count Data	273
	6.6.4 Evaluation Under Poisson-Distributed Data	280
	6.6.5 Evaluation for Fixed-Effects Normality-Based Linear Models	281
6.7	Additional Results and Considerations	288
	6.7.1 Selection Simulation for Nested Models	288
	6.7.2 Simulation of the Distribution of Δ_p	290
	6.7.3 Does AIC Over-fit?	292
	6.7.4 Can Selection Be Improved Based on All the Δ_i ?	294
	6.7.5 Linear Regression, AIC, and Mean Square Error	296
	6.7.6 AIC and Random Coefficient Models	299
	6.7.7 AIC _c and Models for Multivariate Data	302
	6.7.8 There Is No True TIC _c	303
	6.7.9 Kullback–Leibler Information Relationship to the Fisher Information Matrix	304
	6.7.10 Entropy and Jaynes Maxent Principle	304
	6.7.11 Akaike Weights, w_i , Versus Selection Probabilities, π_i	305
	6.7.12 Model Goodness-of-Fit After Selection	306
6.8	Kullback–Leibler Information Is Always ≥ 0	307
6.9	Summary	312
7	Summary	315
7.1	The Scientific Question and the Collection of Data	317
7.2	Actual Thinking and A Priori Modeling	317
7.3	The Basis for Objective Model Selection	319
7.4	The Principle of Parsimony	321
7.5	Information Criteria as Estimates of Relative Kullback–Leibler Information	321
7.6	Ranking and Calibrating Alternative Models	324
7.7	Model-Selection Uncertainty	325
7.8	Inference Based on Model Averaging	326

7.9	More on Inferences	327
7.10	Final Thoughts	328
	References	329
	Index	351