

David R. Anderson

**Model Based Inference  
in the Life Sciences:  
A Primer on Evidence**

# Contents

<b>Preface</b> .....	<b>vii</b>
<b>About the Author</b> .....	<b>xvii</b>
<b>Glossary</b> .....	<b>xix</b>
<b>1. Introduction: Science Hypotheses and Science Philosophy</b> .....	<b>1</b>
1.1 Some Science Background.....	1
1.2 Multiple Working Hypotheses.....	3
1.3 Bovine TB Transmission in Ferrets.....	4
1.4 Approaches to Scientific Investigations.....	6
1.4.1 Experimental Studies.....	7
1.4.2 Descriptive Studies.....	8
1.4.3 Confirmatory Studies.....	8
1.5 Science Hypothesis Set Evolves.....	10
1.6 Null Hypothesis Testing.....	11
1.7 Evidence and Inferences.....	12
1.8 Hardening of Portland Cement.....	13
1.9 What Does Science Try to Provide?.....	14
1.10 Remarks.....	15
1.11 Exercises.....	17
<b>2. Data and Models</b> .....	<b>19</b>
2.1 Data.....	19
2.1.1 Hardening of Portland Cement Data.....	22
2.1.2 Bovine TB Transmission in Ferrets.....	23
2.1.3 What Constitutes a “Data Set”?.....	24

2.2	Models .....	25
2.2.1	True Models (An Oxymoron).....	27
2.2.2	The Concept of Model Parameters.....	28
2.2.3	Parameter Estimation .....	29
2.2.4	Principle of Parsimony .....	30
2.2.5	Tapering Effect Sizes.....	33
2.3	Case Studies.....	33
2.3.1	Models of Hardening of Portland Cement Data.....	33
2.3.2	Models of Bovine TB Transmission in Ferrets .....	35
2.4	Additional Examples of Modeling .....	36
2.4.1	Modeling Beak Lengths .....	37
2.4.2	Modeling Dose Response in Flour Beetles .....	41
2.4.3	Modeling Enzyme Kinetics .....	44
2.5	Data Dredging .....	45
2.6	The Effect of a Flood on European Dippers: Modeling Contrasts .....	46
2.6.1	Traditional Null Hypothesis Testing .....	46
2.6.2	Information-Theoretic Approach .....	47
2.7	Remarks.....	48
2.8	Exercises.....	49
<b>3.</b>	<b>Information Theory and Entropy .....</b>	<b>51</b>
3.1	Kullback–Leibler Information.....	52
3.2	Linking Information Theory to Statistical Theory .....	54
3.3	Akaike’s Information Criterion .....	55
3.3.1	The Bias Correction Term .....	57
3.3.2	Why Multiply by $-2$ ? .....	57
3.3.3	Parsimony is Achieved as a by-Product .....	58
3.3.4	Simple vs. Complex Models .....	59
3.3.5	AIC Scale .....	60
3.4	A Second-Order Bias Correction: AICc.....	60
3.5	Regression Analysis .....	61
3.6	Additional Important Points .....	62
3.6.1	Differences Among AICc Values .....	62
3.6.2	Nested vs. Nonnested Models .....	63
3.6.3	Data and Response Variable Must Remain Fixed .....	63
3.6.4	AICc is not a “Test”.....	64
3.6.5	Data Dredging Using AICc .....	64
3.6.6	Keep all the Model Terms .....	64
3.6.7	Missing Data .....	65
3.6.8	The “Pretending Variable” .....	65
3.7	Cement Hardening Data .....	66
3.7.1	Interpreting AICc Values.....	66
3.7.2	What if all the Models are Bad?.....	67
3.7.3	Prediction from the Best Model .....	68

3.8	Ranking the Models of Bovine Tuberculosis in Ferrets .....	69
3.9	Other Important Issues .....	70
3.9.1	Takeuchi's Information Criterion.....	70
3.9.2	Problems When Evaluating Too Many Candidate Models .....	71
3.9.3	The Parameter Count $K$ and Parameters that Cannot be Uniquely Estimated .....	71
3.9.4	Cross Validation and $AIC_c$ .....	72
3.9.5	Science Advances as the Hypothesis Set Evolves.....	72
3.10	Summary.....	73
3.11	Remarks.....	74
3.12	Exercises.....	80
<b>4.</b>	<b>Quantifying the Evidence About Science Hypotheses.....</b>	<b>83</b>
4.1	$\Delta_i$ Values and Ranking .....	84
4.2	Model Likelihoods.....	86
4.3	Model Probabilities .....	87
4.4	Evidence Ratios .....	89
4.5	Hardening of Portland Cement.....	91
4.6	Bovine Tuberculosis in Ferrets.....	93
4.7	Return to Flather's Models and $R^2$ .....	94
4.8	The Effect of a Flood on European Dippers.....	95
4.9	More about Evidence and Inference.....	98
4.10	Summary.....	100
4.11	Remarks.....	101
4.12	Exercises.....	103
<b>5.</b>	<b>Multimodel Inference .....</b>	<b>105</b>
5.1	Model Averaging .....	106
5.1.1	Model Averaging for Prediction.....	107
5.1.2	Model Averaging Parameter Estimates Across Models .....	108
5.2	Unconditional Variances.....	110
5.2.1	Examples Using the Cement Hardening Data.....	112
5.2.2	Averaging Detection Probability Parameters in Occupancy Models .....	115
5.3	Relative Importance of Predictor Variables.....	118
5.3.1	Rationale for Ranking the Relative Importance of Predictor Variables .....	119
5.3.2	An Example Using the Cement Hardening Data .....	119
5.4	Confidence Sets on Models .....	121
5.5	Summary.....	122
5.6	Remarks.....	122
5.7	Exercises.....	124

<b>6. Advanced Topics .....</b>	<b>125</b>
6.1 Overdispersed Count Data.....	126
6.1.1 Lack of Independence .....	126
6.1.2 Parameter Heterogeneity .....	126
6.1.3 Estimation of a Variance Inflation Factor.....	127
6.1.4 Coping with Overdispersion in Count Data .....	127
6.1.5 Overdispersion in Data on Elephant Seals .....	128
6.2 Model Selection Bias.....	129
6.2.1 Understanding the Issue .....	129
6.2.2 A Solution to the Problem of Model Selection Bias .....	130
6.3 Multivariate AICc.....	133
6.4 Model Redundancy.....	133
6.5 Model Selection in Random Effects Models.....	134
6.6 Use in Conflict Resolution .....	135
6.6.1 Analogy with the Flip of a Coin.....	136
6.6.2 Conflict Resolution Protocol .....	137
6.6.3 A Hypothetical Example: Hen Clam Experiments.....	138
6.7 Remarks.....	140
<b>7. Summary.....</b>	<b>141</b>
7.1 The Science Question .....	142
7.2 Collection of Relevant Data .....	143
7.3 Mathematical Models .....	143
7.4 Data Analysis.....	144
7.5 Information and Entropy .....	144
7.6 Quantitative Measures of Evidence.....	144
7.7 Inferences .....	145
7.8 <i>Post Hoc</i> Issues .....	146
7.9 Final Comment .....	146
<b>Appendices.....</b>	<b>147</b>
Appendix A: Likelihood Theory .....	147
Appendix B: Expected Values.....	155
Appendix C: Null Hypothesis Testing.....	157
Appendix D: Bayesian Approaches.....	158
Appendix E: The Bayesian Information Criterion .....	160
Appendix F: Common Misuses and Misinterpretations.....	162
<b>References.....</b>	<b>167</b>
<b>Index.....</b>	<b>181</b>