

# Contents

<b>Preface</b>	<b>xiii</b>
<b>1. Introduction: Distributions and Inference for Categorical Data</b>	<b>1</b>
1.1 Categorical Response Data, 1	
1.2 Distributions for Categorical Data, 5	
1.3 Statistical Inference for Categorical Data, 9	
1.4 Statistical Inference for Binomial Parameters, 14	
1.5 Statistical Inference for Multinomial Parameters, 21	
Notes, 26	
Problems, 28	
<b>2. Describing Contingency Tables</b>	<b>36</b>
2.1 Probability Structure for Contingency Tables, 36	
2.2 Comparing Two Proportions, 43	
2.3 Partial Association in Stratified $2 \times 2$ Tables, 47	
2.4 Extensions for $I \times J$ Tables, 54	
Notes, 59	
Problems, 60	
<b>3. Inference for Contingency Tables</b>	<b>70</b>
3.1 Confidence Intervals for Association Parameters, 70	
3.2 Testing Independence in Two-Way Contingency Tables, 78	
3.3 Following-Up Chi-Squared Tests, 80	
3.4 Two-Way Tables with Ordered Classifications, 86	
3.5 Small-Sample Tests of Independence, 91	

3.6	Small-Sample Confidence Intervals for $2 \times 2$ Tables,*	98
3.7	Extensions for Multiway Tables and Nontabulated Responses,	101
	Notes,	102
	Problems,	104
<b>4.</b>	<b>Introduction to Generalized Linear Models</b>	<b>115</b>
4.1	Generalized Linear Model,	116
4.2	Generalized Linear Models for Binary Data,	120
4.3	Generalized Linear Models for Counts,	125
4.4	Moments and Likelihood for Generalized Linear Models,*	132
4.5	Inference for Generalized Linear Models,	139
4.6	Fitting Generalized Linear Models,	143
4.7	Quasi-likelihood and Generalized Linear Models,*	149
4.8	Generalized Additive Models,*	153
	Notes,	155
	Problems,	156
<b>5.</b>	<b>Logistic Regression</b>	<b>165</b>
5.1	Interpreting Parameters in Logistic Regression,	166
5.2	Inference for Logistic Regression,	172
5.3	Logit Models with Categorical Predictors,	177
5.4	Multiple Logistic Regression,	182
5.5	Fitting Logistic Regression Models,	192
	Notes,	196
	Problems,	197
<b>6.</b>	<b>Building and Applying Logistic Regression Models</b>	<b>211</b>
6.1	Strategies in Model Selection,	211
6.2	Logistic Regression Diagnostics,	219
6.3	Inference About Conditional Associations in $2 \times 2 \times K$ Tables,	230
6.4	Using Models to Improve Inferential Power,	236
6.5	Sample Size and Power Considerations,*	240
6.6	Probit and Complementary Log-Log Models,*	245

\*Sections marked with an asterisk are less important for an overview.

6.7	Conditional Logistic Regression and Exact Distributions,*	250
	Notes,	257
	Problems,	259
<b>7.</b>	<b>Logit Models for Multinomial Responses</b>	<b>267</b>
7.1	Nominal Responses: Baseline-Category Logit Models,	267
7.2	Ordinal Responses: Cumulative Logit Models,	274
7.3	Ordinal Responses: Cumulative Link Models,	282
7.4	Alternative Models for Ordinal Responses,*	286
7.5	Testing Conditional Independence in $I \times J \times K$ Tables,*	293
7.6	Discrete-Choice Multinomial Logit Models,*	298
	Notes,	302
	Problems,	302
<b>8.</b>	<b>Loglinear Models for Contingency Tables</b>	<b>314</b>
8.1	Loglinear Models for Two-Way Tables,	314
8.2	Loglinear Models for Independence and Interaction in Three-Way Tables,	318
8.3	Inference for Loglinear Models,	324
8.4	Loglinear Models for Higher Dimensions,	326
8.5	The Loglinear-Logit Model Connection,	330
8.6	Loglinear Model Fitting: Likelihood Equations and Asymptotic Distributions,*	333
8.7	Loglinear Model Fitting: Iterative Methods and their Application,*	342
	Notes,	346
	Problems,	347
<b>9.</b>	<b>Building and Extending Loglinear/Logit Models</b>	<b>357</b>
9.1	Association Graphs and Collapsibility,	357
9.2	Model Selection and Comparison,	360
9.3	Diagnostics for Checking Models,	366
9.4	Modeling Ordinal Associations,	367
9.5	Association Models,*	373
9.6	Association Models, Correlation Models, and Correspondence Analysis,*	379

- 9.7 Poisson Regression for Rates, 385
- 9.8 Empty Cells and Sparseness in Modeling Contingency Tables, 391
- Notes, 398
- Problems, 400
- 10. Models for Matched Pairs 409**
- 10.1 Comparing Dependent Proportions, 410
- 10.2 Conditional Logistic Regression for Binary Matched Pairs, 414
- 10.3 Marginal Models for Square Contingency Tables, 420
- 10.4 Symmetry, Quasi-symmetry, and Quasi-independence, 423
- 10.5 Measuring Agreement Between Observers, 431
- 10.6 Bradley–Terry Model for Paired Preferences, 436
- 10.7 Marginal Models and Quasi-symmetry Models for Matched Sets,\* 439
- Notes, 442
- Problems, 444
- 11. Analyzing Repeated Categorical Response Data 455**
- 11.1 Comparing Marginal Distributions: Multiple Responses, 456
- 11.2 Marginal Modeling: Maximum Likelihood Approach, 459
- 11.3 Marginal Modeling: Generalized Estimating Equations Approach, 466
- 11.4 Quasi-likelihood and Its GEE Multivariate Extension: Details,\* 470
- 11.5 Markov Chains: Transitional Modeling, 476
- Notes, 481
- Problems, 482
- 12. Random Effects: Generalized Linear Mixed Models for Categorical Responses 491**
- 12.1 Random Effects Modeling of Clustered Categorical Data, 492
- 12.2 Binary Responses: Logistic-Normal Model, 496
- 12.3 Examples of Random Effects Models for Binary Data, 502
- 12.4 Random Effects Models for Multinomial Data, 513

12.5	Multivariate Random Effects Models for Binary Data,	
	516	
12.6	GLMM Fitting, Inference, and Prediction,	520
	Notes,	526
	Problems,	527
<b>13.</b>	<b>Other Mixture Models for Categorical Data*</b>	<b>538</b>
13.1	Latent Class Models,	538
13.2	Nonparametric Random Effects Models,	545
13.3	Beta-Binomial Models,	553
13.4	Negative Binomial Regression,	559
13.5	Poisson Regression with Random Effects,	563
	Notes,	565
	Problems,	566
<b>14.</b>	<b>Asymptotic Theory for Parametric Models</b>	<b>576</b>
14.1	Delta Method,	577
14.2	Asymptotic Distributions of Estimators of Model Parameters and Cell Probabilities,	582
14.3	Asymptotic Distributions of Residuals and Goodness- of-Fit Statistics,	587
14.4	Asymptotic Distributions for Logit/Loglinear Models,	592
	Notes,	594
	Problems,	595
<b>15.</b>	<b>Alternative Estimation Theory for Parametric Models</b>	<b>600</b>
15.1	Weighted Least Squares for Categorical Data,	600
15.2	Bayesian Inference for Categorical Data,	604
15.3	Other Methods of Estimation,	611
	Notes,	615
	Problems,	616
<b>16.</b>	<b>Historical Tour of Categorical Data Analysis*</b>	<b>619</b>
16.1	Pearson–Yule Association Controversy,	619
16.2	R. A. Fisher’s Contributions,	622

16.3	Logistic Regression, 624	
16.4	Multiway Contingency Tables and Loglinear Models, 625	
16.5	Recent (and Future?) Developments, 629	
<b>Appendix A.</b>	<b>Using Computer Software to Analyze Categorical Data</b>	<b>632</b>
A.1	Software for Categorical Data Analysis, 632	
A.2	Examples of SAS Code by Chapter, 634	
<b>Appendix B.</b>	<b>Chi-Squared Distribution Values</b>	<b>654</b>
<b>References</b>		<b>655</b>
<b>Examples Index</b>		<b>689</b>
<b>Author Index</b>		<b>693</b>
<b>Subject Index</b>		<b>701</b>