

Contents

| | |
|--|-----------|
| PREFACE | v |
| ACKNOWLEDGEMENTS | v |
| DATASETS USED IN THIS BOOK | v |
| 1 INTRODUCTION | 1 |
| 1.1 SPEAKING THE SAME LANGUAGE | 1 |
| 1.2. GENERAL POINTS | 2 |
| 1.3 OUTLINE OF THIS BOOK | 5 |
| 2 OUTLIERS | 7 |
| 2.1 WHAT IS AN OUTLIER? | 7 |
| 2.2 BOXPLOT TO IDENTIFY OUTLIERS IN ONE DIMENSION | 8 |
| 2.2.1 <i>Simple boxplot</i> | 8 |
| 2.2.2 <i>Conditional boxplot</i> | 10 |
| 2.2.3 <i>Multi-panel boxplots from the lattice package</i> | 13 |
| 2.3 CLEVELAND DOTPLOT TO IDENTIFY OUTLIERS | 15 |
| 2.3.1 <i>Simple Cleveland dotplots</i> | 15 |
| 2.3.2 <i>Conditional Cleveland dotplots</i> | 17 |
| 2.3.3 <i>Multi-panel Cleveland dotplots from the lattice package</i> | 18 |
| 2.4 BOXPLOTS OR CLEVELAND DOTPLOTS? | 20 |
| 2.5 CAN WE APPLY A TEST FOR OUTLIERS? | 21 |
| 2.5.1 <i>Z-score</i> | 22 |
| 2.5.2 <i>Grubbs' test</i> | 22 |
| 2.6 OUTLIERS IN THE TWO-DIMENSIONAL SPACE | 24 |
| 2.7 INFLUENTIAL OBSERVATIONS IN REGRESSION MODELS | 25 |
| 2.8 WHAT TO DO IF YOU DETECT POTENTIAL OUTLIERS | 27 |
| 2.9 OUTLIERS AND MULTIVARIATE DATA | 31 |
| 2.10 THE PROS AND CONS OF TRANSFORMATIONS | 33 |
| 3 NORMALITY AND HOMOGENEITY | 37 |
| 3.1 WHAT IS NORMALITY? | 37 |
| 3.2 HISTOGRAMS AND CONDITIONAL HISTOGRAMS | 38 |
| 3.2.1 <i>Multipanel histograms from the lattice package</i> | 39 |
| 3.2.2 <i>When is normality of the raw data considered?</i> | 41 |
| 3.3 KERNEL DENSITY PLOTS | 42 |
| 3.4 QUANTILE–QUANTILE PLOTS | 43 |
| 3.4.1 <i>Quantile–quantile plots from the lattice package</i> | 44 |
| 3.5 USING TESTS TO CHECK FOR NORMALITY | 45 |
| 3.6 HOMOGENEITY OF VARIANCE | 47 |
| 3.6.1 <i>Conditional boxplots</i> | 47 |
| 3.6.2 <i>Scatterplots for continuous explanatory variables</i> | 49 |
| 3.7 USING TESTS TO CHECK FOR HOMOGENEITY | 50 |
| 3.7.1 <i>The Bartlett test</i> | 50 |
| 3.7.2 <i>The F-ratio test</i> | 50 |
| 3.7.3 <i>Levene's test</i> | 51 |
| 3.7.4 <i>So which test would you choose?</i> | 51 |

| | |
|--|------------|
| 3.7.5 <i>R</i> code | 51 |
| 3.7.6 Using graphs? | 52 |
| 4 RELATIONSHIPS..... | 55 |
| 4.1 SIMPLE SCATTERPLOTS | 55 |
| 4.1.1 Example: Clam data | 55 |
| 4.1.2 Example: Rabbit data | 57 |
| 4.1.3 Example: Blow fly data | 58 |
| 4.2 MULTIPANEL SCATTERPLOTS | 60 |
| 4.2.1 Example: Polychaeta data | 60 |
| 4.2.2 Example: Bioluminescence data | 61 |
| 4.3 PAIRPLOTS | 62 |
| 4.3.1 Bioluminescence data | 63 |
| 4.3.2 Cephalopod data | 64 |
| 4.3.3 Zoobenthos data | 65 |
| 4.4 CAN WE INCLUDE INTERACTIONS? | 66 |
| 4.4.1 Irish pH data | 66 |
| 4.4.2 Godwit data | 68 |
| 4.4.3 Irish pH data revisited | 70 |
| 4.4.4 Parasite data | 71 |
| 4.5 DESIGN AND INTERACTION PLOTS | 73 |
| 5 COLLINEARITY AND CONFOUNDING..... | 77 |
| 5.1 WHAT IS COLLINEARITY? | 77 |
| 5.2 THE SAMPLE CORRELATION COEFFICIENT | 77 |
| 5.3 CORRELATION AND OUTLIERS | 78 |
| 5.4 CORRELATION MATRICES | 79 |
| 5.5 CORRELATION AND PAIRPLOTS | 80 |
| 5.6 COLLINEARITY DUE TO INTERACTIONS | 82 |
| 5.7 VISUALISING COLLINEARITY WITH CONDITIONAL BOXPLOTS | 83 |
| 5.8 QUANTIFYING COLLINEARITY USING VIFS | 85 |
| 5.8.1 Variance inflation factors | 85 |
| 5.8.2 Geometric presentation of collinearity | 86 |
| 5.8.3 Tolerance | 88 |
| 5.8.4 What constitutes a high VIF value? | 88 |
| 5.8.5 VIFs in action | 89 |
| 5.9 GENERALISED VIF VALUES | 91 |
| 5.10 VISUALISING COLLINEARITY USING PCA BILOT | 93 |
| 5.11 CAUSES OF COLLINEARITY AND SOLUTIONS..... | 94 |
| 5.12 BE STUBBORN AND KEEP COLLINEAR COVARIATES? | 96 |
| 5.13 CONFOUNDING VARIABLES | 97 |
| 5.13.1 Visualising confounding variables | 99 |
| 5.13.2 Confounding factors in time series analysis | 100 |
| 6 CASE STUDY: METHANE FLUXES | 103 |
| 6.1 INTRODUCTION | 103 |
| 6.2 DATA EXPLORATION | 104 |
| 6.2.1 Where in the world are the sites? | 104 |

| | | |
|----------|---|------------|
| 6.2.2 | <i>Working with ggplot2</i> | 105 |
| 6.2.3 | <i>Outliers</i> | 108 |
| 6.2.4 | <i>Collinearity</i> | 111 |
| 6.2.5 | <i>Relationships</i> | 112 |
| 6.2.6 | <i>Interactions</i> | 114 |
| 6.2.7 | <i>Where in the world are the sites (continued)?</i> | 115 |
| 6.3 | STATISTICAL ANALYSIS USING LINEAR REGRESSION | 118 |
| 6.3.1 | <i>Model formulation</i> | 118 |
| 6.3.2 | <i>Fitting a linear regression model</i> | 118 |
| 6.3.3 | <i>Model validation of the linear regression model</i> | 120 |
| 6.3.4 | <i>Interpretation of the linear regression model</i> | 125 |
| 6.4 | STATISTICAL ANALYSIS USING A MIXED EFFECTS MODEL | 131 |
| 6.4.1 | <i>Model formulation</i> | 131 |
| 6.4.2 | <i>Fitting a mixed effects model</i> | 132 |
| 6.4.3 | <i>Model validation of the mixed effects model</i> | 132 |
| 6.4.4 | <i>Interpretation of the linear mixed effects model</i> | 132 |
| 6.5 | CONCLUSIONS | 134 |
| 6.6 | WHAT TO PRESENT IN A PAPER | 134 |
| 7 | CASE STUDY: OYSTERCATCHER SHELL LENGTH | 135 |
| 7.1 | IMPORTING THE DATA | 136 |
| 7.2 | DATA EXPLORATION | 136 |
| 7.3 | APPLYING A LINEAR REGRESSION MODEL | 138 |
| 7.4 | UNDERSTANDING THE RESULTS | 140 |
| 7.5 | TROUBLE | 143 |
| 7.6 | CONCLUSIONS | 146 |
| 8 | CASE STUDY: HAWAIIAN BIRD TIME SERIES | 147 |
| 8.1 | IMPORTING THE DATA | 147 |
| 8.2 | CODING THE DATA | 148 |
| 8.3 | MULTI-PANEL GRAPH USING XYPLOT FROM LATTICE | 148 |
| 8.3.1 | <i>Attempt 1 using xyplot</i> | 149 |
| 8.3.2 | <i>Attempt 2 using xyplot</i> | 150 |
| 8.3.3 | <i>Attempt 3 using xyplot</i> | 151 |
| 8.4 | MULTI-PANEL GRAPH USING GGLOT2 | 153 |
| 8.5 | CONCLUSIONS | 154 |
| | REFERENCES | 155 |
| | INDEX | 159 |
| | BOOKS BY HIGHLAND STATISTICS | 161 |