Quantitative Paleozoology

*Quantitative Paleozoology* describes and illustrates how the remains of long-dead animals recovered from archaeological and paleontological excavations can be studied and analyzed. The methods range from determining how many animals of each species are represented to determining whether one collection consists of more broken and more burned bones than another. All methods are described and illustrated with data from real collections, while numerous graphs illustrate various quantitative properties.

R. LEE LYMAN is professor of anthropology at the University of Missouri-Columbia. A scholar of late Quaternary paleomammology and human prehistory of the Pacific Northwest United States, he is the author of *Vertebrate Taphonomy*, and, most recently, the coeditor of *Zooarchaeology and Conservation Biology*. 
Cambridge Manuals in Archaeology

General Editor
Graeme Barker, University of Cambridge

Advisory Editors
Elizabeth Slater, University of Liverpool
Peter Bogucki, Princeton University

Cambridge Manuals in Archaeology is a series of reference handbooks designed for an international audience of upper-level undergraduate and graduate students and for professional archaeologists and archaeological scientists in universities, museums, research laboratories, and field units. Each book includes a survey of current archaeological practice alongside essential reference material on contemporary techniques and methodology.

Books in the series

Pottery in Archaeology, CLIVE ORTON, PAUL TYERS, and ALAN VINCE
Vertebrate Taphonomy, R. LEE LYMAN
Photography in Archaeology and Conservation, 2nd edition, PETER G. DORRELL
Alluvial Geoarchaeology, A. G. BROWN
Shells, CHERYL CLAASEN
Sampling in Archaeology, CLIVE ORTON
Excavation, STEVE ROSKAMS
Teeth, 2nd edition, SIMON HILLSON
Lithics, 2nd edition, WILLIAM ANDREFSKY, JR.
Geographical Information Systems in Archaeology, JAMES CONOLLY and MARK LAKE
Demography in Archaeology, ANDREW CHAMBERLAIN
Analytical Chemistry in Archaeology, A. M. POLLARD, C. M. BATT, B. STERN, and S. M. M. YOUNG
Zooarchaeology, 2nd edition, ELIZABETH J. REITZ and ELIZABETH S. WING
CONTENTS

List of figures xi
List of tables xvii
Preface xxi

1. Tallying and Counting: Fundamentals 1
   Paleozoological Concepts 4
   Mathematical and Statistical Concepts 8
   Scales of Measurement 8
   Measured and Target Variables: Reliability and Validity 11
   Absolute and Relative Frequencies and Closed Arrays 13
   Discussion 16
   Background of Some Faunal Samples 17

2. Estimating Taxonomic Abundances: NISP and MNI 21
   The Number of Identified Specimens (NISP) 27
   Advantages of NISP 28
   Problems with NISP 29
   Problems, Schmoblems 30
   A Problem We Should Worry About 36
   The Minimum Number of Individuals (MNI) 38
   Strengths(?) of MNI 43
   Problems with MNI 45
   Aggregation 57
   Defining Aggregates 67
   Discussion 69
   Which Scale of Measurement? 71
   Resolution 78
   Conclusion 81
3. Estimating Taxonomic Abundances: Other Methods
   Biomass and Meat Weight 83
   Measuring Biomass 84
   Problems with Measuring Biomass (based on MNI) 85
   Solving Some Problems in Biomass Measurement 86
   Measuring Meat Weight 87
   The Weight Method (Skeletal Mass Allometry) 88
   Bone Weight 89
   Bone Size and Animal Size Allometry 90
   Ubiquity 91
   Matching and Pairing 92
   More Pairs Means Fewer Individuals 93
   The Lincoln–Petersen Index 94
   Identifying Bilateral Pairs 95
   Correcting for Various Things 96
   Size 97
   Discussion 98

4. Sampling, Recovery, and Sample Size 141
   Sampling to Redundancy 143
   Excavation Amount 144
   NISP as a Measure of Sample Redundancy 145
   Volume Excavated or NISP 146
   The Influences of Recovery Techniques 147
   Hand Picking Specimens by Eye 148
   Screen Mesh Size 149
   To Correct or Not to Correct for Differential Loss 150
   Summary 151
   The Species—Area Relationship 152
   Species—Area Curves Are Not All the Same 153
   Nestedness 154
   Conclusion 155

5. Measuring the Taxonomic Structure and Composition (“Diversity”) of Faunas 172
   Basic Variables of Structure and Composition 174
   Indices of Structure and Similarity 175
   Taxonomic Richness 176
   Taxonomic Composition 177
## Taxonomic Heterogeneity

- Taxonomic Evenness 192
- Discussion 198

## Trends in Taxonomic Abundances

- Conclusion 209

## 6. Skeletal Completeness, Frequencies of Skeletal Parts, and Fragmentation

- History of the MNE Quantitative Unit 214
- Determination of MNE Values 215
  - MNE Is Ordinal Scale at Best 218
  - A Digression on Frequencies of Left and Right Elements 222
- Using MNE Values to Measure Skeletal-Part Frequencies 229
  - Modeling and Adjusting Skeletal-Part Frequencies 232
- Measuring Skeletal Completeness 233
  - A Suggestion 241
- Measuring Fragmentation 244
  - Fragmentation Intensity and Extent 245
  - The NISP:MNE Ratio 251
- Discussion 254
- Conclusion 261

## 7. Tallying for Taphonomy: Weathering, Burning, Corrosion, and Butchering

- Yet Another Quantitative Unit 264
- Weathering 266
- Chemical Corrosion and Mechanical Abrasion 267
- Burning and Charring 273
  - A Digression 274
- Gnawing Damage 275
- Butchering Marks 276
  - Types of Butchering Damage 279
  - Tallying Butchering Evidence: General Comments 280
  - Tallying Percussion Damage 281
  - Tallying Cut Marks and Cut Marked Specimens 283
  - The Surface Area Solution 284
- Discussion 286
- Conclusion 291
# Contents

8. Final Thoughts
   Counting as Exploration 299
   
   Glossary 309
   References 313
   Index 345
LIST OF FIGURES

1.1. Chester Stock's pie diagram of abundances of five mammalian orders represented in faunal remains from Rancho La Brea. page 2
2.1. Schematic illustration of loss and addition to a set of faunal remains studied by a paleozoologist. 23
2.2. Taxonomic relative abundances across five strata. 33
2.3. The theoretical limits of the relationship between NISP and MNI. 49
2.4. The theoretically expected relationship between NISP and MNI. 50
2.5. Relationship between NISP and MNI data pairs for mammal remains from the Meier site. 52
2.6. Relationship between NISP and MNI data pairs for the precontact mammal remains from the Cathlapotle site. 53
2.7. Relationship between NISP and MNI data pairs for the postcontact mammal remains from the Cathlapotle site. 54
2.8. Relationship between NISP and MNI data pairs for remains of six mammalian genera in eighty-four owl pellets. 56
2.9. Amount by which a taxon’s MNI increases if the minimum distinction MNI is changed to the maximum distinction MNI in eleven assemblages. 60
2.10. Change in the ratio of deer to gopher abundances in eleven assemblages when MNImax is used instead of MNImin. 61
2.11. Relationships between NISP and MNImin, and NISP and MNImax at site 45DO214. 66
2.12. Ratios of abundances of four least common taxa in a collection of eighty-four owl pellets based on NISP, MNImax, and MNImin. 72
2.13. Frequency distributions of NISP and MNI taxonomic abundances in the Cathlapotle fauna. 73
LIST OF FIGURES

2.14. Frequency distributions of NISP and MNI taxonomic abundances in the 45OK258 fauna in eastern Washington State. 74
2.15. Frequency distributions of NISP and MNI taxonomic abundances in two lumped late-prehistoric mammal assemblages from the western Canadian Arctic. 75
2.16. Frequency distributions of NISP and MNI taxonomic abundances in four lumped historic era mammalian faunas. 76
3.1. Ontogenetic, seasonal, and sexual variation in live weight of one male and one female Columbian black-tailed deer. 88
3.2. Relationship between bone weight per individual and soft-tissue weight in domestic pig. 98
3.3. Relationship between bone weight per skeletal portion and gross weight per skeletal portion in 6-month-old domestic sheep and 90-month-old domestic sheep. 101
3.4. Frequency distributions of biomass per taxon in two sites in Florida State. 106
3.5. Frequency distributions of biomass per mammalian taxon in a site in Georgia State. 107
3.6. Relationship between lateral length of white-tailed deer astragali and body weight. 112
3.7. Relationship between NISP and ubiquity of six genera in a collection of eighty-four owl pellets. 115
3.8. Relationship between NISP and ubiquity of twenty-eight taxa in eighteen sites. 117
3.9. Relationship between NISP and ubiquity of fifteen taxa in seven analytical units in site 45DO189. 119
3.10. Relationship between NISP and ubiquity of eighteen taxa in four analytical units in site 45OK2. 120
3.11. A model of how the Lincoln–Petersen index is calculated. 125
3.12. Latero-medial width of the distal condyle and minimum antero-posterior diameter of the middle groove of the distal condyle of forty-eight pairs of left and right distal humeri of Odocoileus virginianus and Odocoileus hemionus. 131
3.13. A model of how two dimensions of a bone can be used to determine degree of (a)symmetry between bilaterally paired left and right elements. 132
4.1. Cumulative richness of mammalian genera across cumulative volume of sediment excavated annually at the Meier site. 146
4.2. Cumulative richness of mammalian genera across cumulative annual samples from the Meier site.

4.3. Cumulative richness of mammalian genera across cumulative annual samples from Cathlapotle.

4.4. Relationship of mammalian genera richness and sample size per annual sample at the Meier site.

4.5. Relative abundances of fifteen size classes of mollusk shells recovered during hand picking from the excavation, and recovered from fine-mesh sieves.

4.6. The effect of passing sediment through screens or sieves on recovery of mammal remains relative to hand picking specimens from an excavation unit.

4.7. Cumulative percentage recovery of remains of different size classes of mammals.

4.8. Model of the relationship between area sampled and number of taxa identified.

4.9. Two models of the results of rarefaction.

4.10. Rarefaction curve and 95 percent confidence intervals of richness of mammalian genera based on six annual samples from the Meier site.

4.11. Examples of perfectly nested faunas and poorly nested faunas.


5.1. Two fictional faunas with identical taxonomic richness values but different taxonomic evenness.

5.2. Three fictional faunas with varying richness values and varying evenness values.

5.3. Relationship between genera richness and sample size in eighteen mammalian faunas from eastern Washington State.

5.4. Relationships between NISP and NTAXA of small mammals per stratum at Homestead Cave, Utah.

5.5. Relationship between NISP and NTAXA per stratum at Le Flageolet I, France.

5.6. Two Venn diagrams based on the Meier site and Cathlapotle site collections.

5.7. Bivariate scatterplot of relative abundances of mammalian genera at the Meier site and Cathlapotle.

5.8. Rarefaction analysis of eighteen assemblages of mammal remains from eastern Washington State.
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.9</td>
<td>The relationship between taxonomic heterogeneity and sample size in eighteen assemblages of mammal remains from eastern Washington State.</td>
<td>194</td>
</tr>
<tr>
<td>5.10</td>
<td>Frequency distribution of NISP values across six mammalian genera in a collection of owl pellets.</td>
<td>195</td>
</tr>
<tr>
<td>5.11</td>
<td>Relationship between taxonomic evenness and sample size in eighteen assemblages of mammal remains from eastern Washington State.</td>
<td>197</td>
</tr>
<tr>
<td>5.12</td>
<td>Relationship between sample size and the reciprocal of Simpson’s dominance index in eighteen assemblages of mammal remains from eastern Washington State.</td>
<td>198</td>
</tr>
<tr>
<td>5.13</td>
<td>Percentage abundance of deer in eighteen assemblages from eastern Washington State.</td>
<td>202</td>
</tr>
<tr>
<td>5.14</td>
<td>Abundance of bison remains relative to abundance of all ungulate remains over the past 10,500 years in eastern Washington State.</td>
<td>203</td>
</tr>
<tr>
<td>5.15</td>
<td>Bivariate scatterplot of elk abundances relative to the sum of all ungulate remains in eighty-six assemblages from eastern Washington State.</td>
<td>206</td>
</tr>
<tr>
<td>5.16</td>
<td>Bivariate scatterplot of elk—deer index against stratum at Emeryville Shellmound.</td>
<td>208</td>
</tr>
<tr>
<td>5.17</td>
<td>Relative abundances of <em>Neotoma cinerea</em> and <em>Dipodomys</em> spp. at Homestead Cave.</td>
<td>210</td>
</tr>
<tr>
<td>5.18</td>
<td>Bivariate scatterplot of elk abundances relative to the sum of all ungulate remains in eighty-six assemblages from eastern Washington State summed by age for consecutive 500-year bins.</td>
<td>212</td>
</tr>
<tr>
<td>6.1</td>
<td>Relationship of NISP and MNE values for deer remains from the Meier site.</td>
<td>225</td>
</tr>
<tr>
<td>6.2</td>
<td>Relationship of NISP and MNE values for wapiti remains from the Meier site.</td>
<td>225</td>
</tr>
<tr>
<td>6.3</td>
<td>Frequency distributions of NISP and MNE abundances per skeletal part for deer remains from the Meier site.</td>
<td>226</td>
</tr>
<tr>
<td>6.4</td>
<td>Frequency distributions of NISP and MNE abundances per skeletal part for wapiti remains from the Meier site.</td>
<td>227</td>
</tr>
<tr>
<td>6.5</td>
<td>Frequency distribution of skeletal parts in single skeletons of four taxa.</td>
<td>229</td>
</tr>
<tr>
<td>6.6</td>
<td>Comparison of MNE of left skeletal parts and MNE of right skeletal parts in a collection of pronghorn bones.</td>
<td>231</td>
</tr>
</tbody>
</table>
6.7. Frequencies of skeletal elements per category of skeletal element in a single artiodactyl carcass. 234
6.8. MNE and MAU frequencies for a fictional data set. 235
6.9. MNE values plotted against the MNE skeletal model. 236
6.10. MAU values plotted against the MAU skeletal model. 237
6.11. MAU values for two collections with different MNI values. 240
6.12. %MAU values for two collections with different MNI values. 241
6.13. Relationship between Shotwell's CSI per taxon and NISP per taxon for the Hemphill paleontological mammal assemblage. 243
6.14. Relationship between Thomas's CSI per taxon and NISP per taxon for the Smoky Creek zooarchaeological mammal collection. 245
6.15. Bar graph of frequencies of skeletal parts for two taxa. 247
6.16. Model of the relationship between fragmentation intensity and NISP. 253
6.17. Model of the relationship between NISP and MNE. 254
6.18. Relationship between NISP and MNE values for size class II cervids and bovids at Kobeh Cave, Iran. 257
6.19. Relationship between NISP and MNE values for saiga antelope at Prolom II Cave, Ukraine. 258
6.20. Relationship between NISP and MNE values for caprine remains from Neolithic pastoral site of Ngamuriak, Kenya. 260
6.21. Relationship between $\sum$ (lefts + rights) and MNI per skeletal part. 262
7.1. Weathering profiles for two collections of ungulate remains from Olduvai Gorge. 269
7.2. Relationship between years since death and the maximum weathering stage displayed by bones of a carcass. 271
7.3. Weathering profiles based on fictional data for a collection of bones with skyward surfaces representing one profile and groundward surfaces representing another profile. 272
7.4. Frequency distribution of seven classes of burned bones in two kinds of archaeological contexts. 275
7.5. Relationship between number of arm strokes and number of cut marks on thirty-one skeletal elements. 291
7.6. Relationship between number of arm strokes necessary to deflesh a bone and the amount of flesh removed. 293
7.7. Relationship between number of cut marks and the amount of flesh removed from thirty-one limb bones. 293
7.8. Relationships between number of cut marks and the amount of flesh removed from six hindlimbs in each of three carcass sizes. 295
7.9. Relationship between number of cut marks and the amount of flesh removed from eighteen hindlimbs. 295
8.1. Relationship between NISP and MNI in seven paleontological assemblages of bird remains from North America. 304
8.2. Relationship between NISP and MNI in eleven paleontological assemblages of mammal remains from North America. 304
8.3. Relationship between NISP and MNI in twenty-two archaeological assemblages of bird remains from North America. 305
8.4. Relationship between NISP and MNI in thirty-five archaeological assemblages of mammal remains from North America. 306
LIST OF TABLES

1.1. An example of the Linnaean taxonomy.  
1.2. Fictional data on the absolute abundances of two taxa in six chronologically sequent strata.  
1.3. Description of the mammalian faunal record at Meier and at Cathlapotle.  
2.1. Fictional data on abundances of three taxa in five strata.  
2.2. Data in Table 2.1 adjusted as if each individual of taxon A had ten skeletal elements per individual, taxon B had one skeletal element per individual, and taxon C had five skeletal elements per individual.  
2.3. The differential exaggeration of sample sizes by NISP.  
2.4. Some published definitions of MNI.  
2.5. A fictional sample of seventy-one skeletal elements representing a minimum of seven individuals.  
2.7. Statistical summary of the relationship between NISP and MNI for mammal assemblages from fourteen archaeological sites in eastern Washington State.  
2.8. Maximum distinction and minimum distinction MNI values for six genera of mammals in a sample of eighty-four owl pellets.  
2.9. Adams's data for calculating MNI values based on Odocoileus sp. remains.  
2.10. Differences in site total MNI between the MNI minimum distinction results and the MNI maximum distinction results.  
2.11. The most abundant skeletal part representing thirteen mammalian genera in two (sub)assemblages at Cathlapotle.
2.12. Fictional data showing how the distribution of most abundant skeletal elements of one taxon can influence MNI across different aggregates. 63
2.13. Fictional data showing how the distribution of skeletal elements of two taxa across different aggregates can influence MNI. 64
2.14. Fictional data showing that identical distributions of most common skeletal elements of two taxa across different aggregates will not influence MNI. 65
2.15. Ratios of abundances of pairs of taxa in eighty-four owl pellets. 72
3.1. Biomass of deer and wapiti at Cathlapotle. 86
3.2. Meat weight for deer and wapiti at Cathlapotle, postcontact assemblage. 90
3.3. Comparison of White’s conversion values to derive usable meat with Stewart and Stahl’s conversion values to derive usable meat. 91
3.4. Variation by age and sex of wapiti butchered weight as a percentage of live weight. 92
3.5. Weight of a 350-kilogram male wapiti in various stages of butchering. 93
3.6. Descriptive data on animal age, bone weight per individual, and soft-tissue weight per individual domestic pig. 97
3.7. Statistical summary of the relationship between bone weight and weight of various categories of soft-tissue for domestic pig. 98
3.8. Descriptive data on dry bone weight per anatomical portion and total weight per anatomical portion for domestic sheep. 100
3.9. Statistical summary of the relationship between bone weight and gross weight or biomass of skeletal portions of two domestic sheep. 101
3.10. Relationship between NISP and bone weight of mammalian taxa in seventeen assemblages. 104
3.11. Results of applying the bone-weight allometry equation to five randomly generated collections of domestic sheep bone. 105
3.12. Deer astragalus length and live weight. 110
3.13. Ubiquity and sample size of twenty-eight mammalian taxa in eighteen sites. 116
3.14. Ubiquity and sample size of mammalian taxa across analytical units in two sites. 118
3.15. Fictional data illustrating influences of NISP and the number of pairs on the Lincoln–Petersen index. 126
3.16. Abundances of beaver and deer remains at Cathlapotle, and WAE values and ratios of NISP and WAE values per taxon per assemblage. 135
3.17. Estimates of individual body size of seventeen white-tailed deer based on the maximum length of right and left astragali. 139

4.1. Volume excavated and NISP of mammals per annual field season at the Meier site. 144

4.2. Annual NISP samples of mammalian genera at the Meier site. 145

4.3. Annual NISP samples of mammalian genera at Cathlapotle. 147

4.4. Mammalian NISP per screen-mesh size class and body-size class for three sites. 155

4.5. Two sets of faunal samples showing a perfectly nested set of faunas and a poorly nested set of faunas. 169

5.1. Sample size, taxonomic richness, taxonomic heterogeneity, taxonomic evenness, and taxonomic dominance of mammalian genera in eighteen assemblages from eastern Washington State. 181

5.2. \( \sum \) NISP and NTAXA for small mammals at Homestead Cave, Utah. 183

5.3. \( \sum \) NISP and NTAXA for ungulates at Le Flageolet I, France. 184

5.4. NISP per taxon in two chronologically distinct samples of eighty-four owl pellets. 188

5.5. Expected values and interpretation of taxonomic abundances in two temporally distinct assemblages of owl pellets. 188

5.6. Derivation of the Shannon—Wiener index of heterogeneity for the Meier site. 193

5.7. Total NISP of mammals, NISP of deer, and relative abundance of deer in eighteen assemblages from eastern Washington State. 199

5.8. Frequencies of bison and nonbison ungulates per time period in ninety-one assemblages from eastern Washington State. 204

5.9. Frequencies of elk, deer, and medium artiodactyl remains per stratum at Emeryville Shellmound. 207

5.10. Frequencies of two taxa of small mammal per stratum at Homestead Cave. 209

6.1. MNE values for six major limb bones of ungulates from the FLK Zinjanthropus site. 219

6.2. Fictional data showing how the distribution of specimens of two skeletal elements across different aggregates can influence MNE. 223

6.3. NISP and MNE per skeletal part of deer and wapiti at the Meier site. 224

6.4. Frequencies of major skeletal elements in a single mature skeleton of several common mammalian taxa. 228

6.5. MNE frequencies of left and right skeletal parts of pronghorn from site 39FA83. 230
### List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.6</td>
<td>Expected MNE frequencies of pronghorn skeletal parts at site 39FA83, and adjusted residuals and probability values for each.</td>
<td>232</td>
</tr>
<tr>
<td>6.7</td>
<td>Frequencies of skeletal elements in a single generic artiodactyl skeleton.</td>
<td>233</td>
</tr>
<tr>
<td>6.8</td>
<td>MNE and MAU frequencies of skeletal parts and portions.</td>
<td>236</td>
</tr>
<tr>
<td>6.9</td>
<td>MAU and%MAU frequencies of bison from two sites.</td>
<td>239</td>
</tr>
<tr>
<td>6.10</td>
<td>Skeletal-part frequencies for two taxa of artiodactyl.</td>
<td>246</td>
</tr>
<tr>
<td>6.11</td>
<td>Expected frequencies of deer and wapiti remains at Meier, adjusted residuals, and probability values for each.</td>
<td>249</td>
</tr>
<tr>
<td>6.12</td>
<td>Ratios of NISP:MNE for four long bones of deer in two sites on the coast of Oregon State.</td>
<td>252</td>
</tr>
<tr>
<td>6.13</td>
<td>African bovid size classes.</td>
<td>255</td>
</tr>
<tr>
<td>6.14</td>
<td>NISP and MNE frequencies of skeletal parts of bovid/cervid size class II remains from Kobeh Cave, Iran.</td>
<td>256</td>
</tr>
<tr>
<td>6.15</td>
<td>NISP and MNE frequencies of skeletal parts of saiga antelope from Prolom II Cave, Ukraine.</td>
<td>257</td>
</tr>
<tr>
<td>6.16</td>
<td>Relationship between NISP and MNE in twenty-nine assemblages.</td>
<td>259</td>
</tr>
<tr>
<td>6.17</td>
<td>NISP and MNI frequencies of skeletal parts of caprines from Ngamuriak, Kenya.</td>
<td>260</td>
</tr>
<tr>
<td>6.18</td>
<td>Relationship between NISP and MNI per skeletal part or portion in twenty-two assemblages.</td>
<td>261</td>
</tr>
<tr>
<td>7.1</td>
<td>Weathering stages as defined by Behrensmeyer.</td>
<td>267</td>
</tr>
<tr>
<td>7.2</td>
<td>Weathering stage data for two collections of mammal remains from Olduvai Gorge.</td>
<td>268</td>
</tr>
<tr>
<td>7.3</td>
<td>Expected frequencies of specimens per weathering stage in two collections, adjusted residuals, and probability values for each.</td>
<td>269</td>
</tr>
<tr>
<td>7.4</td>
<td>Frequencies of cut marks per anatomical area on six experimentally butchered goat hindlimbs.</td>
<td>288</td>
</tr>
<tr>
<td>7.5</td>
<td>Frequencies of arm strokes and cut marks on sixteen limbs of cows and horses.</td>
<td>290</td>
</tr>
<tr>
<td>7.6</td>
<td>Number of cut marks generated and amount of meat removed from eighteen mammal hindlimbs by butchering.</td>
<td>294</td>
</tr>
<tr>
<td>8.1</td>
<td>Statistical summary of relationship between NISP and MNI in collections of paleontological birds, paleontological mammals, archaeological birds, and archaeological mammals.</td>
<td>303</td>
</tr>
</tbody>
</table>
Several years ago I had the opportunity to have a relaxed discussion with my doctoral advisor, Dr. Donald K. Grayson. In the course of that discussion, I asked him if he would ever revise his then 20-year-old book titled *Quantitative Zooarchaeology*, which had been out of print for at least a decade. He said “No” and explained that the topic had been resolved to his satisfaction such that he could do the kinds of analyses he wanted to do. A spur-of-the-moment thought prompted me to ask, “What if I write a revision?” by which I meant not literally a revised edition but instead a new book that covered some of the same ground but from a 20-years-later perspective. Don said that he thought that was a fine idea.

After the conversation with Grayson, I began to mentally outline what I would do in the book. I realized that it would be a good thing for me to write such a book because, although I thought I understood many of the arguments Grayson had made regarding the counting of animal remains when I was a graduate student, there were other arguments made by other investigators subsequent to the publication of Grayson’s book that I didn’t know (or if I knew of those arguments, I wasn’t sure I understood them very well). I also knew that the only way for me to learn a topic well was to write about it because such a task forced me to learn its nuances, its underpinning assumptions, the interrelations of various aspects of the argument, and all those things that make an approach or analytical technique work the way that it does (or not work as it is thought to, as the case may be).

As I mentally outlined the book over the next several months, it occurred to me that at least one new quantitative unit similar to the traditional ones Grayson had considered had become a focus of analytical attention over the two decades subsequent to the publication of Grayson’s book (MNE, and the related MAU). And an increasing number of paleozoologists were measuring taxonomic diversity – a term that had several different meanings for several different variables as well as being measured several different ways. What were those measurement techniques and
what were those measured variables? Finally, there were other kinds of phenomena that zooarchaeologists and paleontologists had begun to regularly tally and analyze. These phenomena – butchering marks, carnivore gnawing marks, rodent gnawing marks, burned bones – had become analytically important as paleozoologists had come to realize that to interpret the traditional quantitative measures of taxonomic abundances, potential biases in those measures caused by differential butchery, carnivore attrition, and the like across taxa had to be accounted for. As I indicate in this volume, there are several ways to tally up carnivore gnawing marks and the like, and few analysts have explored the fact that each provides a unique result.

Finally, it had become clear to me during the 1990s that many paleozoologists were unaware of what I took to be two critical things. First, zooarchaeologists seemed to seldom notice what is published in paleontological journals; at least they seldom referenced that literature. Thus, they were often ignorant of various suggestions made by paleontologists regarding quantitative methods. Paleontologists were equally unaware of what zooarchaeologists have determined regarding quantification of bones and shells and teeth. Therefore, it seemed best to title this volume *Quantitative Paleozoology* for the simple reason that were it to be titled “Quantitative Zooarchaeology,” it likely would not be read by paleontologists. A very interesting book with the title *Quantitative Zoology* coauthored by a paleontologist (Simpson et al. 1960) already exists, so that title could not be used, aside from it being misleading. *Quantitative Paleozoology* is a good title for two reasons. The first reason is that the subject materials, whether collected by a paleontologist or an archaeologist, do not have a proximate zoological source (though their source is ultimately zoological) but rather have a proximate geological source, whether paleontological (without associated human artifacts) or archaeological (with associated and often causally related human artifacts). I conceive of all such remains as paleozoological. The second reason *Quantitative Paleozoology* is a good title is that the volume concerns how to count or tally, how to quantify zoological materials and their attributes, specifically those zoological remains recovered from geological contexts. Not all such topics are discussed here, but many are; for an introduction to many of those that are not, see Simpson et al. (1960), a still-useful book that was, fortunately, reprinted in 2003.

The second critical thing that many paleozoologists seem to be unaware of is basic statistical concepts and methods. I was stunned in 2004 to learn that an anonymous individual who had reviewed a manuscript I submitted for publication did not know what a “closed array” was and therefore did not understand why my use of this particular analytical tool could have been influencing (some might say biasing, but that is a particular kind of influencing) the statistical results. In the 1960s and early 1970s, many archaeologists and paleontologists did not have very high levels of statistical sophistication; I had thought that most of them did have such sophistication (or at
least knowledge of the basics) in the twenty-first century. The anonymous reviewer’s comments indicate that at least some of them do not. Therefore, it seemed that any book on quantitative paleozoology had to include brief discussions of various statistical and mathematical concepts. In order to not dilute the central focus of the volume—quantitative analysis of paleozoological remains—I have kept discussion of statistical methods to a minimum, assuming that the serious reader will either already know what is necessary or will learn it as he or she reads the book. I have, however, devoted the first chapter to several critical mathematical concepts as well as some key paleozoological concepts.

Many of the faunal collections used to illustrate various points in the text were provided over the years by friends and colleagues who entrusted me with the analysis of those collections. Many of the things I have learned about quantitative paleozoology are a direct result of their trust. To these individuals, I offer my sincere thanks: Kenneth M. Ames, David R. Brauner, Jerry R. Galm, Stan Gough, Donald K. Grayson, David Kirkpatrick, Lynn Larson, Frank C. Leonhardy, Dennis Lewarch, Michael J. O’Brien, Richard Pettigrew, and Richard Ross. Perhaps more importantly, any clarity this book brings to the issues covered herein is a result of the collective demand for clarity by numerous students who sat through countless lectures about the counting units and methods discussed in this book. A major source of inspiration for the first several chapters was provided in 2004 by the Alaska Consortium of Zooarchaeologists (ACZ). That group invited me to give a daylong workshop on the topics of quantification and taphonomy, and that forced me to think through several things that had previously seemed less than important. I especially thank Diane Hansen and Becky Saleeby of the ACZ for making that workshop experience memorable.

An early draft of the manuscript was reviewed by Jack Broughton, Corey Hudson, Alex Miller, and an anonymous individual. Broughton and the anonymous reviewer ensured that a minimum of both glaring errors in logic and stupid errors in mathematics remain in this version. Broughton and the anonymous reviewer insisted that I include several recently described analytical techniques, and they identified where I overstepped and where I misstepped. These individuals deserve credit for many of the good things here.

I wrote much of the first draft of this volume between July 2005 and August 2006. During that time, I lost my younger brother and both parents. They all had an indirect hand in this book. My parents taught me to hunt and fish, and all of the things that accompany those activities. My brother did not discourage me from collecting owl pellets from his farm equipment shed, or laugh too hard when I collected them; he even grew to appreciate what could be learned from the mouse bones they contained. I miss them all, and I dedicate this book to the three of them.

June 2007