Assignment_2_Thrisha Rajkumar

Thrisha Rajkumar

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#Assignment 2

1. Data Wrangling

1.1 (Q1) Select and filter

(Q1). Use a combination of the select() and filter() functions to generate a data frame called "hSF" which is a sub-table of the original Hawks data frame, such that 1. Your data frame should include the columns: a) "Wing" b) "Weight" c) "Tail" 2. Your data frame should contain a row for every hawk such that: a) They belong to the species of Red-Tailed hawks b) They have weight at least 1kg. 3. Use the pipe operator "%>%" to simplify your code.

1.1 (Q2)

```r
# Load required packages
library(Stat2Data)
library(tidyverse)
```

```
## -- Attaching core tidyverse packages ------------------------ tidyverse 2.0.0 --
## v dplyr     1.1.4     v readr     2.1.5
## v forcats   1.0.0     v stringr   1.5.1
## v ggplot2   3.5.1     v tibble    3.2.1
## v lubridate 1.9.3     v tidyr     1.3.1
## v purrr     1.0.2
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
## i Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors
```

```r
library(dplyr)
library(knitr)
#Load the Hawks data frame
data(Hawks)

#View the first few rows of the data
head(Hawks)
```

```
##   Month Day Year CaptureTime ReleaseTime  BandNumber Species Age Sex Wing
## 1     9  19 1992       13:30               877-76317      RT   I       385
## 2     9  22 1992       10:30               877-76318      RT   I       376
## 3     9  23 1992       12:45               877-76319      RT   I       381
## 4     9  23 1992       10:50               745-49508      CH   I   F   265
## 5     9  27 1992       11:15              1253-98801      SS   I   F   205
## 6     9  28 1992       11:25             1207-55910       RT   I       412
##   Weight Culmen Hallux Tail StandardTail Tarsus WingPitFat KeelFat Crop
## 1    920   25.7   30.1  219           NA     NA         NA      NA   NA
## 2    930     NA     NA  221           NA     NA         NA      NA   NA
## 3    990   26.7   31.3  235           NA     NA         NA      NA   NA
## 4    470   18.7   23.5  220           NA     NA         NA      NA   NA
## 5    170   12.5   14.3  157           NA     NA         NA      NA   NA
## 6   1090   28.5   32.2  230           NA     NA         NA      NA   NA
```

```
# Get the column headers
column_headers <- colnames(Hawks)

# Print the column headers
print(column_headers)
```

```
##  [1] "Month"        "Day"          "Year"         "CaptureTime"  "ReleaseTime"
##  [6] "BandNumber"   "Species"      "Age"          "Sex"          "Wing"
## [11] "Weight"       "Culmen"       "Hallux"       "Tail"         "StandardTail"
## [16] "Tarsus"       "WingPitFat"   "KeelFat"      "Crop"
```

```
# Get unique species
unique_species <- unique(Hawks$Species)

# Print the unique species
print(unique_species)
```

```
## [1] RT CH SS
## Levels: CH RT SS
```

```
ncol(Hawks)
```

```
## [1] 19
```

```
# Filter and select relevant columns
hSF <- Hawks %>%
  filter(Species == "RT", Weight >= 1000) %>%
  select(Wing, Weight, Tail)


# Print the filtered data
print(hSF)
```

```
##      Wing Weight Tail
## 1   412.0   1090  230
## 2   412.0   1210  210
```

```
## 3   405.0   1120  238
## 4   393.0   1010  222
## 5   371.0   1010  217
## 6   390.0   1120  213
## 7   416.0   1170  243
## 8   436.0   1390  232
## 9   418.0   1150  238
## 10  396.0   1010  227
## 11  399.0   1070  222
## 12  416.0   1190  237
## 13  392.0   1330  213
## 14  399.0   1100  190
## 15  401.0   1190  245
## 16  427.0   1490  246
## 17  395.0   1040  207
## 18  396.0   1030  200
## 19  391.0   1300  215
## 20  413.0   1500  219
## 21  371.0   1080  198
## 22  385.0   1320  207
## 23  378.0   1490  204
## 24  416.0   1500  205
## 25  384.0   1060  230
## 26  382.0   1140  227
## 27  390.0   1030  208
## 28  390.0   1000  231
## 29  393.0   1050  222
## 30  378.0   1040  225
## 31  398.0   1110  225
## 32  412.0   1300  233
## 33  422.0   1120  233
## 34  394.0   1270  245
## 35  410.0   1255  229
## 36  241.0   1320  235
## 37  408.0   1320  221
## 38   37.2   1180  210
## 39  396.0   1250  225
## 40  416.0   1300  235
## 41  390.0   1080  209
## 42  391.0   1130  212
## 43  387.0   1160  209
## 44  420.0   1345  250
## 45  435.0   1385  235
## 46  400.0   1210  222
## 47  398.0   1455  236
## 48  395.0   1180  210
## 49  410.0   1500  239
## 50  369.0   1025  228
## 51  415.0   1360  233
## 52  412.0   1255  236
## 53  375.0   1065  216
## 54  385.0   1125  233
## 55  422.0   1340  248
## 56  391.0   1050  221
```

```
## 57  410.0   1210  227
## 58  381.0   1000  219
## 59  416.0   1390  225
## 60  406.0   1275  238
## 61  418.0   1180  235
## 62  412.0   1210  222
## 63  405.0   1085  238
## 64  428.0   1240  245
## 65  381.0   1010  210
## 66  420.0   1210  241
## 67  395.0   1170  238
## 68  406.0   1350  235
## 69  414.0   1370  240
## 70  423.0   1310  234
## 71  365.0   1035  232
## 72  391.0   1125  220
## 73  392.0   1140  214
## 74  410.0   1210  238
## 75  422.0   1205  238
## 76  385.0   1045  229
## 77  363.0   1090  202
## 78  450.0   1190  226
## 79  385.0   1110  122
## 80  384.0   1075  208
## 81  363.0   1070  204
## 82  409.0   1120  229
## 83  390.0   1060  205
## 84  420.0   1125  244
## 85  381.0   1100  225
## 86  408.0   1360  239
## 87  398.0   1095  209
## 88  394.0   1075  211
## 89  394.0   1140  216
## 90  416.0   1240  250
## 91  445.0   1465  260
## 92  388.0   1105  217
## 93  397.0   1010  228
## 94  384.0   1075  218
## 95  379.0   1060  220
## 96  393.0   1015  227
## 97  386.0   1100  211
## 98  397.0   1010  222
## 99  382.0   1000  225
## 100 417.0   1240  231
## 101 403.0   1360  235
## 102 401.0   1405  235
## 103 377.0   1055  200
## 104 432.0   1670  216
## 105 390.0   1250  223
## 106 381.0   1030  210
## 107 403.0   1040  229
## 108 390.0   1090  226
## 109 386.0   1050  207
## 110 402.0   1110  238
```

```
## 111 374.0   1010  197
## 112 370.0   1060  215
## 113 398.0   1195  230
## 114 375.0   1110  224
## 115 409.0   1100  215
## 116 415.0   1285  239
## 117 381.0   1025  232
## 118 398.0   1240  243
## 119 412.0   1160  255
## 120 411.0   1240  276
## 121 415.0   1240  231
## 122 383.0   1030  216
## 123 390.0   1250  210
## 124 365.0   1120  260
## 125 345.0   1000  200
## 126 400.0   1040  230
## 127 380.0   1150  220
## 128 330.0   1000  220
## 129 410.0   1360  235
## 130 409.0   1260  221
## 131 411.0   1300  238
## 132 380.0   1040  212
## 133 415.0   1320  235
## 134 410.0   1280  229
## 135 412.0   1310  251
## 136 404.0   1220  225
## 137 410.0   1135  267
## 138 398.0   1280  248
## 139 425.0   1220  241
## 140 401.0   1000  212
## 141 387.0   1120  221
## 142 420.0   1280  230
## 143 405.0   1350  226
## 144 398.0   1020  217
## 145 410.0   1000  230
## 146 382.0   1020  225
## 147 111.0   1340  226
## 148 396.0   1300  214
## 149 363.0   1015  242
## 150 390.0   1000  250
## 151 390.0   1050  220
## 152 415.0   1175  230
## 153 417.0   1260  234
## 154 379.0   1050  226
## 155 412.0   1330  218
## 156 420.0   1540  235
## 157 368.0   1060  223
## 158 406.0   1420  245
## 159 392.0   1142  235
## 160 352.0   1024  216
## 161 370.0   1023  216
## 162 368.0   1244  220
## 163 368.0   1244  220
## 164 400.0   1289  242
```

```
## 165 362.0   1004  221
## 166 378.0   1097  236
## 167 372.0   1092  235
## 168 369.0   1049  231
## 169 367.0   1091  238
## 170 375.0   1151  249
## 171 360.0   1159  240
## 172 395.0   1239  231
## 173 400.0   1216  227
## 174 369.0   1039  223
## 175 365.0   1079  228
## 176 375.0   1159  242
## 177 382.0   1403  247
## 178 478.0   1473  267
## 179 469.0   1001  257
## 180 386.0   1059  214
## 181 384.0   1147  229
## 182 374.0   1064  201
## 183 374.0   1213  244
## 184 389.0   1200  230
## 185 379.0   1040  227
## 186 403.0   1487  240
## 187 400.0   1254  237
## 188 405.0   1189  210
## 189 407.0   1339  246
## 190 403.0   1199  225
## 191 406.0   1344  230
## 192 395.0   1039  230
## 193 410.0   1054  233
## 194 425.0   1449  232
## 195 480.0   1598  239
## 196 381.0   1354  213
## 197 382.0   1080  214
## 198 391.0   1097  217
## 199 397.0   1439  216
## 200 376.0   1019  216
## 201 410.0   1239  222
## 202 381.0   1399  288
## 203 396.0   1169  238
## 204 383.0   1164  199
## 205 395.0   1215  236
## 206 370.0   1030  225
## 207 391.0   1165  241
## 208 364.0   1044  210
## 209 381.0   1080  223
## 210 392.0   1105  229
## 211 398.0   1310  211
## 212 367.0   1060  204
## 213 408.0   1270  236
## 214 399.0   1170  247
## 215 388.0   1225  227
## 216 370.0   1060  225
## 217 371.0   1145  215
## 218 386.0   1090  226
```

```
## 219 400.0   1345  227
## 220 390.0   1050  236
## 221 382.0   1040  210
## 222 403.0   1105  242
## 223 375.0   1045  221
## 224 368.0   1015  219
## 225 393.0   1385  225
## 226 370.0   1165  221
## 227 410.0   1460  216
## 228 410.0   1585  130
## 229 390.0   1460  221
## 230 404.0   1315  220
## 231 375.0   1019  186
## 232 395.0   1215  217
## 233 379.0   1005  209
## 234 382.0   1350  215
## 235 404.0   1145  214
## 236 377.0   1010  207
## 237 390.0   1120  210
## 238 394.0   1210  207
## 239 376.0   1145  226
## 240 399.0   1150  232
## 241 399.0   1560  228
## 242 400.0   1089  228
## 243 382.0   1194  237
## 244 390.0   1015  230
## 245 376.0   1035  223
## 246 331.0   1055  210
## 247 394.0   1220  234
## 248 358.0   1025  204
## 249 380.0   1000  204
## 250 397.0   1210  224
## 251 392.0   1185  229
## 252 412.0   1150  230
## 253 391.0   1120  225
## 254 410.0   1120  229
## 255 410.0   1200  247
## 256 425.0   1120  222
## 257 368.0   1120  220
## 258 392.0   1220  234
## 259 418.0   1310  248
## 260 408.0   1225  225
## 261 393.0   1400  215
## 262 365.0   1025  225
## 263 405.0   1140  244
## 264 381.0   1080  232
## 265 390.0   1135  238
## 266 384.0   1430  231
## 267 390.0   1050  218
## 268 400.0   1225  222
## 269 387.0   1090  227
## 270 409.0   1350  235
## 271 400.0   1190  231
## 272 403.0   1310  237
```

```
## 273 373.0   1270  207
## 274 394.0   1290  225
## 275 377.0   1045  223
## 276 364.0   1090  218
## 277 385.0   1180  222
## 278 390.0   1195  235
## 279 383.0   1055  208
## 280 365.0   1025  216
## 281 402.0   1335  219
## 282 394.0   1085  235
## 283 378.0   1090  212
## 284 378.0   1090  201
## 285 262.0   1020  200
## 286 379.0   1000  217
## 287 380.0   1085  223
## 288 380.0   1045  199
## 289 393.0   1060  217
## 290 389.0   1135  207
## 291 395.0   1210  222
## 292 377.0   1125  220
## 293 385.0   1195  216
## 294 363.0   1005  222
## 295 405.0   1170  226
## 296 392.0   1085  210
## 297 395.0   1115  235
## 298 390.0   1195  222
## 299 389.0   1165  223
## 300 385.0   1085  216
## 301 378.0   1030  218
## 302 373.0   1015  215
## 303 419.0   1030  224
## 304 414.0   1215  242
## 305 404.0   1170  237
## 306 379.0   1435  221
## 307 407.0   1235  243
## 308 376.0   1055  222
## 309 380.0   1105  208
## 310 408.0   1390  245
## 311 374.0   1080  206
## 312 372.0   2030  196
## 313 389.0   1265  210
## 314 404.0   1300  224
## 315 395.0   1170  218
## 316 368.0   1075  213
## 317 377.0   1095  206
## 318 277.0   1500  207
## 319 435.0   1595  230
## 320 393.0   1225  226
## 321 402.0   1255  242
## 322 362.0   1305  234
## 323 388.0   1185  225
## 324 392.0   1030  214
## 325 412.0   1215  230
## 326 371.0   1075  220
```

```
## 327 385.0   1225  225
## 328 400.0   1315  230
## 329 395.0   1155  233
## 330 403.0   1160  235
## 331 361.0   1030  231
## 332 377.0   1040  225
## 333 375.0   1005  226
## 334 401.0   1250  230
## 335 407.0   1275  238
## 336 375.0   1030  217
## 337 406.0   1290  227
## 338 386.0   1020  230
## 339 378.0   1055  217
## 340 379.0   1010  216
## 341 364.0   1015  215
## 342 350.0   1115  199
## 343 380.0   1320  210
## 344 395.0   1180  217
## 345 372.0   1145  212
## 346 367.0   1045  215
## 347 386.0   1065  221
## 348 375.0   1110  215
## 349 405.0   1255  218
## 350 371.0   1015  204
## 351 368.0   1090  216
## 352 372.0   1085  220
## 353 396.0   1065  230
## 354 365.0   1125  213
## 355 374.0   1050  220
## 356 376.0   1180  214
## 357 369.0   1095  215
## 358 391.0   1330  217
## 359 397.0   1100  219
## 360 366.0   1115  215
## 361 385.0   1400  211
## 362 400.0   1175  234
## 363 384.0   1260  226
## 364 396.0   1195  228
## 365 391.0   1035  221
## 366 393.0   1155  223
## 367 397.0   1260  232
## 368 384.0   1010  230
## 369 396.0   1240  237
## 370 428.0   1290  253
## 371 364.0   1150  196
## 372 400.0   1130  227
## 373 398.0   1205  227
## 374 385.0   1040  238
## 375 372.0   1010  197
## 376 400.0   1285  230
## 377 403.0   1350  140
## 378 375.0   1010  218
## 379 385.0   1370  233
## 380 392.0   1250  222
```

```
## 381 415.0   1285  242
## 382 380.0   1005  205
## 383 411.0   1220  236
## 384 393.0   1265  233
## 385 370.0   1020  211
## 386 371.0   1160  218
## 387 400.0   1585  241
## 388 382.0   1140  218
## 389 371.0   1115  208
## 390 370.0   1145  212
## 391 392.0   1030  196
## 392 387.0   1065  212
## 393 400.0   1050  237
## 394 370.0   1000  201
## 395 360.0   1325  224
## 396 402.0   1350  219
## 397 380.0   1525  224
## 398 199.0   1290  222
```

1.1 (Q2)

How many variables does the data frame hSF have?

–> In my assignment to understand the column headers in the Hawks data frame –> Get the column headers column_headers <- colnames(Hawks) which provides the column names i.e. variables in a vector form.

–> ncol(Hawks) will give you the number of columns or variables in the dataframe.

```r
ncol(Hawks)
```

```
## [1] 19
```

What would you say to communicate this information to a Machine Learning Practitioner?

–> To communicate the above Information to a Machine Learning Practitoner I would mention the features or variables in use which is Species name =Red Tailed Hawks, Weight of the hawks above 1000 g / 1 kg, wing and Tail.

–>The importance of the number of variables for model complexity.

–>The choices of the variables taken for the model performance.

How many examples does the data frame hSF have? How many observations ? How many cases?

```r
num_observations <- nrow(hSF)
print(num_observations)
```

```
## [1] 398
```

##1.2 (Q1) The arrange function ....

```
sorted_hSF <- hSF %>%
  arrange(Wing)

head(sorted_hSF, 5)
```

```
##    Wing Weight Tail
## 1  37.2   1180  210
## 2 111.0   1340  226
## 3 199.0   1290  222
## 4 241.0   1320  235
## 5 262.0   1020  200
```

##1.3 (Q1) Join and rename functions

(Q1). Use data.frame() to create a data frame that is called hawkSpeciesNameCodes and is the same as the above data frame (i.e., containing the correspondence between codes and the full species names).

```
species_code <- c("CH", "RT", "SS")
species_name_full <- c("Cooper's", "Red-tailed", "Sharp-shinned")
hawkSpeciesNameCodes <- data.frame(species_code, species_name_full)

print(hawkSpeciesNameCodes)
```

```
##   species_code species_name_full
## 1           CH          Cooper's
## 2           RT        Red-tailed
## 3           SS     Sharp-shinned
```

##1.3 (Q2)

(Q2). Use a combination of the functions left_join(), the rename() and the select() functions to create a new data frame called "hawksFullName" which is the same as the "Hawks" data frame except that the Species column contains the full names rather than the two-letter codes.

```
install.packages("dplyr")
```

```
## Warning: package 'dplyr' is in use and will not be installed
```

```
library(dplyr)


hawksFullName <- Hawks %>%
  left_join(hawkSpeciesNameCodes, by = c("Species" = "species_code")) %>%
  select(Species = species_name_full, Wing, Weight)

print(hawksFullName)
```

```
##           Species  Wing Weight
## 1      Red-tailed 385.0    920
## 2      Red-tailed 376.0    930
```

```
## 3      Red-tailed 381.0    990
## 4         Cooper's 265.0    470
## 5   Sharp-shinned 205.0    170
## 6      Red-tailed 412.0   1090
## 7      Red-tailed 370.0    960
## 8      Red-tailed 375.0    855
## 9      Red-tailed 412.0   1210
## 10     Red-tailed 405.0   1120
## 11     Red-tailed 393.0   1010
## 12     Red-tailed 371.0   1010
## 13     Red-tailed 390.0   1120
## 14     Red-tailed 393.0     NA
## 15     Red-tailed 416.0   1170
## 16     Red-tailed 436.0   1390
## 17     Red-tailed 418.0   1150
## 18     Red-tailed 381.0    950
## 19     Red-tailed 378.0    910
## 20     Red-tailed 396.0   1010
## 21     Red-tailed 399.0   1070
## 22     Red-tailed 416.0   1190
## 23     Red-tailed 415.0    101
## 24     Red-tailed 392.0   1330
## 25     Red-tailed 380.0    990
## 26  Sharp-shinned 173.0    100
## 27     Red-tailed 399.0   1100
## 28     Red-tailed 401.0   1190
## 29  Sharp-shinned 205.0    180
## 30     Red-tailed 427.0   1490
## 31     Red-tailed 395.0   1040
## 32     Red-tailed 362.0    820
## 33     Red-tailed 396.0   1030
## 34     Red-tailed 391.0   1300
## 35     Red-tailed 413.0   1500
## 36     Red-tailed 371.0   1080
## 37     Red-tailed 385.0   1320
## 38     Red-tailed 378.0   1490
## 39     Red-tailed 416.0   1500
## 40  Sharp-shinned 193.0    100
## 41  Sharp-shinned 171.0     88
## 42        Cooper's 233.0    324
## 43     Red-tailed 384.0   1060
## 44     Red-tailed 382.0   1140
## 45     Red-tailed 390.0   1030
## 46     Red-tailed 390.0   1000
## 47     Red-tailed 393.0   1050
## 48     Red-tailed 378.0   1040
## 49     Red-tailed 398.0   1110
## 50     Red-tailed 412.0   1300
## 51     Red-tailed 400.0    980
## 52     Red-tailed 422.0   1120
## 53  Sharp-shinned 202.0    134
## 54     Red-tailed 394.0   1270
## 55     Red-tailed 369.0    880
## 56        Cooper's 252.0    340
```

```
## 57       Cooper's 240.0    340
## 58     Red-tailed 410.0   1255
## 59     Red-tailed 241.0   1320
## 60     Red-tailed 408.0   1320
## 61     Red-tailed  37.2   1180
## 62     Red-tailed 380.0    760
## 63     Red-tailed 396.0   1250
## 64     Red-tailed 326.0     NA
## 65  Sharp-shinned 158.0    100
## 66     Red-tailed 416.0   1300
## 67       Cooper's 271.0    475
## 68  Sharp-shinned 176.0    100
## 69  Sharp-shinned 194.0     NA
## 70     Red-tailed 390.0   1080
## 71     Red-tailed 391.0   1130
## 72     Red-tailed 387.0   1160
## 73     Red-tailed 420.0   1345
## 74     Red-tailed 435.0   1385
## 75     Red-tailed 400.0   1210
## 76     Red-tailed 398.0   1455
## 77     Red-tailed 395.0   1180
## 78     Red-tailed 410.0   1500
## 79     Red-tailed 369.0   1025
## 80     Red-tailed 372.0    930
## 81     Red-tailed 415.0   1360
## 82     Red-tailed 412.0   1255
## 83  Sharp-shinned 205.0    194
## 84  Sharp-shinned 204.0    159
## 85  Sharp-shinned 170.0     90
## 86       Cooper's 233.0    340
## 87     Red-tailed 375.0   1065
## 88     Red-tailed 385.0   1125
## 89     Red-tailed 422.0   1340
## 90     Red-tailed 391.0   1050
## 91     Red-tailed 410.0   1210
## 92     Red-tailed 385.0    980
## 93     Red-tailed 381.0   1000
## 94     Red-tailed 416.0   1390
## 95     Red-tailed 406.0   1275
## 96     Red-tailed 418.0   1180
## 97     Red-tailed 412.0   1210
## 98  Sharp-shinned 208.0    168
## 99  Sharp-shinned 208.0    146
## 100 Sharp-shinned 175.0    108
## 101 Sharp-shinned 166.0     94
## 102    Red-tailed 405.0   1085
## 103 Sharp-shinned 198.0    188
## 104 Sharp-shinned 200.0    154
## 105    Red-tailed 380.0    810
## 106    Red-tailed 381.0    905
## 107 Sharp-shinned 169.0     94
## 108      Cooper's 260.0    420
## 109    Red-tailed 428.0   1240
## 110    Red-tailed 400.0    990
```

```
## 111      Cooper's 265.0    365
## 112 Sharp-shinned 177.0     91
## 113    Red-tailed 381.0   1010
## 114    Red-tailed 403.0    980
## 115    Red-tailed 382.0    860
## 116    Red-tailed 382.0    970
## 117    Red-tailed 399.0    980
## 118    Red-tailed 380.0    985
## 119    Red-tailed 375.0    990
## 120    Red-tailed 420.0   1210
## 121 Sharp-shinned 170.0     89
## 122 Sharp-shinned 177.0     97
## 123    Red-tailed 375.0    990
## 124    Red-tailed 395.0   1170
## 125 Sharp-shinned 170.0     93
## 126    Red-tailed 406.0   1350
## 127    Red-tailed 414.0   1370
## 128 Sharp-shinned 173.0    103
## 129 Sharp-shinned 209.0    151
## 130 Sharp-shinned 177.0    101
## 131    Red-tailed 388.0    985
## 132    Red-tailed 277.0    940
## 133    Red-tailed 423.0   1310
## 134    Red-tailed 365.0   1035
## 135    Red-tailed 383.0    965
## 136    Red-tailed 391.0   1125
## 137    Red-tailed 389.0    975
## 138    Red-tailed 392.0   1140
## 139    Red-tailed 375.0    950
## 140    Red-tailed 410.0   1210
## 141 Sharp-shinned 179.0     95
## 142 Sharp-shinned 172.0     89
## 143 Sharp-shinned 202.0    195
## 144 Sharp-shinned 174.0     93
## 145    Red-tailed 422.0   1205
## 146    Red-tailed 385.0   1045
## 147    Red-tailed 363.0   1090
## 148    Red-tailed 450.0   1190
## 149    Red-tailed 380.0    960
## 150    Red-tailed 385.0    955
## 151    Red-tailed 385.0   1110
## 152 Sharp-shinned 171.0    100
## 153    Red-tailed 380.0    900
## 154    Red-tailed 384.0   1075
## 155    Red-tailed 373.0    980
## 156    Red-tailed 381.0    940
## 157    Red-tailed 363.0   1070
## 158    Red-tailed 409.0   1120
## 159    Red-tailed 390.0   1060
## 160 Sharp-shinned 204.0    168
## 161 Sharp-shinned 197.0    211
## 162    Red-tailed 420.0   1125
## 163    Red-tailed 381.0   1100
## 164    Red-tailed 408.0   1360
```

```
## 165    Red-tailed 388.0    995
## 166    Red-tailed 398.0   1095
## 167 Sharp-shinned 209.0    196
## 168 Sharp-shinned 209.0    176
## 169    Red-tailed 394.0   1075
## 170 Sharp-shinned 204.0    180
## 171 Sharp-shinned 204.0    164
## 172 Sharp-shinned 209.0    158
## 173    Red-tailed 394.0   1140
## 174    Red-tailed 416.0   1240
## 175    Red-tailed 445.0   1465
## 176 Sharp-shinned 209.0    169
## 177    Red-tailed 388.0   1105
## 178    Red-tailed 397.0   1010
## 179    Red-tailed 384.0   1075
## 180    Red-tailed 379.0   1060
## 181    Red-tailed 393.0   1015
## 182    Red-tailed 386.0   1100
## 183    Red-tailed 397.0   1010
## 184    Red-tailed 382.0   1000
## 185    Red-tailed 386.0    980
## 186    Red-tailed 417.0   1240
## 187    Red-tailed 403.0   1360
## 188       Cooper's 239.0    183
## 189    Red-tailed 401.0   1405
## 190    Red-tailed 377.0   1055
## 191    Red-tailed 432.0   1670
## 192    Red-tailed 390.0   1250
## 193    Red-tailed 381.0   1030
## 194    Red-tailed 403.0   1040
## 195 Sharp-shinned 213.0    190
## 196 Sharp-shinned 172.0    105
## 197    Red-tailed 390.0   1090
## 198 Sharp-shinned 204.0    190
## 199    Red-tailed 386.0   1050
## 200    Red-tailed 402.0   1110
## 201 Sharp-shinned 201.0    206
## 202 Sharp-shinned 202.0    195
## 203    Red-tailed 374.0   1010
## 204    Red-tailed 358.0    880
## 205    Red-tailed 370.0   1060
## 206    Red-tailed 390.0    920
## 207    Red-tailed 398.0   1195
## 208    Red-tailed 360.0    890
## 209    Red-tailed 355.0    900
## 210    Red-tailed 375.0   1110
## 211 Sharp-shinned 200.0    160
## 212 Sharp-shinned 179.0    105
## 213 Sharp-shinned 175.0     99
## 214 Sharp-shinned 203.0    165
## 215 Sharp-shinned 205.0    100
## 216 Sharp-shinned 213.0    125
## 217    Red-tailed 409.0   1100
## 218 Sharp-shinned 202.0     NA
```

```
## 219 Sharp-shinned 195.0    155
## 220    Red-tailed 415.0   1285
## 221      Cooper's 236.0    390
## 222    Red-tailed 363.0    920
## 223    Red-tailed 381.0   1025
## 224    Red-tailed 350.0    940
## 225    Red-tailed 398.0   1240
## 226    Red-tailed 412.0   1160
## 227 Sharp-shinned 203.0    150
## 228 Sharp-shinned 201.0    130
## 229    Red-tailed 411.0   1240
## 230    Red-tailed 373.0    930
## 231 Sharp-shinned 178.0     90
## 232    Red-tailed 415.0   1240
## 233    Red-tailed 383.0   1030
## 234      Cooper's 223.0    550
## 235    Red-tailed 390.0   1250
## 236    Red-tailed 390.0    999
## 237    Red-tailed 365.0   1120
## 238    Red-tailed 345.0   1000
## 239      Cooper's 273.0    530
## 240    Red-tailed 400.0   1040
## 241    Red-tailed 380.0   1150
## 242    Red-tailed 330.0   1000
## 243    Red-tailed 410.0   1360
## 244    Red-tailed 313.0    930
## 245    Red-tailed 384.0    980
## 246    Red-tailed 409.0   1260
## 247    Red-tailed 390.0    900
## 248    Red-tailed 411.0   1300
## 249      Cooper's 259.0    470
## 250    Red-tailed 380.0   1040
## 251    Red-tailed 370.0    950
## 252    Red-tailed 415.0   1320
## 253 Sharp-shinned 215.0    180
## 254    Red-tailed 410.0   1280
## 255    Red-tailed 412.0   1310
## 256    Red-tailed 384.0    910
## 257    Red-tailed 404.0   1220
## 258    Red-tailed 375.0    920
## 259    Red-tailed 410.0   1135
## 260    Red-tailed 384.0    940
## 261    Red-tailed 385.0    920
## 262    Red-tailed 398.0   1280
## 263      Cooper's    NA    480
## 264    Red-tailed 425.0   1220
## 265    Red-tailed 401.0   1000
## 266    Red-tailed 387.0   1120
## 267    Red-tailed 376.0    925
## 268 Sharp-shinned 171.0     90
## 269    Red-tailed 420.0   1280
## 270    Red-tailed 385.0    985
## 271    Red-tailed 405.0   1350
## 272    Red-tailed 350.0    730
```

```
## 273    Red-tailed 388.0    890
## 274    Red-tailed 398.0   1020
## 275    Red-tailed 410.0   1000
## 276 Sharp-shinned 202.0    150
## 277 Sharp-shinned 204.0    180
## 278    Red-tailed 382.0   1020
## 279    Red-tailed 111.0   1340
## 280    Red-tailed 396.0   1300
## 281    Red-tailed 363.0   1015
## 282    Red-tailed 360.0    900
## 283    Red-tailed 390.0   1000
## 284 Sharp-shinned 195.0    150
## 285    Red-tailed 390.0   1050
## 286    Red-tailed 380.0    950
## 287      Cooper's 225.0    350
## 288      Cooper's 247.0    375
## 289    Red-tailed 415.0   1175
## 290    Red-tailed 354.0    980
## 291    Red-tailed 417.0   1260
## 292    Red-tailed 379.0   1050
## 293    Red-tailed 412.0   1330
## 294    Red-tailed 377.0    980
## 295    Red-tailed 372.0    920
## 296    Red-tailed 420.0   1540
## 297    Red-tailed 368.0   1060
## 298    Red-tailed 406.0   1420
## 299      Cooper's 225.0    400
## 300    Red-tailed 392.0   1142
## 301 Sharp-shinned 191.0    157
## 302 Sharp-shinned 161.0     98
## 303    Red-tailed 365.0    813
## 304 Sharp-shinned 156.0     94
## 305 Sharp-shinned 191.0    155
## 306 Sharp-shinned 198.0    181
## 307 Sharp-shinned 160.0     92
## 308 Sharp-shinned 164.0     98
## 309    Red-tailed 352.0   1024
## 310      Cooper's 265.0    464
## 311 Sharp-shinned 163.0    100
## 312 Sharp-shinned 193.0    186
## 313 Sharp-shinned 190.0    164
## 314 Sharp-shinned 165.0     98
## 315 Sharp-shinned 162.0     NA
## 316 Sharp-shinned 198.0    158
## 317    Red-tailed 370.0   1023
## 318    Red-tailed 230.0    340
## 319      Cooper's 194.0    163
## 320 Sharp-shinned 157.0     92
## 321 Sharp-shinned 260.0    550
## 322      Cooper's 377.0   1119
## 323    Red-tailed 364.0    917
## 324    Red-tailed 367.0    946
## 325    Red-tailed 233.0    337
## 326      Cooper's 336.0    742
```

```
## 327 Sharp-shinned 259.0    439
## 328      Cooper's 199.0    187
## 329 Sharp-shinned 165.0     92
## 330 Sharp-shinned 370.0   1094
## 331    Red-tailed 362.0    832
## 332    Red-tailed 368.0   1244
## 333    Red-tailed 368.0   1244
## 334    Red-tailed 367.0    974
## 335    Red-tailed 400.0   1289
## 336    Red-tailed 379.0    999
## 337    Red-tailed 360.0    994
## 338    Red-tailed 362.0   1004
## 339    Red-tailed 378.0   1097
## 340 Sharp-shinned 201.0    185
## 341 Sharp-shinned 193.0    181
## 342    Red-tailed 372.0   1092
## 343    Red-tailed 369.0   1049
## 344    Red-tailed 354.0    998
## 345    Red-tailed 367.0   1091
## 346    Red-tailed 349.0    987
## 347    Red-tailed 375.0   1151
## 348    Red-tailed 343.0    971
## 349    Red-tailed 360.0   1159
## 350    Red-tailed 395.0   1239
## 351    Red-tailed 400.0   1216
## 352 Sharp-shinned 170.0    177
## 353      Cooper's 268.0    469
## 354    Red-tailed 369.0   1039
## 355    Red-tailed 365.0   1079
## 356    Red-tailed 375.0   1159
## 357 Sharp-shinned 230.0    162
## 358      Cooper's 213.0    339
## 359    Red-tailed 382.0   1403
## 360 Sharp-shinned 168.0    175
## 361    Red-tailed 478.0   1473
## 362    Red-tailed 469.0   1001
## 363 Sharp-shinned 172.0     98
## 364    Red-tailed 373.0    914
## 365    Red-tailed 386.0   1059
## 366    Red-tailed 384.0   1147
## 367    Red-tailed 351.0    949
## 368 Sharp-shinned 168.0    102
## 369    Red-tailed 363.0    973
## 370 Sharp-shinned 199.0    196
## 371      Cooper's 235.0    327
## 372    Red-tailed 374.0   1064
## 373    Red-tailed 369.0    749
## 374 Sharp-shinned 202.0    201
## 375 Sharp-shinned 202.0    180
## 376    Red-tailed 374.0   1213
## 377    Red-tailed 389.0   1200
## 378    Red-tailed 379.0   1040
## 379 Sharp-shinned 170.0    113
## 380    Red-tailed 373.0    919
```

```
## 381    Red-tailed 403.0   1487
## 382    Red-tailed 400.0   1254
## 383 Sharp-shinned 205.0    156
## 384    Red-tailed 405.0   1189
## 385    Red-tailed 382.0    979
## 386 Sharp-shinned 165.0     96
## 387    Red-tailed 407.0   1339
## 388    Red-tailed 403.0   1199
## 389    Red-tailed 406.0   1344
## 390    Red-tailed 381.0    969
## 391    Red-tailed 395.0   1039
## 392    Red-tailed 410.0   1054
## 393      Cooper's 243.0    334
## 394 Sharp-shinned 170.0    101
## 395 Sharp-shinned 210.0    181
## 396    Red-tailed 425.0   1449
## 397    Red-tailed 402.0    985
## 398    Red-tailed 480.0   1598
## 399    Red-tailed 412.0    992
## 400      Cooper's 260.0    569
## 401    Red-tailed 381.0   1354
## 402    Red-tailed 392.0    969
## 403    Red-tailed 382.0   1080
## 404 Sharp-shinned 196.0    185
## 405    Red-tailed 391.0   1097
## 406    Red-tailed 397.0   1439
## 407    Red-tailed 361.0     NA
## 408    Red-tailed 376.0   1019
## 409    Red-tailed 410.0   1239
## 410    Red-tailed 381.0   1399
## 411    Red-tailed 396.0   1169
## 412    Red-tailed 383.0   1164
## 413 Sharp-shinned 203.0    176
## 414    Red-tailed 271.0     NA
## 415      Cooper's 255.0    429
## 416 Sharp-shinned 196.0    160
## 417 Sharp-shinned 168.0    105
## 418    Red-tailed 392.0    890
## 419 Sharp-shinned 163.0    100
## 420 Sharp-shinned 205.0     NA
## 421    Red-tailed 395.0   1215
## 422 Sharp-shinned 163.0    100
## 423    Red-tailed 370.0   1030
## 424      Cooper's 225.0    340
## 425 Sharp-shinned 197.0    165
## 426    Red-tailed 376.0    985
## 427    Red-tailed 372.0    975
## 428    Red-tailed 391.0   1165
## 429 Sharp-shinned 165.0     95
## 430    Red-tailed 364.0   1044
## 431 Sharp-shinned 202.0    180
## 432 Sharp-shinned 163.0    125
## 433    Red-tailed 381.0   1080
## 434    Red-tailed 375.0    890
```

```
## 435    Red-tailed 392.0   1105
## 436    Red-tailed 398.0   1310
## 437    Red-tailed 371.0    895
## 438    Red-tailed 367.0   1060
## 439 Sharp-shinned 193.0    165
## 440    Red-tailed 375.0    960
## 441    Red-tailed 408.0   1270
## 442       Cooper's 252.0    540
## 443       Cooper's 237.0    365
## 444    Red-tailed 399.0   1170
## 445       Cooper's 268.0    590
## 446    Red-tailed 388.0   1225
## 447 Sharp-shinned 200.0    175
## 448 Sharp-shinned 192.0    170
## 449 Sharp-shinned 167.0    100
## 450    Red-tailed 370.0   1060
## 451 Sharp-shinned 162.0    110
## 452    Red-tailed 363.0    850
## 453    Red-tailed 371.0   1145
## 454 Sharp-shinned 199.0    165
## 455    Red-tailed 386.0   1090
## 456    Red-tailed 400.0   1345
## 457    Red-tailed 390.0   1050
## 458 Sharp-shinned 199.0    200
## 459       Cooper's 254.0    505
## 460    Red-tailed 382.0   1040
## 461 Sharp-shinned 196.0    155
## 462    Red-tailed 354.0    965
## 463    Red-tailed 403.0   1105
## 464 Sharp-shinned 194.0    155
## 465    Red-tailed 375.0   1045
## 466    Red-tailed 369.0    900
## 467    Red-tailed 368.0   1015
## 468    Red-tailed 393.0   1385
## 469    Red-tailed 370.0   1165
## 470    Red-tailed 378.0    905
## 471    Red-tailed 369.0    985
## 472    Red-tailed 364.0    800
## 473    Red-tailed 387.0    995
## 474    Red-tailed 410.0   1460
## 475 Sharp-shinned 194.0    165
## 476    Red-tailed 410.0   1585
## 477 Sharp-shinned 194.0    185
## 478    Red-tailed 373.0    920
## 479    Red-tailed 390.0   1460
## 480    Red-tailed 404.0   1315
## 481    Red-tailed 375.0   1019
## 482    Red-tailed 395.0   1215
## 483    Red-tailed 379.0   1005
## 484    Red-tailed 382.0   1350
## 485    Red-tailed 404.0   1145
## 486 Sharp-shinned 205.0    175
## 487    Red-tailed 377.0   1010
## 488 Sharp-shinned 184.0    155
```

```
## 489    Red-tailed 390.0   1120
## 490    Red-tailed 404.0    280
## 491    Red-tailed 351.0    775
## 492    Red-tailed 394.0   1210
## 493 Sharp-shinned 175.0    107
## 494    Red-tailed 372.0    909
## 495 Sharp-shinned 169.0     95
## 496    Red-tailed 376.0   1145
## 497    Red-tailed 399.0   1150
## 498    Red-tailed 399.0   1560
## 499    Red-tailed 357.0    940
## 500 Sharp-shinned 195.0    145
## 501    Red-tailed 400.0   1089
## 502    Red-tailed 382.0   1194
## 503 Sharp-shinned 161.0     95
## 504    Red-tailed 390.0   1015
## 505    Red-tailed 379.0    975
## 506    Red-tailed 376.0   1035
## 507    Red-tailed 331.0   1055
## 508    Red-tailed 371.0    945
## 509 Sharp-shinned 160.0     90
## 510    Red-tailed 361.0    785
## 511       Cooper's 268.0     56
## 512    Red-tailed 394.0   1220
## 513 Sharp-shinned 191.0    175
## 514    Red-tailed 358.0   1025
## 515    Red-tailed 380.0   1000
## 516 Sharp-shinned 188.0    175
## 517    Red-tailed 397.0   1210
## 518 Sharp-shinned 196.0    180
## 519 Sharp-shinned 190.0    175
## 520 Sharp-shinned 161.0     90
## 521       Cooper's 145.0    320
## 522    Red-tailed 392.0   1185
## 523 Sharp-shinned 190.0     NA
## 524       Cooper's 230.0    350
## 525    Red-tailed 406.0     NA
## 526    Red-tailed 363.0    950
## 527 Sharp-shinned 162.0     85
## 528    Red-tailed 374.0    895
## 529    Red-tailed 412.0   1150
## 530       Cooper's 272.0    565
## 531    Red-tailed 388.0    950
## 532    Red-tailed 371.0    990
## 533       Cooper's 225.0    325
## 534    Red-tailed 391.0   1120
## 535 Sharp-shinned 163.0     90
## 536    Red-tailed 410.0   1120
## 537    Red-tailed 368.0    820
## 538    Red-tailed 410.0   1200
## 539    Red-tailed 425.0   1120
## 540    Red-tailed 368.0   1120
## 541    Red-tailed 392.0   1220
## 542 Sharp-shinned 250.0    470
```

```
## 543    Red-tailed 418.0   1310
## 544    Red-tailed 370.0    920
## 545 Sharp-shinned 170.0    100
## 546 Sharp-shinned 203.0    180
## 547    Red-tailed 370.0    955
## 548    Red-tailed 408.0   1225
## 549    Red-tailed 393.0   1400
## 550    Red-tailed 365.0   1025
## 551    Red-tailed 405.0   1140
## 552    Red-tailed 381.0   1080
## 553    Red-tailed 390.0   1135
## 554    Red-tailed 384.0   1430
## 555    Red-tailed 390.0   1050
## 556    Red-tailed 381.0    920
## 557 Sharp-shinned 194.0    175
## 558    Red-tailed 371.0    905
## 559    Red-tailed 356.0    915
## 560    Red-tailed 377.0    910
## 561    Red-tailed 362.0    950
## 562 Sharp-shinned 165.0    105
## 563 Sharp-shinned 155.0    100
## 564    Red-tailed 400.0   1225
## 565 Sharp-shinned 161.0    105
## 566    Red-tailed 387.0   1090
## 567    Red-tailed 409.0   1350
## 568 Sharp-shinned 195.0    200
## 569 Sharp-shinned 196.0    200
## 570 Sharp-shinned 169.0    100
## 571    Red-tailed 385.0    940
## 572    Red-tailed 377.0    920
## 573    Red-tailed 400.0   1190
## 574 Sharp-shinned 164.0     90
## 575 Sharp-shinned 165.0     95
## 576    Red-tailed 363.0    915
## 577       Cooper's 266.0    535
## 578    Red-tailed 403.0   1310
## 579    Red-tailed 375.0    950
## 580 Sharp-shinned 166.0    120
## 581    Red-tailed 373.0    975
## 582    Red-tailed 373.0    990
## 583 Sharp-shinned 170.0    110
## 584    Red-tailed 373.0   1270
## 585    Red-tailed 354.0    960
## 586    Red-tailed 394.0   1290
## 587 Sharp-shinned 165.0     95
## 588       Cooper's 261.0    505
## 589    Red-tailed 377.0   1045
## 590    Red-tailed 364.0   1090
## 591    Red-tailed 385.0   1180
## 592    Red-tailed 390.0   1195
## 593    Red-tailed 383.0   1055
## 594    Red-tailed 365.0   1025
## 595 Sharp-shinned 201.0    175
## 596    Red-tailed 376.0    940
```

```
## 597    Red-tailed 402.0   1335
## 598    Red-tailed 394.0   1085
## 599      Cooper's 223.0    375
## 600    Red-tailed 378.0   1090
## 601    Red-tailed 369.0    995
## 602    Red-tailed 378.0   1090
## 603    Red-tailed 262.0   1020
## 604 Sharp-shinned 165.0    100
## 605    Red-tailed 379.0   1000
## 606    Red-tailed 380.0   1085
## 607    Red-tailed 380.0   1045
## 608    Red-tailed 393.0   1060
## 609    Red-tailed 389.0   1135
## 610    Red-tailed 395.0   1210
## 611 Sharp-shinned 207.0    185
## 612    Red-tailed 367.0    965
## 613    Red-tailed 368.0    905
## 614    Red-tailed 377.0   1125
## 615    Red-tailed 374.0    950
## 616    Red-tailed 385.0   1195
## 617    Red-tailed 363.0   1005
## 618 Sharp-shinned 164.0     95
## 619 Sharp-shinned 199.0    175
## 620    Red-tailed 378.0    995
## 621 Sharp-shinned 200.0    165
## 622    Red-tailed 405.0   1170
## 623 Sharp-shinned 194.0    145
## 624 Sharp-shinned 190.0    175
## 625 Sharp-shinned 195.0    170
## 626 Sharp-shinned 161.0    105
## 627 Sharp-shinned 168.0     95
## 628 Sharp-shinned 160.0     95
## 629    Red-tailed 392.0   1085
## 630 Sharp-shinned 201.0    165
## 631    Red-tailed 395.0   1115
## 632    Red-tailed 390.0   1195
## 633 Sharp-shinned 161.0    100
## 634      Cooper's 230.0    365
## 635 Sharp-shinned 192.0    170
## 636 Sharp-shinned 156.0     90
## 637 Sharp-shinned 158.0     95
## 638 Sharp-shinned 167.0    115
## 639 Sharp-shinned 199.0    155
## 640      Cooper's 320.0    229
## 641    Red-tailed 389.0   1165
## 642      Cooper's 227.0    155
## 643      Cooper's 230.0    340
## 644 Sharp-shinned 199.0    180
## 645    Red-tailed 378.0    235
## 646 Sharp-shinned 164.0    105
## 647    Red-tailed 385.0   1085
## 648    Red-tailed 369.0    970
## 649    Red-tailed 378.0   1030
## 650    Red-tailed 373.0   1015
```

```
## 651    Red-tailed 419.0   1030
## 652    Red-tailed 414.0   1215
## 653 Sharp-shinned 203.0    185
## 654 Sharp-shinned 162.0     95
## 655 Sharp-shinned 165.0     95
## 656 Sharp-shinned 161.0     95
## 657 Sharp-shinned 161.0    110
## 658    Red-tailed 404.0   1170
## 659 Sharp-shinned 165.0    105
## 660 Sharp-shinned 199.0    175
## 661 Sharp-shinned 171.0     95
## 662 Sharp-shinned 213.0    190
## 663 Sharp-shinned 169.0    105
## 664    Red-tailed 379.0   1435
## 665    Red-tailed 407.0   1235
## 666    Red-tailed 376.0   1055
## 667    Red-tailed 380.0   1105
## 668 Sharp-shinned 172.0    120
## 669    Red-tailed 408.0   1390
## 670 Sharp-shinned 167.0    105
## 671    Red-tailed 374.0   1080
## 672    Red-tailed 376.0    910
## 673       Cooper's 258.0    490
## 674    Red-tailed 370.0    845
## 675 Sharp-shinned 202.0    175
## 676    Red-tailed 363.0    865
## 677 Sharp-shinned 200.0    180
## 678    Red-tailed 372.0   2030
## 679    Red-tailed 378.0    960
## 680       Cooper's 254.0    515
## 681    Red-tailed 361.0    970
## 682    Red-tailed 389.0   1265
## 683    Red-tailed 404.0   1300
## 684 Sharp-shinned 195.0    170
## 685 Sharp-shinned 203.0    191
## 686       Cooper's 253.0    540
## 687 Sharp-shinned 199.0    185
## 688 Sharp-shinned 194.0    165
## 689 Sharp-shinned 196.0    205
## 690 Sharp-shinned 168.0     95
## 691    Red-tailed 395.0   1170
## 692    Red-tailed 368.0   1075
## 693 Sharp-shinned 210.0    200
## 694    Red-tailed 401.0    965
## 695    Red-tailed 355.0    785
## 696    Red-tailed 377.0   1095
## 697 Sharp-shinned 197.0    160
## 698 Sharp-shinned 171.0     95
## 699    Red-tailed 277.0   1500
## 700    Red-tailed 435.0   1595
## 701    Red-tailed 372.0    985
## 702       Cooper's 260.0    565
## 703    Red-tailed 390.0    240
## 704    Red-tailed 359.0    875
```

```
## 705    Red-tailed 393.0   1225
## 706    Red-tailed 402.0   1255
## 707    Red-tailed 362.0    950
## 708      Cooper's 227.0    330
## 709    Red-tailed 359.0    895
## 710 Sharp-shinned 155.0    100
## 711      Cooper's 261.0    455
## 712 Sharp-shinned 160.0     90
## 713 Sharp-shinned 166.0    105
## 714    Red-tailed 362.0   1305
## 715    Red-tailed 375.0    975
## 716    Red-tailed 388.0   1185
## 717    Red-tailed 392.0   1030
## 718    Red-tailed 412.0   1215
## 719    Red-tailed 371.0   1075
## 720      Cooper's 255.0    960
## 721    Red-tailed 391.0    795
## 722 Sharp-shinned 190.0    180
## 723    Red-tailed 385.0   1225
## 724 Sharp-shinned 166.0    110
## 725 Sharp-shinned 197.0    165
## 726    Red-tailed 370.0    920
## 727 Sharp-shinned 190.0    170
## 728    Red-tailed 400.0   1315
## 729 Sharp-shinned 162.0    100
## 730 Sharp-shinned 194.0    155
## 731    Red-tailed 395.0   1155
## 732    Red-tailed 403.0   1160
## 733    Red-tailed 386.0    955
## 734 Sharp-shinned 193.0    190
## 735 Sharp-shinned 203.0    180
## 736 Sharp-shinned 159.0     90
## 737 Sharp-shinned 163.0    100
## 738 Sharp-shinned 191.0    190
## 739 Sharp-shinned 166.0    105
## 740    Red-tailed 361.0   1030
## 741      Cooper's 260.0    565
## 742      Cooper's 234.0    380
## 743    Red-tailed 377.0   1040
## 744    Red-tailed 361.0    910
## 745    Red-tailed 375.0   1005
## 746 Sharp-shinned 193.0    180
## 747 Sharp-shinned 196.0    175
## 748 Sharp-shinned 159.0    105
## 749 Sharp-shinned 192.0    190
## 750    Red-tailed 401.0   1250
## 751 Sharp-shinned 198.0    185
## 752    Red-tailed 407.0   1275
## 753 Sharp-shinned 162.0    105
## 754      Cooper's 169.0    640
## 755 Sharp-shinned 168.0    100
## 756 Sharp-shinned 168.0    105
## 757      Cooper's 223.0    390
## 758    Red-tailed 375.0   1030
```

```
## 759    Red-tailed 406.0   1290
## 760    Red-tailed 386.0   1020
## 761 Sharp-shinned 160.0    105
## 762    Red-tailed 378.0   1055
## 763 Sharp-shinned 193.0    185
## 764    Red-tailed 379.0   1010
## 765    Red-tailed 364.0   1015
## 766    Red-tailed 350.0   1115
## 767    Red-tailed 380.0   1320
## 768    Red-tailed 395.0   1180
## 769    Red-tailed 372.0   1145
## 770    Red-tailed 376.0    995
## 771    Red-tailed 367.0   1045
## 772      Cooper's 230.0    340
## 773    Red-tailed 366.0    935
## 774    Red-tailed 386.0   1065
## 775    Red-tailed 375.0   1110
## 776 Sharp-shinned 199.0    190
## 777    Red-tailed 405.0   1255
## 778    Red-tailed 371.0   1015
## 779 Sharp-shinned 193.0    190
## 780    Red-tailed 350.0    960
## 781 Sharp-shinned 193.0    200
## 782    Red-tailed 368.0   1090
## 783 Sharp-shinned 185.0    170
## 784    Red-tailed 372.0   1085
## 785    Red-tailed 396.0   1065
## 786    Red-tailed 365.0   1125
## 787    Red-tailed 374.0   1050
## 788      Cooper's 253.0    525
## 789    Red-tailed 372.0    980
## 790    Red-tailed 376.0   1180
## 791 Sharp-shinned 166.0    115
## 792    Red-tailed 369.0   1095
## 793    Red-tailed 391.0   1330
## 794 Sharp-shinned 193.0    185
## 795    Red-tailed 397.0   1100
## 796    Red-tailed 366.0   1115
## 797    Red-tailed 385.0   1400
## 798    Red-tailed 400.0   1175
## 799 Sharp-shinned 198.0    185
## 800    Red-tailed 365.0    970
## 801 Sharp-shinned 194.0    170
## 802 Sharp-shinned 195.0    175
## 803 Sharp-shinned 200.0    165
## 804    Red-tailed 384.0   1260
## 805 Sharp-shinned 159.0    110
## 806 Sharp-shinned 161.0    100
## 807 Sharp-shinned 191.0    190
## 808      Cooper's 216.0    305
## 809      Cooper's 256.0    510
## 810 Sharp-shinned 161.0     90
## 811    Red-tailed 396.0   1195
## 812    Red-tailed 391.0   1035
```

```
## 813 Sharp-shinned 160.0     90
## 814 Sharp-shinned 183.0    160
## 815 Sharp-shinned 156.0     85
## 816    Red-tailed 393.0   1155
## 817    Red-tailed 397.0   1260
## 818 Sharp-shinned 159.0     95
## 819       Cooper's 255.0    440
## 820 Sharp-shinned 197.0    175
## 821       Cooper's 218.0    295
## 822 Sharp-shinned 196.0    160
## 823    Red-tailed 384.0   1010
## 824    Red-tailed 385.0    990
## 825 Sharp-shinned 181.0    150
## 826       Cooper's 225.0    300
## 827    Red-tailed 379.0    945
## 828 Sharp-shinned 201.0    188
## 829 Sharp-shinned 161.0     95
## 830       Cooper's 230.0    330
## 831 Sharp-shinned 159.0     95
## 832    Red-tailed 367.0    970
## 833    Red-tailed 396.0   1240
## 834 Sharp-shinned 157.0    105
## 835 Sharp-shinned 191.0    165
## 836 Sharp-shinned 191.0    170
## 837 Sharp-shinned 168.0    100
## 838    Red-tailed 428.0   1290
## 839       Cooper's 252.0    470
## 840 Sharp-shinned 192.0    175
## 841 Sharp-shinned 195.0    195
## 842       Cooper's 233.0    335
## 843    Red-tailed 364.0   1150
## 844    Red-tailed 370.0    960
## 845    Red-tailed 400.0   1130
## 846    Red-tailed 375.0    925
## 847    Red-tailed 398.0   1205
## 848    Red-tailed 385.0   1040
## 849 Sharp-shinned 156.0    100
## 850       Cooper's 230.0    335
## 851       Cooper's 220.0    335
## 852 Sharp-shinned 163.0    105
## 853    Red-tailed 376.0    860
## 854    Red-tailed 360.0    935
## 855    Red-tailed 372.0   1010
## 856    Red-tailed 400.0   1285
## 857 Sharp-shinned 194.0    210
## 858    Red-tailed 370.0    830
## 859 Sharp-shinned 160.0     95
## 860    Red-tailed 403.0   1350
## 861    Red-tailed 375.0   1010
## 862    Red-tailed 373.0    960
## 863    Red-tailed 385.0   1370
## 864 Sharp-shinned 143.0    170
## 865 Sharp-shinned 162.0    100
## 866    Red-tailed 392.0   1250
```

```
## 867    Red-tailed 372.0    915
## 868    Red-tailed 375.0    850
## 869    Red-tailed 415.0   1285
## 870 Sharp-shinned 161.0     95
## 871    Red-tailed 380.0   1005
## 872    Red-tailed 411.0   1220
## 873 Sharp-shinned 161.0     95
## 874 Sharp-shinned 165.0    100
## 875    Red-tailed 393.0   1265
## 876    Red-tailed 370.0   1020
## 877      Cooper's 230.0    360
## 878    Red-tailed 365.0    895
## 879    Red-tailed 371.0   1160
## 880    Red-tailed 400.0   1585
## 881    Red-tailed 382.0   1140
## 882    Red-tailed 371.0   1115
## 883    Red-tailed 370.0   1145
## 884 Sharp-shinned 194.0    185
## 885    Red-tailed 347.0    990
## 886    Red-tailed 363.0    945
## 887 Sharp-shinned 195.0    165
## 888    Red-tailed 392.0   1030
## 889      Cooper's 220.0    320
## 890 Sharp-shinned 193.0    105
## 891    Red-tailed 365.0    990
## 892    Red-tailed 387.0   1065
## 893    Red-tailed 400.0   1050
## 894    Red-tailed 362.0    840
## 895 Sharp-shinned 198.0    190
## 896 Sharp-shinned 190.0    200
## 897 Sharp-shinned 197.0    185
## 898    Red-tailed 370.0   1000
## 899 Sharp-shinned 200.0    185
## 900    Red-tailed 360.0   1325
## 901    Red-tailed 366.0    945
## 902    Red-tailed 402.0   1350
## 903    Red-tailed 366.0    805
## 904    Red-tailed 380.0   1525
## 905 Sharp-shinned 190.0    175
## 906    Red-tailed 360.0    790
## 907    Red-tailed 369.0    860
## 908    Red-tailed 199.0   1290
```

1.3 (Q3)

Q3). Use a combination of the head() and select() functions to print out the top seven rows of the columns "Species", "Wing" and "Weight" of the data frame called "hawksFullName". Do this without modifying the data frame you just created.

```r
head(hawksFullName, 7)
```

```
##          Species Wing Weight
## 1    Red-tailed  385    920
```

```
## 2    Red-tailed  376    930
## 3    Red-tailed  381    990
## 4       Cooper's  265    470
## 5 Sharp-shinned  205    170
## 6    Red-tailed  412   1090
## 7    Red-tailed  370    960
```

#Does it matter what type of join function you use here? In what situations would it make a difference?

–> Yes, Left join is the suitable join function for this dataframe creation. As Left join keeps all the rows from the lft data frame which is Hawks and addss the matching rows from the right data frame (hawksSpeciesNameCodes). If there is no match NA will be inserted for the missing values from the right data frame.

–> Left join is idea as we require all the Rows from the Hawks dataframe.

1.4 The mutate function

(Q1). Use the mutate(), select() and arrange() functions to create a new data frame called "hawksWithBMI" which has the same number of rows as the original Hawks data frame but only two columns - one with their Species and one with their "bird BMI". Also, arrange the rows in descending order of "bird BMI".

```
# Create the hawksWithBMI data frame
hawksWithBMI <- Hawks %>%
  mutate(bird_BMI = Weight*1000 / (Wing^2)) %>%  # Calculate bird BMI
  select(Species, bird_BMI) %>%                # Select only Species and bird BMI
  arrange(desc(bird_BMI))                      # Arrange rows in descending order of bird BMI

# View the new dataframe
head(hawksWithBMI, 8)
```

```
##   Species  bird_BMI
## 1      RT 852.69973
## 2      RT 108.75741
## 3      RT  32.57493
## 4      RT  22.72688
## 5      CH  22.40818
## 6      RT  19.54932
## 7      CH  15.21998
## 8      RT  14.85927
```

##1.5 (Q1) Summarize and group-by functions

(Q1). In combination with the summarize() and the group_by functions, create a summary table, broken down by Hawk species, which contains the following summary quantities: 1. The number of rows (num_rows); 2. The average wing span in centimeters (mn_wing); 3. The median wing span in centimeters (nd_wing); 4. The trimmed average wing span in centimeters with trim=0.1, i.e., the mean of the numbers after the 10% largest and the 10% smallest values being removed (t_mn_wing); 5. The biggest ratio between wing span and tail length (b_wt_ratio). Hint: type ?summarize to see a list of useful functions (mean, sum, etc) that can be used to compute the summary quantities.

```
hawksSummary <- Hawks %>%
  group_by(Species) %>%
```

```
  summarize(num_rows = n(),
            mn_wing = mean(Wing, na.rm = TRUE),
            nd_wing = median(Wing, na.rm = TRUE),
            t_mn_wing = mean(Wing, trim = 0.1, na.rm=TRUE),
            b_wt_ratio = max(Wing/Tail, na.rm = TRUE)
              )
print(hawksSummary)
```

```
## # A tibble: 3 x 6
##   Species num_rows mn_wing nd_wing t_mn_wing b_wt_ratio
##   <fct>      <int>   <dbl>   <dbl>     <dbl>      <dbl>
## 1 CH            70    244.     240      243.       1.67
## 2 RT           577    383.     384      385.       3.16
## 3 SS           261    185.     191      184.       1.67
```

##1.5 (Q2) Summarize and group-by functions (Q2). Next create a summary table of the following form: Your summary table will show the number of missing values, broken down by species, for the columns Wing, Weight, Culmen, Hallux, Tail, StandardTail, Tarsus, and Crop. You can complete this task by combining the select(), group__by(), summarize(), across(), everything(), sum() and is.na() functions.

```
missingValuesSummary <- Hawks %>%
  group_by(Species) %>%
  summarize( across(c(Wing, Weight, Culmen, Hallux, Tail, StandardTail, Tarsus, Crop), ~sum(is.na(.))))
#A formula that sums the number of NA values in each specified column.

# View the summary table
print(missingValuesSummary)
```

```
## # A tibble: 3 x 9
##   Species  Wing Weight Culmen Hallux  Tail StandardTail Tarsus  Crop
##   <fct>   <int>  <int>  <int>  <int> <int>        <int>  <int> <int>
## 1 CH          1      0      0      0     0           19     62    21
## 2 RT          0      5      4      3     0          250    538   254
## 3 SS          0      5      3      3     0           68    233    68
```

##2. Random experiments, events and sample spaces, and the set theory

##2.1 Random experiments, events and sample spaces (Q1) Firstly, write down the definition of a random experiment, event and sample space. This question aims to help you recall the basic concepts before completing the subsequent tasks.

–>

Random experiments - It is a procedure which is either real or imaginary which has a well-defined set of possible outcomes and could (atleast in principle) be repeated arbitarily many times.

Event - An event is a set of possible outcomes of an experiments Sample Spaces - It is a set of all possible outcomes of interest of an experiment.

(Q2) Consider a random experiment of rolling a dice twice. Give an example of what is an event in this random experiment. Also, can you write down the sample space as a set? What is the total number of different events in this experiment? Is the empty set considered as an event?

Event A: Getting at least one "6" when rolling the die twice.

Sample space is all the possible outcomes S={(1,1),(1,2),(1,3),(1,4),(1,5),(1,6),(2,1),(2,2),(2,3),(2,4),(2,5),(2,6),(3,1),(3,2),(3,3)

2^n Total number of different events=2^36

Yes an empty set is considered as an event.

##2.2 Set theory Remember that a set is just a collection of objects. All that matters for the identity of a set is the objects it contains. In particular, the elements within the set are unordered, so for example the set {1, 2, 3} is exactly the same as the set {3, 2, 1}. In addition, since sets are just collections of objects, each object can only be either included or excluded and multiplicities do not change the nature of the set. In particular, the set {1, 2, 2, 2, 3, 3} is exactly the same as the set A = {1, 2, 3}. In general there is no concept of "position" within a set, unlike a vector or matrix.

(Q1) Set operations: Let the sets A, B, C be defined by A := {1, 2, 3}, B := {2, 4, 6}, C := {4, 5, 6}. 1. What are the unions and ? –> {1,2,3,4,6} and {1,2,3,4,5,6}

2. What are the intersections and ? –> {2} and {null}
3. What are the complements and ? –> {1,3} and {1,2,3}
4. Are and disjoint? Are and disjoint? –> NO and YES
5. Are and disjoint? –> YES
6. Write down an arbitrary partition of {1,2,3,4,5,6} consisting of two sets. Also, write down another partition of {1,2,3,4,5,6} consisting of three sets. –> P1={{1,2,3},{4,5,6}} P2={{1,2},{3,4},{5,6}}

(Q2) Complements, subsets and De Morgan's laws 1. Can you give an expression for (A$^{c)}$c without using the notion of a complement?

$$A^c = w \in \Omega : w \notin A$$

2. What is ^c?

$$(A^c)^c = w \in \Omega : w \notin Ac = w \in \Omega : w \in A = A$$

3. (Subsets) Show that if , then Let

$$w \in B^c \implies w \notin B$$

$$w \notin A \implies w \in A^c$$

Therefore,

$$B^c \subseteq A^c$$

4. (De Morgan's laws) Show that ( ) = . Let's suppose we have a sequence of events 1, 2, , . Can you write out an expression for (=1) ?

$$\left(\bigcap_{k=1}^{K} A_k\right)^c = \bigcup_{k=1}^{K} A_k^c$$

5. (De Morgan's laws) Show that ( ) =

$$\left(\bigcup_{k=1}^{K} A_k\right)^c = \bigcap_{k=1}^{K} A_k^c$$

Let's suppose we have a sequence of events 1, 2, , . Can you write out an expression for (=1) ?

$$\left(\bigcup_{k=1}^{K} A_k\right)^c = \bigcap_{k=1}^{K} A_k^c$$

(Q3) Cardinality and the set of all subsets: Suppose that = { 1, 2, , } contains elements for some natural number . Here has cardinality K. Let be a set of all subsets of , i.e., : = { | }. Note that here is a set. Give a formula for the cardinality of in terms of .

$$|E| = 2^K$$

(Q4) Disjointness and partitions. Suppose we have a sample space , and events 1, 2, 3, 4 are subsets of . 1. Can you think of a set which is disjoint from every other set? That is, find a set such that = for all .

–> The empty set = is disjoint from every other set, since = A B= for all Ω.

2. Define events 1 : = 1, 2 = 2 1, 3 = 3 (1 2), 4 = 4 (1 2 3). Show that 1, 2, 3, 4 form a partition of 1 2 3 4.

–>

Disjoint and Union proves

(Q5) Indicator function. Suppose we have a sample space , and the event is a subset of . Let be the indicator function of .

1. Write down the indicator function of (use in your formula).

$$1_A^c = 1_\Omega - 1_A$$

2. Can you find a set whose indicator function is + ?

$$B = A^c$$

$$1_B = 1_A^c$$

$$1_A^c + 1_A = 1_\Omega$$

3. Recall that = and = max(,) = + − for any and . Combining this with the conclusion from Question (Q5) 1, use indicator functions to prove ( ) = (De Morgan's laws).

$$\mathbb{1}_{(A\cap B)^c} = \mathbb{1}_\Omega - \mathbb{1}_{A\cap B} = 1 - \mathbb{1}_A \cdot \mathbb{1}_B$$

Using the union of complements, we have:

$$\mathbb{1}_{A^c\cup B^c} = \max(\mathbb{1}_{A^c}, \mathbb{1}_{B^c}) = (1 - \mathbb{1}_A) + (1 - \mathbb{1}_B) - (1 - \mathbb{1}_A)(1 - \mathbb{1}_B)$$

This simplifies to:

$$\mathbb{1}_{A^c\cup B^c} = 1 - \mathbb{1}_A \cdot \mathbb{1}_B$$

Hence, we have verified that:

$$(A \cap B)^c = A^c \cup B^c$$

(Q6) Uncountable infinities (this is an optional extra). This is a challenging optional extra. You may want to return to this question once you have completed all other questions. Show that the set of numbers : = [0,1] is uncountably infinite.

##3. Probability theory

##3.1 Rules of probability

(Q1) Construct a probability function based on the Rules of probability Consider a sample space = { , , } and a set of events = { } (i.e., consists of all subsets of). Based on the rules of probability, find a probability function : → [0,1] that satisfies ({ , }) = 0.6 and ({ , }) = 0.5. In your example, you need to define a function called . The function maps each event in to a number. Make sure that your function satisfies the three rules, but you don't need to write down the proof (that it satisfies the three rules).

Let P({a}) = x, P({b}) = y, P({c}) = z

x+y+z = 1, x+y =0.6, y+z = 0.5

(Q2) Verify that the following probability space satisfies the rules of probability. Consider a setting in which the sample space = {0,1}, and = { } ={ ,{0},{1},{0,1}}. For a fixed [0,1], define a function : → [0,1] by ( ) = 0, ({0}) = 1 − , ({1}) = , ({0,1}) = 1. Show that the probability space (, ,) satisfies the three rules of probability.

P( ) = 0 P({0}) = 1- q P({1}) = q P({0,1}) = 1

P(S) = P( )+P({0})+P({1})+P({0,1}) = 1 Hence all the rules of probability satisfied

3.2 Deriving new properties from the rules of probability

(Q1) Union of a finite sequence of disjoint events.

for an infinite sequence of pairwise disjoint events 1, 2, . Show that for a finite sequence of disjoint events 1, 2, , for any integer bigger than 1, the below equality holds as a consequence of Rule 3:

$$P\left(\bigcup_{i=1}^{n} A_i\right) = \sum_{i=1}^{n} P(A_i)$$

(Q2) Probability of a complement. Prove that if is a sample space, is an event and := is its complement, then we have ( ) = 1 − ( ).

$$P(S^c) = P(\Omega \setminus S) = 1 - P(S)$$

(Q3) The union bound In Rule 3, for pairwise disjoint events 1, 2, , we have Give an example of a probability space and a sequence of sets 1, 2,

$$P(S_1 \cup S_2) < P(S_1) + P(S_2)$$

(Q4) Probability of union and intersection of events. Show that for events and , we have ( ) = ( ) + ( ) − ( )

$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$