Chi-square Test of Goodness-of-Fit

Examples in *Summary and Analysis of Extension Program Evaluation*
SAEEPER: Goodness-of-Fit Tests for Nominal Variables

Packages used in this chapter
The following commands will install these packages if they are not already installed:

```
if(!require(dplyr)){install.packages("dplyr")}
if(!require(ggplot2)){install.packages("ggplot2")}
if(!require(grid)){install.packages("grid")}
if(!require(pwr)){install.packages("pwr")}
```

When to use it
Null hypothesis
See the *Handbook* for information on these topics.

How the test works
Chi-square goodness-of-fit example

```
### ---------------------------------------------------------------
### Drosophila example, Chi-square goodness-of-fit, p. 46
### ---------------------------------------------------------------

observed = c(770, 230)        # observed frequencies
expected = c(0.75, 0.25)      # expected proportions

chisq.test(x = observed,
           p = expected)

   X-squared = 2.1333, df = 1, p-value = 0.1441
```

```
#     #     #
```

Post-hoc test
Assumptions
See the *Handbook* for information on these topics.

Examples: extrinsic hypothesis

```
### ---------------------------------------------------------------
### Crossbill example, Chi-square goodness-of-fit, p. 47
### ---------------------------------------------------------------

observed = c(1752, 1895)    # observed frequencies
expected = c(0.5, 0.5)      # expected proportions

chisq.test(x = observed,
           p = expected)

   X-squared = 5.6071, df = 1, p-value = 0.01789
```

```
..    ..    ..
```

```
#     #     #
```

```
### ------------------------------------------------------------
### Rice example, Chi-square goodness-of-fit, p. 47
### ------------------------------------------------------------

observed = c(772, 1611, 737)
expected = c(0.25, 0.50, 0.25)

chisq.test(x = observed,
           p = expected)

   X-squared = 4.1199, df = 2, p-value = 0.1275
```

```
#     #     #
```

```
### ------------------------------------------------------------
### Bird foraging example, Chi-square goodness-of-fit, pp. 47-48
### ------------------------------------------------------------

observed = c(70, 79, 3, 4)
expected = c(0.54, 0.40, 0.05, 0.01)

chisq.test(x = observed,
           p = expected)

   X-squared = 13.5934, df = 3, p-value = 0.0035
```

```
#     #     #
```

Example: intrinsic hypothesis

```
### ------------------------------------------------------------
### Intrinsic example, Chi-square goodness-of-fit, p. 48
### ------------------------------------------------------------

observed       = c(1203,  2919,  1678)
expected.prop  = c(0.211, 0.497, 0.293)

expected.count = sum(observed)*expected.prop

chi2 = sum((observed- expected.count)^2/ expected.count)

chi2

   [1] 1.082646

pchisq(chi2,
       df=1,
       lower.tail=FALSE)

   [1] 0.2981064
```

```
#     #     #
```

Graphing the results

The first example below will use the *barplot* function in the native *graphics* package to produce a simple plot. First we will calculate the observed proportions and then copy those results into a matrix format for plotting. We'll call this matrix *Matriz*. See the "Chi-square Test of Independence" section for a few notes on creating matrices.

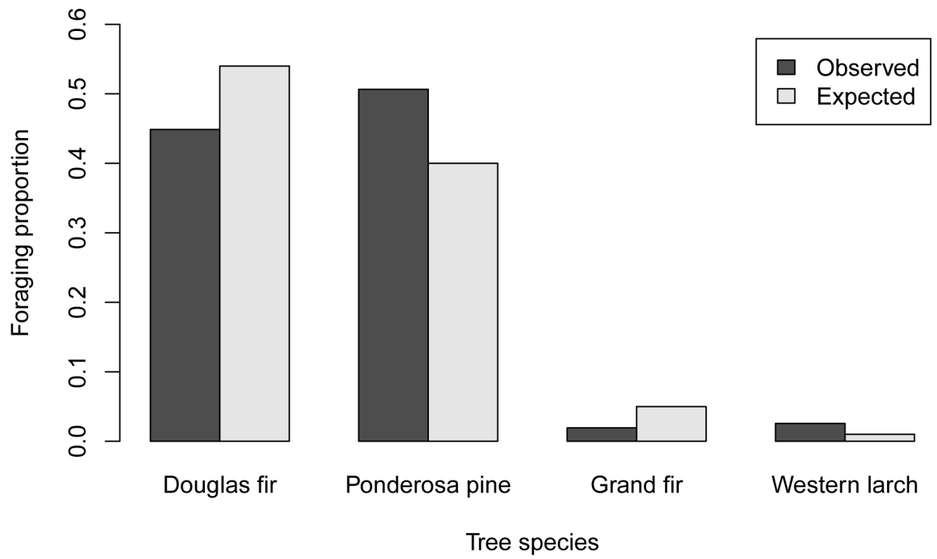
The second example uses the package *ggplot2*, and uses a data frame instead of a matrix. The data frame is named *Forage*. For this example, the code calculates confidence intervals and adds them to the data frame. This code could be skipped if those values were determined manually and put into a data frame from which the plot could be generated.

Sometimes factors will need to have the order of their levels specified for *ggplot2* to put them in the correct order on the plot, as in the second example. Otherwise R will alphabetize levels.

Simple bar plot with barplot

```
### ------------------------------------------------------------
### Simple bar plot of proportions, p. 49
###      Uses data in a matrix format
### ------------------------------------------------------------

observed = c(70, 79, 3, 4)

expected = c(0.54, 0.40, 0.05, 0.01)

total = sum(observed)

observed.prop = observed / total
```

```
observed.prop

   [1] 0.44871795 0.50641026 0.01923077 0.02564103


### Re-enter data as a matrix

Input =("
Value     Douglas.fir  Ponderosa.pine  Grand.fir   Western.larch
Observed  0.4487179    0.5064103       0.01923077  0.02564103
Expected  0.5400000    0.4000000       0.05000000  0.01000000
")

Matriz = as.matrix(read.table(textConnection(Input),
                  header=TRUE,
                  row.names=1))

Matriz

          Douglas fir Ponderosa pine  Grand fir Western larch
Observed   0.4487179      0.5064103 0.01923077    0.02564103
Expected   0.5400000      0.4000000 0.05000000    0.01000000


barplot(Matriz,
        beside=TRUE,
        legend=TRUE,
        ylim=c(0, 0.6),
        xlab="Tree species",
        ylab="Foraging proportion")
```




```
                                                                  #     #     #
```

***Bar plot with confidence intervals with* ggplot2**

The plot below is a bar char with confidence intervals. The code calculates confidence intervals. This code could be skipped if those values were determined manually and put in to a data frame from which the plot could be generated.

Sometimes factors will need to have the order of their levels specified for *ggplot2* to put them in the correct order on the plot. Otherwise R will alphabetize levels.

```
### ---------------------------------------------------------------
### Graph example, Chi-square goodness-of-fit, p. 49
###    Using ggplot2
###    Plot adapted from:
###       shinyapps.stat.ubc.ca/r-graph-catalog/
### ---------------------------------------------------------------

Input =("
Tree             Value      Count   Total Proportion  Expected
'Douglas fir'    Observed   70      156   0.4487      0.54
'Douglas fir'    Expected   54      100   0.54        0.54
'Ponderosa pine' Observed   79      156   0.5064      0.40
'Ponderosa pine' Expected   40      100   0.40        0.40
'Grand fir'      Observed    3      156   0.0192      0.05
'Grand fir'      Expected    5      100   0.05        0.05
```

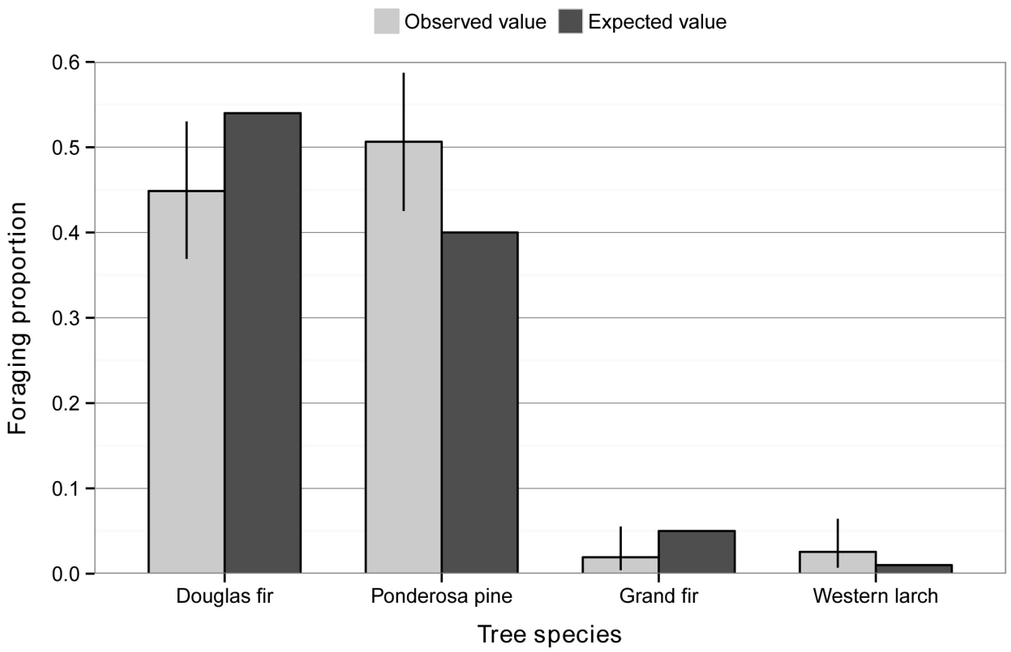
```
'Western larch'   Observed    4      156   0.0256      0.01
'Western larch'   Expected    1      100   0.01        0.01
")

Forage = read.table(textConnection(Input),header=TRUE)


### Specify the order of factor levels. Otherwise R will alphabetize them.

library(dplyr)

Forage =
mutate(Forage,
       Tree = factor(Tree, levels=unique(Tree)),
       Value = factor(Value, levels=unique(Value))
       )


### Add confidence intervals

Forage =
mutate(Forage,
       low.ci = apply(Forage[c("Count", "Total", "Expected")],
                      1,
                      function(x)
                      binom.test(x["Count"], x["Total"], x["Expected"]
                                 )$ conf.int[1]),

        upper.ci = apply(Forage[c("Count", "Total", "Expected")],
                         1,
                         function(x)
                         binom.test(x["Count"], x["Total"], x["Expected"]
                                    )$ conf.int[2])
        )

Forage$ low.ci [Forage$ Value == "Expected"] = 0
Forage$ upper.ci [Forage$ Value == "Expected"] = 0

Forage
```

	Tree	Value	Count	Total	Proportion	Expected	low.ci	upper.ci
1	Douglas fir	Observed	70	156	0.4487	0.54	0.369115906	0.53030534
2	Douglas fir	Expected	54	100	0.5400	0.54	0.000000000	0.00000000
3	Ponderosa pine	Observed	79	156	0.5064	0.40	0.425290653	0.58728175
4	Ponderosa pine	Expected	40	100	0.4000	0.40	0.000000000	0.00000000
5	Grand fir	Observed	3	156	0.0192	0.05	0.003983542	0.05516994
6	Grand fir	Expected	5	100	0.0500	0.05	0.000000000	0.00000000
7	Western larch	Observed	4	156	0.0256	0.01	0.007029546	0.06434776
8	Western larch	Expected	1	100	0.0100	0.01	0.000000000	0.00000000

```
### Plot adapted from:
###   shinyapps.stat.ubc.ca/r-graph-catalog/

library(ggplot2)
library(grid)

ggplot(Forage,
   aes(x = Tree, y = Proportion, fill = Value,
       ymax=upper.ci, ymin=low.ci))  +
       geom_bar(stat="identity", position = "dodge", width = 0.7) +
       geom_bar(stat="identity", position = "dodge",
                colour = "black", width = 0.7,
                show_guide = FALSE)  +
       scale_y_continuous(breaks = seq(0, 0.60, 0.1),
                limits = c(0, 0.60),
                expand = c(0, 0))  +
       scale_fill_manual(name = "Count type",
                 values = c('grey80', 'grey30'),
                 labels = c("Observed value",
                            "Expected value"))  +
       geom_errorbar(position=position_dodge(width=0.7),
                     width=0.0, size=0.5, color="black")  +
       labs(x = "Tree species",
            y = "Foraging proportion")  +
       ## ggtitle("Main title") +
       theme_bw()  +
       theme(panel.grid.major.x = element_blank(),
             panel.grid.major.y = element_line(colour = "grey50"),
             plot.title = element_text(size = rel(1.5),
             face = "bold", vjust = 1.5),
             axis.title = element_text(face = "bold"),
             legend.position = "top",
             legend.title = element_blank(),
             legend.key.size = unit(0.4, "cm"),
             legend.key = element_rect(fill = "black"),
```

```
 axis.title.y = element_text(vjust= 1.8),
 axis.title.x = element_text(vjust= -0.5)
)
```

```
#     #     #
```



Bar plot of proportions vs. categories. Error bars indicate 95% confidence intervals for each observed proportion.

Similar tests

Chi-square vs. G–test

See the *Handbook* for information on these topics. The *exact test of goodness-of-fit*, the G-*test of goodness-of-fit*, and the *exact test of goodness-of-fit* tests are described elsewhere in this book.

How to do the test

Chi-square goodness-of-fit example

```
### ---------------------------------------------------------------
### Pea color example, Chi-square goodness-of-fit, pp. 50-51
### ---------------------------------------------------------------

observed = c(423, 133)
expected = c(0.75, 0.25)

chisq.test(x = observed,
           p = expected)
```

```
   X-squared = 0.3453, df = 1, p-value = 0.5568
```

```
                                                                    #     #     #
```

Power analysis

Power analysis for chi-square goodness-of-fit

```
### ---------------------------------------------------------------
### Power analysis, Chi-square goodness-of-fit, snapdragons, p. 51
### ---------------------------------------------------------------

library(pwr)

P0      = c(0.25,  0.50, 0.25)
P1      = c(0.225, 0.55, 0.225)

effect.size = ES.w1(P0, P1)

degrees = length(P0) - 1

pwr.chisq.test(
               w=effect.size,
```

```
            N=NULL,           # Total number of observations
            df=degrees,
            power=0.80,       # 1 minus Type II probability
            sig.level=0.05)   # Type I probability

N = 963.4689
```

```
#     #     #
```
