Statistics Case Study: Cross Fell Grazing 2013

CK

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# Natural England Statistics Case Study

## Analysis of Variance in a grazing impacts study at Cross Fell SSSI

**Study:** *Survey of Grazing Impact on Cross Fell Montane Heath and Analysis of Change 2003-2013, Martin D., Natural England, 2014*

## Background

Cross Fell is part of Kirkland Fell, one of five contiguous upland commons in eastern Cumbria that came into Countryside Stewardship Scheme (CSS) Agreement Between 2000 and 2003. Under the terms of the agreement, stocking levels were reduced and shepherding introduced to further limit grazing pressure on sensitive habitats. As part of the project, the area of montane heath on the summit plateau of Cross Fell was surveyed in October 2003. Attributes of the vegetation condition and species composition were recorded. The survey was repeated in 2005, 2008, 2010 and 2013.

## Field Method

Surveyors measured vegetation height of a variety of taxa, including bilberry *Vaccinium myrtillus* on five sucessive surveys on montane grassland at Cross Fell in the North Pennines. The surveys took place in 2003, 2005, 2008, 2010 and 2013. Survey quadrats were randomly located each year. There were different numbers of quadrats in each survey year.

|  |  |
| --- | --- |
| year | n.total |
| 2003 | 42 |
| 2005 | 44 |
| 2008 | 20 |
| 2010 | 31 |
| 2013 | 56 |

Quadrats were placed at the random points that fell within montane heath on Cross Fell. The same set of random points was used in 2003 and 2005, but new sets generated in each of 2008, 2010 and 2013.

There is a record for each height measurement per year (although the quadrats are not labelled). Up to four bilberry height measurements were taken in each quadrat.

The number of measurements taken in each year is as follows:

|  |  |
| --- | --- |
| year | measurements |
| 2003 | 21 |
| 2005 | 53 |
| 2008 | 44 |
| 2010 | 40 |
| 2013 | 70 |

## Data analysis and results

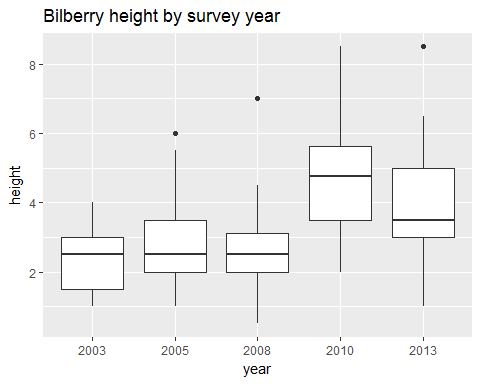
One of the desired outcomes of the intervention was a significant increase in bilberry height, as an indicator of favourable condition. The bilberry height data was therefore analysed for differences in the mean height between years.

**For each year** the following summary values of **vegetation height** were calculated:

Bilberry vegetation height summary

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| year | mean | median | sd | n |
| 2003 | 2.40 | 2.50 | 0.94 | 21 |
| 2005 | 2.88 | 2.50 | 1.15 | 53 |
| 2008 | 2.58 | 2.50 | 1.21 | 44 |
| 2010 | 4.66 | 4.75 | 1.73 | 40 |
| 2013 | 3.68 | 3.50 | 1.52 | 70 |

Plotted this looks as follows:



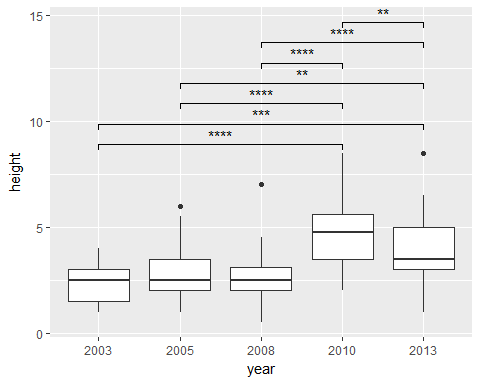
The data was tested for normality using the Anderson Darling test. Only the measurements in 2005 were not normally distributed (A = 1.2507, p = 0.0027). The other years' measurements were normally distributed (2003: A = 0.4746, p = 0.216; 2008: A = 0.7769, p = 0.0403; 2010: A = 0.3875, p = 0.3717; 2013: A = 0.6164, p = 0.1046)

The data were tested for homoscedasticity (homogeneity of variances) using the Bartlett Test. The variances were not found to be homogeneous (Bartlett's K-squared = 14.7949104, p = 0.005146). The data was found not to meet the requirements of homoscedasticity required for ANOVA so non-parametric testing was required.

The mean difference vegetation height in each taxon was tested using the Kruskall Wallace rank sum test test. There was a significant difference between the means (Kruskal-Wallis chi-squared = 50.3392199, p = 3.067429210^{-10}).

Having found significant differences, post-hoc testing using pairwise was carried out to identify and characterise the change. There earliest significant increase in vegetation height occurs in 2010. There was a significant increase in mean height of 2.26cm between 2003 (mean = 2.4cm) and 2010 (mean = 4.66cm) (p = 1.8e-06), and in fact also between 2010 and all previous survey years (2005: height increase = 1.27, p = 0.00045; 2008: height increase = 1.79, p = 6.2e-07). Although the mean height of bilberry subsequently decreased by -0.98cm between 2010 (mean = 4.66cm) and 2013 (mean = 3.68cm) (p = 0.00584), over the entire survey period there is an overall increase of 0.8cm between 2003 (mean = 2.4cm) and 2013 (mean = 3.68cm) (p = 0.00191).

This is shown in the graph below:



## Understanding the statistics

### Topic

* What question does it answer:
* How do I read it:
* How does it work:
* Tips:

### Mean

* What question does it answer: What is the average value of my data?
* How do I read it: It is the average of all the values.
* How does it work: It is the sum of all the values, divided by the number of values.

### Median

* What question does it answer: What is the middle value of my data?
* How do I read it: It's just the middle value.
* How does it work: All the values are lined up in order and the middle value is found.

### standard deviation, sd, sigma,

* What question does it answer: How spread out are the values?
* How do I read it: The greater the standard deviation, the wider the values are spread around the mean.
* How does it work: The standard deviation is the square root of the variance. The variance is the average of the squared differences from the mean.

### n

* What question does it answer: What is the size of my sample?
* How do I read it / how does it work: It is simply the number of observations.
* Tips: If n is very small (e.g. below 5), then most statistics are unlikely to be accurate.

### boxplot (box and whisker plot)

* What does it show: It shows the distribution of the data.
* How do I read it: First understand how it is drawn (below). Then you can use it to:
  + get an impression of how evenly the data is distributed (is the boxplot symmetrical),
  + whether the data is skewed (is the median closer to one end of the box than the other),
  + whether there are outliers,
  + whether the variances of two samples are similar (similar sized boxes).
* How does it work: There are many ways of drawing these but the most common is as follows:
  + the middle line is the *median*,
  + the box goes from the first to the third quartile (i.e. it encloses the middle half of the data), known as the *inter-quartile range*,
  + the lines extend to the highest and lowest values,
  + points show *outliers*, which are usually defined as values which are further than 1.5 times the inter-quartile range from the first or third quartile.

### p value

* What question does it answer: Is the statistic I have calculated *statistically significant*?
* How do I read it: In most cases, if p is smaller than 0.05 then you have found a statistically significant result. It means that you have a smaller than 1 in 20 chance of your *null hypothesis* being true purely by chance. In most cases in ecology the null hypothesis (*H0*) is 'no difference'. However, it depends on the test you are carrying out and you should always check. It also depends on the *significance level* (alpha or ) that has been decided beforehand. In ecology is usually 0.05.
* How does it work: It is the probability of finding the observed, or more extreme, results when the null hypothesis (H0) of a study question is true – the definition of ‘extreme’ depends on how the hypothesis is being tested.
* Tips: Always carefully check what the *null hypothesis* is.

### Anderson Darling test for test for the composite hypothesis of normality

* What question does it answer: Is the data normally distributed?
* How do I read it: If p is greater than 0.05 then the distribution is normal.
* How does it work: The test compares the data to a normal distribution with the same mean and standard deviation and calculates the probability of getting a more extreme result (i.e. more different to normal) by chance.

### Bartlett test for homogeneity of variances

* What question does it answer: How different is the spread (variance) of each sample? Are they homogeneous?
* How do I read it: If the p-value is smaller than 0.05 then the variances are very different and not homogeneous.
* How does it work: The null hypothesis is that the variance is the same for all samples. The test compares the variances to each other and calculates the probability of getting a more extreme result (i.e. more different from each other) by chance.

#### Kruskal-Wallace

* What question does it answer: How different are the means of our samples from each other?
* How do I read it: If the p-value is smaller than 0.05 then at least two of the samples are significantly different from each other. It will not tell you which two samples.
* How does it work: The null hypothesis is that the samples are drawn from the same population, i.e. the true mean is the same for each survey. The test lines up all the values in order and assigns ranks to them. It then calculates the probability of getting a more extreme result (i.e. more different from each other) by chance.
* Tip: You can use this test if your data is not normally distributed or if the variances are not homogeneous.

#### pairwise Wilcoxson rank sum tests (also known as Mann-Whitney U test)

* What question does it answer: Which pairs of samples are significantly different from each other.
* How do I read it: The test will return a p-value for combination of two samples. If the p-value is smaller than 0.05 for a particular pairing then the two samples are significantly different from each other.
* How does it work: The null hypothesis is that the samples are drawn from the same population, i.e. the true mean is the same for each survey. The test lines up all the values in order and assigns ranks to them. It then calculates the probability of getting a more extreme result (i.e. more different from each other) by chance.
* Tip: You cannot use this test unless you have already found that there is a significant difference between at least two samples. If there is not, the test may suggest that there are significant differences, but this is likely to be a false-positive.