**Two-way ANOVA questions**

**Question 8: 2009**

You want to establish a Wollemi Pine plantation for timber harvesting and need to know the best conditions for tree growth. Nutrients and sunlight are thought to be key factors affecting plant growth generally. So to test this idea you design an experiment to examine the effect of fertilizer and aspect on the growth of Wollemi Pine seedlings in field trials. You have 3 different levels of fertilizer (10 kg/ha/week, 30 kg/ha/week and 100 kg/ha/week) and you apply these to small field-based plots on hillsides with 4 different aspects (North facing, South facing, West facing and East facing slopes). There are 7 experimental units per treatment combination and each unit consists of a 0.01 ha plot located at random in the area. The response variable is the mean growth of 10 seedlings per plot over 6 weeks and the dataset meets the assumptions of ANOVA.

An ANOVA on these data yields the following table:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | SS | Df | MS | F | P |
| Fertiliser | 155.26 | 2 | 77.63 | 27.4 | <0.01 |
| Aspect | 15.54 | 3 | 5.18 | 1.8 | 0.15 |
| Aspect x Fertiliser | 75.06 | 6 | 12.51 | 4.4 | <0.01 |
| Within | 203.76 | 72 | 2.83 | - | - |
| Total | 449.62 | 83 | - | - | - |

1. What null hypotheses are being tested by this ANOVA? (3 marks)
2. What are the assumptions of the dataset that must be met to be able to use ANOVA. (3 marks)
3. Using the design above draw 2 examples of an interactions plot, first where there is a significant interaction and second where there is no significant interaction between the factors. (4 marks)
4. State your interpretation of the results of this experiment. (3 marks)
5. Explain the differences between fixed and random factors and how this difference influences your interpretation of such a factor in ANOVA. (5 marks)
6. What is confounding in ANOVA designs and is this design confounded? (2 marks)

**QUESTION 5.** **2010**

Bait palatability is a major issue in rodent management. If rats eat too little because of poor palatability, then animals will consume sub-lethal doses, become sick and develop bait aversion. If they eat too much because of high palatability, then a large amount of bait is wasted. Most trials of palatability have been done with choice tests where animals are offered a choice of food treated with the toxin or not treated. However, animals in the wild have to work to find alternate foods and may eat more of foods they don’t like if they have to search hard for other food stuffs.

To test whether access to alternate food influences bait palatability you run an experiment examining how much bait (a non-toxic one) is eaten when alternate, non treated food is either freely available or hidden. Individual rats are offered baits with one of four different concentrations along with the non- treated food which is either hidden in a matrix of tubes or easy to find in one central location. The response is the amount of baited food eaten and there are seven rats in each treatment combination.

Question 5 continued. An ANOVA on these data yields the following table.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | SS | df | MS | F | P |
| Bait concentration | 155.26 | 3 | 51.75 | ? | ? |
| Access to alternate food | 15.54 | 1 | ? | 1.8 | 0.15 |
| Conc. x Access | ? | 3 | 12.51 | ? | <0.01 |
| Within | 203.76 | 48 | ? | - | - |
| Total | 429.61 | 55 | - | - | - |

Answer all parts 5A-D.

**5A)** Draw an explanatory diagram of this experimental design. (4 marks)

**5B)** Complete the ANOVA table (where there are the “?” symbols) as far as possible from these data (reproduce it in the answer booklet and give your calculations). (6 marks)

**5C)** Does bait palatability change with access to alternate food? Explain your reasoning. (4 marks)

**5D)** The data in this design meets the assumption of independence. Explain what this means for the way replicates are collected and treatments are applied. (6 marks)

**QUESTION 7.**  **2011**

A researcher conducted an experiment to study the effect of the presence of guppy predators (absent versus introduced) and food abundance (low food versus high food) on the size at hatching of baby Killifish. Below is a graph of the data (ignore the ellipses drawn around two of the mean values), and a partial table of output from a GLM analyses on that data.



Source SS df MS F P

Feeding - - - 4.1 0.062

Introduction - - - 8.2 0.041

Feed\*Intro - - - 15.5 0.013

Within (error) - - -

Total - -

Answer all parts 7A-7I.

**7A)** Are there any assumptions violated? If so, state which and describe why. (2 marks)

**7B)** Based on results above, what would you conclude from this experiment? (2 marks)

**7C)** What is the GLM (in words) that is being tested (fitted) on this data? (3 marks)

**7D)** What is the null hypothesis in words? And written as a GLM? (2 marks)

**7E)** What is this experimental design called? (2 marks)

**7F)** If an interaction effect is significant, what does this mean for the interpretation of the main effects? (3 marks)

**7G)** The analysis above tells us differences exist among groups, but not which groups differ – how could we assess this and what test might we use? (2 marks)

**7H)** What is the traditional name for this analysis? (2 marks)

**7I)** If we added another predictor variable to this model, what would the traditional label for such an analysis be? (2 marks)

**QUESTION 7. 2014**

You want to examine the response of fish recruitment to environmental flows and need to know the best conditions for growth of larval fish. The density of microinvertebrates which are eaten by fish and temperature are known to be two key factors affecting larval growth generally. To test this idea, you design an experiment to examine the effect of varying the density of prey (cladocerans, also known as water fleas) and water temperature on the growth of Murray cod.

You have three different levels of cladoceran density (10/L, 100/L and 1000/L) and you add these to small aquaculture tanks with 4 different temperatures (15 °C, 20 °C, 25 °C and 30 °C). There are 7 experimental units per treatment combination and each unit consists of a 30 L tank placed at random in the laboratory. The response variable is the mean growth of 10 larval fish per tank over 3 months and the dataset meets the assumptions of ANOVA.

An ANOVA table on these data yields the following table:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | SS | df | MS | F | P |
| Cladoceran density | 155.26 | 2 | 77.63 | 27.4 | <0.01 |
| Temperature | 15.54 | 3 | 5.18 | 1.8 | 0.15 |
| Cladocerans x Temperature | 75.06 | 6 | 12.51 | 4.4 | <0.01 |
| Within | 203.76 | 72 | 2.83 |  |  |
| Total | 449.62 | 83 |  |  |  |

Answer all parts 7A to 7E.

**7A)** What null hypothesis are being tested by this ANOVA (3 marks)

**7B)** Using the design above draw two examples of an interactions plot, first where there is a significant interaction and second where there is no significant interaction between the factors. (4 marks)

**7C)** State your interpretation of the results of this experiment. (4 marks)

**7D)** Explain the differences between fixed and random factors and how this difference influences your interpretation of such a factor in ANOVA. (5 marks)

**7E)** What do the sums of squares tell us about variation among sources in this experiment? (4 marks)

# QUESTION 9: 2006

People are concerned about the impacts of dogs urinating on trees in your local areas. Therefore, the local council has employed you to determine whether dog urine (from dogs being walked in parks) affects tree seedling growth. But different trees have different nutrient requirements and may show unique responses to the impact of the dog urine. So to test this idea you design an experiment to examine the effect of urine on the growth of several species of Eucalyptus seedlings in field trials. You have 3 different levels of dog urine (20 ml/plant/week and 100 ml/plant/week and no urine) and you apply these treatment to 8 seedlings of 3 different species chosen randomly from the range of species found in your local areas. The response variable is the mean growth of seedlings over 6 weeks and the dataset meets the assumptions of ANOVA.

An ANOVA on these data yields the following table:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | SS | Df | MS | F | P |
| Dog urine | 77.63 | 1 | 77.63 | 8.27 | 0.10 |
| Species | 7.77 | 2 | 3.85 | 1.17 | 0.3 |
| Urine x Species | 18.77 | 2 | 9.39 | 2.96 | 0.06 |
| Within | 203.76 | 63 | 3.28 | - | - |
| Total | 449.62 | 71 | - | - | - |

1. What null hypotheses are being tested by this ANOVA? 3 marks
2. Using the design above draw 2 examples of an interactions plot, first where there is a significant interaction and second where there is no significant interaction between the factors. 5 marks
3. State your interpretation of the results of this experiment. 6 marks

Explain the differences between fixed and random factors; what would it mean if Species was a fixed factor in this design; how would this change influence the analysis and interpretation of this ANOVA? 6 marks

# QUESTION 8: 2006 supp

You design an experiment to examine the effect of fertilizer and location on the growth of eucalypt trees in field trials. You have 3 different levels of fertilizer (30kg/ha, 60kg/ha and 100kg/ha) and you conduct these trials at 4 different areas around Sydney chosen at random. There are 5 experimental units per treatment combination and each unit consists of a 1ha plot located at random in the area. The dataset meets the assumptions of ANOVA.

An ANOVA on this data yields the following table:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source | SS | df | MS | F | P |
| Fertilizer | 155.26 | 2 | 77.63 | 6.2 | 0.035 |
| Location | 15.54 | 3 | 5.18 | 1.2 | 0.414 |
| Fertilizer x Location | 75.06 | 6 | 12.51 | 2.9 | 0.017 |
| Within | 207.36 | 48 | 4.32 | - | - |
| Total | 453.22 | 59 | - | - | - |

1. What are the benefits of doing 2-factor ANOVA versus several 1-factor ANOVA’s? (4 marks)
2. In general terms, what does the F-ratio do (i.e. what is it a measure of?) (3 marks)
3. Give a definition of degrees of freedom and explain how they influence the outcome and interpretation of ANOVAs. (4 Marks)
4. Using the design above draw 2 examples of an interaction plot, first where there is a significant interaction and second where there is no significant interaction between the factors. (4 marks)
5. Explain the differences between fixed and random factors and how this difference influences your interpretation of such a factor in THIS ANOVA. (5 marks)