Chapter 8 Experiments with several factors (factorial designs)

Additional self-test questions

Q8.1 A new food supplement has been produced to enhance growth in farmed fish. You are tasked with identifying whether this supplement is more effective commercially in sea trout or rainbow trout. How would you go about this?

This is a classic example of testing an interaction: does species influence the effect of diet on growth? You need four groups. There are lots of things to get right here. Because we want to work out an effect of species, we need to make sure that lots of other things, like cage type, initial size structure, and stocking density, are held the same. We need to make sure that the person weighing the fish is blind to diet (supplemented or not), even if they can't be blind to species. As far as replication is concerned, probably a single farm does not keep both species, so you are going to have to do this across farms (taking account of possible confounders: latitude, farm size, water temperature). We think this investigation has to be done on a farm-scale, rather than in isolated fish in the lab, because we are interested in commercially relevant effects.

Q8.2 Can you imagine a circumstance where a split-plot design would be useful in zoology?

We might be interested in how diet and a hormone injection combine to affect some aspect of behaviour (say vocalization frequency) of free-range chickens. Because the chickens are free-range it is difficult to organize making a food supplement available to some chickens in a run and not to others that share the same space. So we will make 'run' our main plot factor and allocate entire runs to different dietary treatments. But within a run, we will allocate individual chickens to whether they get the hormone injection or a sham injection.

Q8.3 What do people mean by a fully crossed design?

This implies that we have a factorial design where subjects can be allocated all possible combinations of levels of the different factors. So if there are two factors, factor A with two levels and factor B with three levels, then there will be six different groups (2 x 3) each of which a given subject could be allocated to.

Q8.4 Explain the concept of an interaction between a factor and a covariate by way of an example.

Imagine that we have an experiment to test three different anthelmintic drugs on horses and have reason to expect that the drugs might be differentially effective on horses of different ages. We randomly assign horses to one of four treatment groups. The group is defined by the drug applied and has four levels (since we have a control group given a placebo treatment). We also record the age of each horse. We measure the rate of infectious material excreted a month after the course of treatment as our response variable. In order to test whether the drugs are differentially effective in horses of different ages we test the interaction between the factor 'drug type' and the covariate 'age' in our statistical analysis.

Q8.5 We predict that a given dietary regime will lead to greater weight loss in women than men. We randomly allocate individuals to one factor, 'diet', with two levels, dietary regime or control group experiencing no change, and for each individual note their sex (another factor 'sex' with two levels). In our statistical analysis we find that the interaction between these two factors is significant; does that provide evidence in support of the original prediction?

Perhaps. It does indicate that the two dietary situations have different effects on men and women; however it might be that the new regime actually causes weight gain, or causes greater weight loss in men than women. In order to understand the nature of the interaction you have found, you need to plot or otherwise examine the mean weight changes for individuals in all the four groups.

Q8.6 In the experiment of the last question, can we be sure that the effect we find is due to sex or might it be due to some factor that is linked to sex?

Because individuals are not randomly allocated to sex, there is a danger that there is an effect of something that correlates with sex. For example, it might be that the diet does not really have a differential effect on the two sexes but it has a stronger effect on people with lower starting body mass, and women tend to have lower starting body mass than men in our study. In order to explore this we could see if we find a trend with initial body mass in each sex separately. This same approach could be taken with all potential covariates that we can think of and measure, but it does not protect us against any that we don't think of.

Q8.7 Explain the attractions and drawbacks of split-plot designs in your own words.

We have two factors that individual subjects are assigned to levels of. If one of these factors is practically tricky to apply to individual subjects but easier to apply to a group of subjects, then we could switch to a split-plot design making this factor the main-plot factor. The other factor (now identified as the sub-plot factor) is applied independently to individual subjects. This encapsulates the benefit of a split-plot design—increased practical convenience. The cost (relative to complete randomization) is reduced statistical power to detect effects of the main-plot factor. This may be a price worth paying if we expect these effects to be strong and/or if what we are mainly interested in is not the main effect of this factor but how it interacts with the other.

Q8.8 Explain the attractions and drawbacks of Latin square designs for three-factor studies in your own words.

The attraction is simple—fewer experimental subjects are required than the equivalent complete randomization experiment. The design can only be used in restricted circumstances, however. It gives no ability to test interactions, so should only be used when these are of no interest and are not expected to be strong. Also, the number of levels must be the same for each of the three factors involved.

Q8.9 Discuss what we mean by data recorded on an ordinal scale.

An ordinal scale is a set of categories that have a rank order but have no quantitative relationship. If we subjectively scored female spiders' responses to approaching males on a scale of 0–5, where 0 implies strong receptivity and 5 implies aggressive attack, this would be an ordinal scale. If one interaction is scored 2 and the next is scored 4 then this implies that the second interaction shows more hostility than the first, but is does not imply that it was in any sense twice as hostile.