The Ecology Centre

The University of Queensland

# DEVELOPMENT OF DECISION SUPPORT MODELS FOR WEED CONTAINMENT AND ERADICATION

## II. Survey Design

## Branched Broomrape

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A report prepared for Dr Rick Roush, CRC for Weed Management
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# Contents

# 1 Introduction

This report outlines the survey methodology for branched broomrape due to commence on the 9th of September 2002.

This report has four sections. The first section presents the concept of transect surveying, a survey practice that has been implemented over the past three years for surveying branched broomrape. Here, we provide a brief description of the sampling method, present the benefits in the context of branched broomrape, discuss current practice and outline the implementation and improvement of the survey design for future surveys.

The remaining sections of this report focus on quantifying three sources of error, which we refer to as *false negative error*.

The first source of error is termed *observer error*, that is, the error due to the observer not seeing branched broomrape on the transect, despite its emergence. Since the weed is difficult to see and can be easily camouflaged it is not unreasonable to assume that detection on the transect is not 100%. At present, we hypothesise detection on the transect to be approximately 90%. To quantify this source of error, we suggest using multiple field observers. This is discussed further in Section 3.

The second source of false negative error represents the error incurred through the design of the survey. This is referred to as *design error*. Although there are many different survey designs that we could consider for branched broomrape, all contribute a source of error that needs to be taken into account when exploring and modelling the data. Section 4 discusses using transect distances to help quantify the shape of the detectability distribution and therefore aid in the estimation of the design error.

The final source of error, which remains difficult to quantify is the error resulting from an observer not observing the weed because it has not emerged. Its emergence is affected by climatic conditions, the time of year and most importantly the presence of a host. Some suggestions have been made to perform extensive searches of paddocks to try and differentiate and disentangle the *emergence error* from the observer and design error. This is difficult to achieve and will be discussed in further detail in Section 5.

In the final section of this report we present a summary of the survey practices that should be implemented in the 2002 survey.

# 2 Sampling and Surveying

## 2.1 Description

Line transect surveys are useful for surveying and monitoring populations in which detectability depends on the location of the observer. Krishnaiah & Rao (1988), Thompson (1992) and Buckland (1993) discuss distance sampling in great length. Buckland (1993) in particular, promotes distance sampling as a method for estimating abundance of biological populations.

Individual transects are characterised by a function that measures detectability. For many populations this function highlights increased detection along the transect and decreased detection as objects are located further from the transect. Ideally, detection on the transect should be perfect with objects not exhibiting any clustering or spatial aggregation that could make detection difficult.

Recent publications have focussed on the pitfalls of distance sampling when detection is not 100% on the transect. For example, Barry & Welsh (2001) highlight the problem of confounding between the detection function and density of objects, therefore making it difficult to identify the cause of low counts, that is, whether low counts are caused by small numbers of objects or alternatively through poor detection. As a result, difficulties in estimating the detection function and spatial distribution of objects arise.

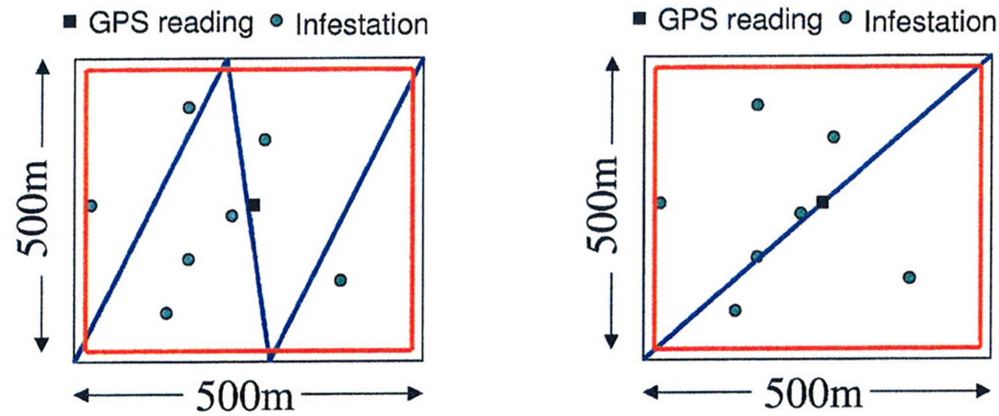
## 2.2 Benefits

There are two main benefits associated with distance sampling. First, the approach is simple and relatively quick to implement compared to other methods that require intensive searches over regions, searches that require stratified approaches and point-to-point sampling that requires distances between infestations to be recorded. The second benefit is that distance sampling has been widely used in practice for estimating species abundance.

Although a recent paper by Barry & Welsh (2001) has highlighted the pitfalls of distance sampling, especially when detection on the transect is not perfect, methods for quantifying false negative errors, that is, errors associated with not observing the object despite its presence, can be put in place. Furthermore, the sophistication of Bayesian hierarchical models can account for such errors in a model.

## 2.3 Current Practice

Current practice for surveying branched broomrape involves surveying the perimeter of paddocks in addition to surveying the centre using a $Z$ shaped transect as shown in Figure 1(a). Two raters are used simultaneously to survey each paddock, with one rater typically surveying the perimeter and the other surveying along the $Z$. A Global Positioning System (GPS) reading is also recorded at the centre of each paddock for mapping purposes. This is denoted by a black square in Figure 1(a).




(a) (b)

Figure 1: Survey designs showing (a) perimeter transects (red) and a $Z$ shaped transect (blue) overlayed on a 25ha paddock and (b) perimeter transects (red) and a transect measured diagonally from the south-west corner to the north-east corner (blue). Random infestations are shown by light blue circles, while the centre of the paddock, recorded by GPS is shown as a black square.

Anecdotal evidence suggests that broomrape is found more often along the perimeter than in the centre. Visual inspection of data in ArcView collected for either cereal or cereal hay crops identified 59 infestations. Of these, only two were located along the $Z$ transect, suggesting that we are 30 times more likely to observe an infestation on the perimeter than on a $Z$ transect for cereal crops. This information was obtained by manual inspection of infested paddocks and observing paddocks with infestations within 10 metres from the paddock boundary.

## 2.4 Implementation for Future Surveys

The above results indicate that it may be more worthwhile concentrating efforts on perimeter searches rather than intensive searches within a paddock using a $Z$ transect. Moreover, since GPS readings are required for each paddock surveyed and these readings are obtained *roughly* at the centre of the paddock, a diagonal transect starting from the south-west corner and continuing through to the north-east corner of the paddock (Figure 1(b)) could be substituted for the $Z$ transect. This survey design would result in fewer transects being investigated, corresponding to a distance less than half of what is required to complete the $Z$ survey for each paddock. Separating perimeter searches from the diagonal transect would also allow investigation and comparison of the abundance on the perimeter and along the diagonal.

A second important aspect of this design is concerned with how the data is recorded. An identification number unique to each paddock which can be linked back to previous survey years should be recorded in the database. Although Easting and Northing co-ordinates are available via GPS readings, they are not accurate. Recording paddock identifications is important for tracking spatial and temporal trends in the data and also for comparing management strategies and effectiveness of spraying from year to year. A suggestion is to use the paddock identification numbers already stored in the database for the 2001 survey.

# 3 Multiple Field Observers

## 3.1 Description and Benefits

Multiple field observers are essential in distance surveys where interest is in measuring the reliability of raters and therefore determining the probability of detecting objects on the transect.

Consider the detectability functions shown in Figure 2. In each of these diagrams we assume that the probability of detection on the transect is not perfect. This information is largely based on anecdotal evidence from past surveys and discussions with field observers. Multiple field observers can help to quantify this probability measure and therefore determine the height of this function and how it varies for different crops and under different conditions.

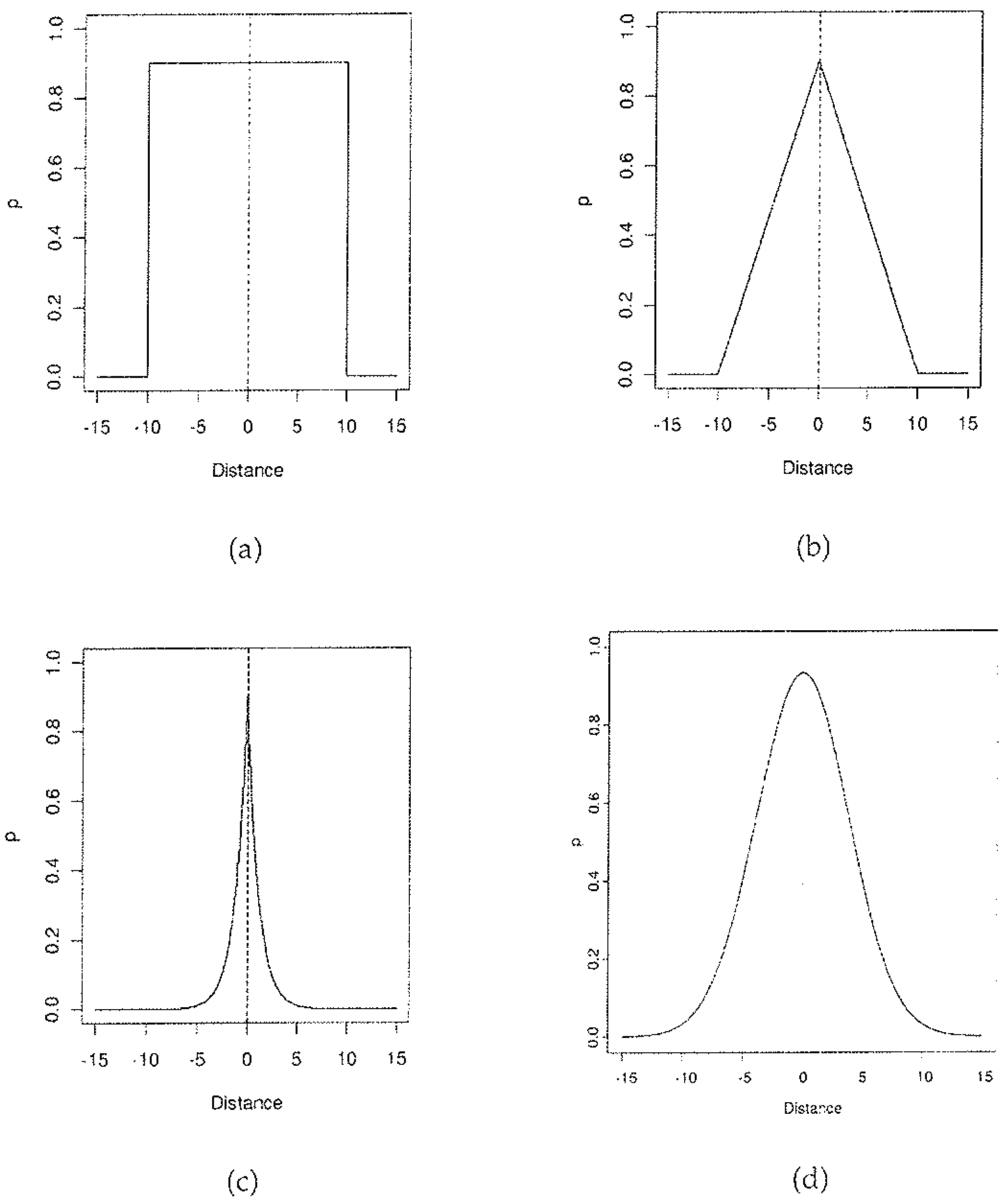



Figure 2: Distributions for detectability proposed for branched broomrape: (a) Uniform, (b) Triangular, (c) Exponential and (d) Normal. These distributions are based on the assumption that the probability of detection on the transect is 0.9 and beyond 10 metres, the probability of detecting infestations is small.

## 3.2 Current Practice

Presently, two field observers are used simultaneously to survey paddocks. One field observer typically surveys the perimeter, while a second surveys using the $Z$ transect.

## 3.3 Implementation for Future Surveys

At least two field observers should be used to survey paddocks for branched broomrape. This should be conducted as a double blind experiment, ensuring that field observer 1 completes the survey independently and without knowledge of field observer 2. Furthermore, both field observers should begin their survey from the same geographic location along the boundary of a paddock to allow for comparison.

Ideally it would be useful to implement this for all paddocks. However this does not seem feasible given that on average, approximately 4000 paddocks are surveyed each year. An alternative strategy is to perform a double blind survey on a subset of paddocks. This usually involves selecting a random sample of paddocks prior to conducting the survey to perform the repeat analysis.

Results from previous surveys indicate that approximately 4% of paddocks surveyed contain infestations. Since the proportion of infested paddocks is small, the number of samples required to ensure that at least one infested paddock is captured using simple random sampling becomes large. To avoid this problem, we suggest performing the double blind survey on a subset of paddocks. Table 3.3 shows sample sizes corresponding to the level of significance $\alpha$, power $1 - \beta$ and true measure of agreement $\kappa$. Cohen's Kappa ($\kappa$) statistic (Cohen, 1960; Landis & Koch, 1977) is a measure of reliability between raters and has been adopted here to determine the level at which we can conclude reliability between raters is at least substantial ($\kappa > 0.6$).

Table 3.3 shows that if we want to have 90% power of detecting a significant result (that is, at least substantial reliability between raters) at the 1% level when the true estimate is 0.8, then at least 80 samples are required. This estimate for $N$ drops to 63 if we are prepared to sacrifice power for 80% reliability.

The power calculations reported in Table 3.3 have been calculated using the measures proposed by Donner & Eliasziw (1987), which assumes that the systematic differences among ratings on a given object are not separable from random error. The calculations also assume that the same two field observers are rating paddocks. Although this may not be entirely applicable for branched broomrape, we can still use these estimates as a lower bound for estimating sample size since

| $\alpha$ | $1-\beta$ | $\kappa$ | $N$ |
|---|---|---|---|
| 0.01 | 0.90 | 0.8 | 80 |
| 0.01 | 0.80 | 0.8 | 63 |
| 0.05 | 0.90 | 0.8 | 54 |
| 0.05 | 0.80 | 0.8 | 39 |
| 0.01 | 0.90 | 0.9 | 23 |
| 0.01 | 0.80 | 0.9 | 18 |
| 0.05 | 0.90 | 0.9 | 15 |
| 0.05 | 0.80 | 0.9 | 12 |

Table 1: Power calculations for the broomrape study assuming that reliability between field observers is at least substantial ($\kappa > 0.6$). The table shows power calculations for different levels of significance $\alpha$, power $\beta$ and true measure of agreement, $\kappa$.

Donner & Eliasziw (1987) report that the estimates derived by their calculations are conservative.

Based on power calculations proposed by Donner & Eliasziw (1987), we recommended an approach which involves surveying 40 infested and 40 non-infested paddocks that are identified *during* the survey. That is, when field observer 1 locates an infested paddock, a second field observer is brought in to independently assess the paddock. Ideally the same two field observers should rate paddocks ensuring that the order of raters is noted. This type of surveying is continued until 40 infested and 40 non-infested paddocks are identified. For all remaining paddocks, one field observer can be used to determine the status of paddocks.

The numbers of infested and non-infested paddocks were chosen to ensure that the power of observing at least 'substantial' reliability ($\kappa \geq 0.6$) between field observers at the 1% level of significance is 90% when the true measure of agreement is 0.8.

# 4 Transect Distances

## 4.1 Description and Benefits

By measuring the distance from an infestation perpendicular to the transect, we can obtain a measure of how well objects can be detected from the transect and how effective the survey design is in detecting objects.

Figure 3 illustrates this concept for a simple example where a North-South transect is projected on a 25ha paddock with a random number of infestations. In this example, the distance for points close to the transect is measured by drawing a straight line from the infestation, perpendicular to the transect. Note that some points have no lines drawn because they are located at a distance too far from the transect.

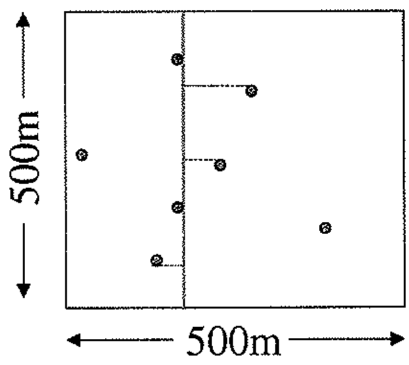



Figure 3: Illustration of calculating the distance from an infestation, perpendicular to the transect for a random allocation of infestations using a N-S transect.

By observing the frequencies of distances, we can form a probability distribution that shows the relationships between the distance and the probability of detecting objects at that distance.

Examples of detectability distributions were shown in Figure 2. The one most likely reflecting the detection of branched broomrape is the Normal distribution (Figure 2(d)). This distribution shows a shoulder of high probability of detection close to the transect with detection decaying towards zero for objects located further from the transect.

## 4.2 Current Practice

Current practice does not involve recording transect distances. Once an infestation has been sited along a transect, a second team is called in to map the perimeter of the infestation and record its location by roughly determining the centre of the infestation.

### 4.3 Implementation for Future Surveys

For future surveys it is important to record the distance from an infestation, perpendicular to the transect. This will allow us to quantify the shape of the detectability distribution and therefore the error due to the survey design.

For this particular part of the survey, it is sufficient to give an approximation of the distance rather than an actual measure. Field observers that do wander off the transect should always ensure that they return to the last point on the transect. This will ensure repeatability if the paddock is to be surveyed by a second field observer as described in Section 3. Finally, transect distances need only be performed for the subset of paddocks identified in Section 3. Once 40 infested and 40 non-infested paddocks have been identified, the usual method for surveying can be carried out.

## 5 Intensive Sampling

### 5.1 Description and Benefits

Intensive sampling or what has been referred to as an *emu search* represents a complete and an intensive search of a paddock with the aim of detecting all objects. This represents a very time consuming process and still runs the risk of missing objects, particularly if detection along a transect line is not 100%.

For branched broomrape, the benefit of an *emu search* is that we have the 'potential' to find all emerged weeds. However, disentangling observer error from emergence error may be difficult, since the weed itself is so variable.

A better option would be to perform intensive searches on paddocks which have undergone certain management practices to determine how effective they have been at eradicating the weed.

### 5.2 Current Practice

Current practice does not involve any intensive searches on paddocks and resorts to detection using only transect surveying.

### 5.3 Implementation for Future Surveys

Rather than focusing on intensive searches for the purpose of quantifying *emergence error*, we suggest using intensive searches for determining effectiveness of eradication methods.

A number of paddocks have undergone some type of eradication procedure ranging from herbicidal spraying, fumigation (methyl bromide) or solarisation. Intensive searches of these paddocks in the 2002 survey can allow us to assess the effectiveness of each method over time. The feasibility of this approach and its effectiveness for evaluating management strategies is left for discussion.

## 6 Concluding Remarks

This report outlined sampling and survey practices for determining presence or absence of branched broomrape and numbers and size of infestations.

The following recommendations should be introduced at the next survey, scheduled for the 9th of September 2002.

1. Concentrate on perimeter searches of paddocks
2. Replace the $Z$ transect with a diagonal transect starting in the south-west and continuing to north-east corner of each paddock. Using this transect, record the centre of the paddock.
3. Ensure that each paddock has a unique paddock identification number that can be traced back to previous survey periods.
4. Use two field observers to independently rate paddocks. We suggest performing a double blind survey on 40 infested and 40 non-infested paddocks identified during the survey.
5. Record the (approximate) distance from the transect, perpendicular to infestations. This should be performed for the subset of paddocks outlined above.

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