3 Methodology

This chapter outlines the methods used to examine the four main objectives of this thesis; the validity of producer perceptions, determining the key weeds of graziers, the best management practices for weeds and examining the challenges to adoption of these practices. The chapter is broken up into five main sections which outline the major research activities undertaken for this project: 1) key informant interviews; 2) the postal survey; 3) on farm visits for validation; 4) telephone interviews and 5) producer focus groups. For each section (apart from the key informant interviews and telephone interviews) a review of the relevant literature is presented followed by a description of the methodologies undertaken.

The overall aim of this project is to harvest local knowledge. Because this local knowledge is rarely written down and requires the application of social science to gather biological information, combining two frequently disparate scientific disciplines, it has been described as a formidable task (Huntington 2000). This project involves the use of a variety of scientific research methods, and it integrates methods from both natural and social science. The natural science component is applied to examine the validity of producer perceptions.

The social science methods used in this study fall into two general categories, qualitative and quantitative research techniques. Quantitative methods deal with numbers and measurements of defined characteristics, which enable statistical analysis of the results. Qualitative methods are used to seek to understand reasons behind various behaviours, trying to understand these in some depth. Quantitative research is useful in that it provides a broad view of trends which can be readily statistically analysed. However, quantitative research is limited as it cannot always provide enough detail to explain the trends it uncovers. Qualitative research provides deeper insights and can explain the "how" and "why" of problems, but is often limited by being highly context specific and difficult to analyse (Maykut and Morehouse 1994; Miles and Huberman 1994; Morse and Richards 2002).

The combination of both quantitative and qualitative methods can be synergistic and both techniques have purposely been employed in this project providing a broad overview of trends and where necessary, an in depth understanding of the reasons or workings behind these trends.

3.1 KEY INFORMANT INTERVIEWS

The project began with key informant interviews which involved telephone and in person interviews of people experienced in the grazing industry, pasture weed and survey methodology. Producers were also interviewed to gain a basic understanding of the industry and the impact of pasture weeds. The producers interviewed responded to advertisements placed in the newsletters of NSW Farmers Association, Landcare and the Cicerone Project Inc. (a farmer research-adoption group based in the New England Tablelands region of New South Wales). An important part of the producer interviews involved learning the language used to describe the issues surrounding weeds and weed management. This information was used to direct the wording of questions in the survey. Further lessons learnt through the key informant interviews are discussed later in the methodology section.

3.2 POSTAL SURVEY

A postal survey was used as the major research component in this project. There are many examples of the use of postal surveys in agricultural research (Varvarigos and Lawton 1991; Doney and Packer 2001; Mather and Lower 2001; Hamilton *et al.* 2004; Weber and Gut 2005). More specifically, there have been many studies that have used surveys to examine agricultural weeds (Ayres and Kemp 1998, Hamilton *et al.* 1990, Hawthorn-Jackson *et al.* 2004, Jones *et al.* 2000, Kristiansen 2003, McLaren *et al.* 2004, McLaren *et al.* 2002a, Shelton *et al.* 2003, Trotter and Sindel 1998, Llewellyn *et al.* 2002, Stansbury and Scott 1999, Crossman and Weidenbach 2004, Sindel and Michael 1988, Bourdot *et al.* 1994, Lemerle *et al.* 1996, Charles 1991 and Llewellyn *et al.* 2004). These surveys helped shape the direction of the postal questionnaire used in this project.

A REVIEW OF RELEVANT LITERATURE

WHAT IS A POSTAL SURVEY? AND WHAT ARE THE BENEFITS OF USING THEM?

A postal survey involves the mailing out of a questionnaire to target recipients, to be completed and returned, usually by mail. Postal surveys have been described as one of the easiest forms of collecting information (Auld 1995) and can be cheaper than many other forms of survey research such as face-to-face or telephone interviews (Dillman 1978). Due to being relatively inexpensive, postal surveys can be used to gain information from a large number of respondents enabling comprehensive statistical analysis. Written questionnaires are also easy to analyse compared with other survey methods, with many computer programs now available to facilitate this process. Postal surveys tend to be less intrusive as the respondent can complete them in their own time. Written surveys also remove any bias that interviewers may cause (Kanuk and Berenson 1975).

Despite these benefits there are some significant problems associated with the use of mail surveys which can bring all the benefits undone if not carefully considered.

WHAT ARE THE PROBLEMS AND HOW DO YOU OVER COME THEM?

OBTAINING A REPRESENTATIVE SAMPLE OF RECIPIENTS

One of the biggest problems is finding a suitable mailing list from which to select recipients for a survey. For many surveys it is important to obtain a representative sample of the population (Dillman 1978). However as distribution lists have become increasingly difficult to obtain, researchers frequently have to resort to using lists that are far from representative.

Within agricultural research, it is common for lists to be drawn from various farming organisations. However, Auld *et al.* (1987) warn that these groups will vary from the general population.

The obvious solution to this problem is to obtain a sample from a high quality data base such as is held by the Australian Bureau of Statistics (Australian Bureau of Statistics 2005b). However, these types of lists are rarely available outside the organisations that posses them and when they are, they are usually expensive. If a representative sample of the population is essential, but unattainable through a mailing list, another solution to this problem involves the weighting of responses. This involves assigning greater values to those respondents who make up a smaller proportion of the population. A key characteristic may be used to weight a sample. For example, Jones *et al.* (2000) used regional population numbers and use of agronomists in their study of weeds in winter cropping systems to weight the data. In some cases a non-random (or non-probability) sampling strategy may be used to reduce costs or target a specific population.

MAINTAINING A REPRESENTATIVE SAMPLE OF RESPONDENTS

Response rate

Once a list of recipients has been obtained and questionnaires sent out, the next problem is having them completed and returned. If a large number of the recipients fail to return the survey then the representativeness of the sample is again called into question (Dillman 1978). The issues surrounding response rate and non-response bias have been widely studied, and a variety of problems and potential solutions identified (Freebairn 1967; Kanuk and Berenson 1975; Armstrong 1977).

There are a number of reasons that a recipient might fail to complete and return a survey. These may include specific limitations such as illiteracy or the inability to complete the survey due to blindness and other common ailments. Whilst these are important (particularly for some populations) the principal reason that a recipient may not respond has been identified by Dillman (1978) as the perceived cost of replying being too high compared with the perceived benefits. Costs are not only financial, although this is an important factor. Costs might include the release of sensitive personal information, a perceived cost of sub-ordination of the recipient to the researcher or the time required to complete and return the questionnaire (Dillman 1978). Likewise, the benefits provided by a survey do not have to be financial. A recipient may perceive that they are part of a consulting process in which their opinions are valued, they may find the survey topic interesting or they may be made aware that the information they provide could help develop policies or technologies that will benefit them in the future. To increase response rate and reduce response bias, it is important to reduce the perceived costs and increase the perceived benefits. There are a number of techniques for doing this related to different components of the survey.

Respondent contact prior to survey

Some authors suggest that contacting the recipient prior to sending the survey form can increase response rates (Kanuk and Berenson 1975; Fox *et al.* 1988). Time of the contact and mail out may be of particular concern in the study of some populations (Turley 1999). Farmers, for example, will be busy at certain times of the year with seasonal tasks such as sowing, harvesting and shearing. It is obviously best to identify and avoid these peak periods.

Covering letter

The inclusion of a cover letter is essential and should be as personalised as possible (Dillman 1978). The covering letter should make an appeal to the recipient to return the survey as well as outlining any benefits that the recipient might receive. Careful wording can encourage non-financial benefits to become apparent to recipients. They might be made aware that returning the survey will assist the researcher, the community and possibly themselves in the long term (Fox *et al.* 1988). The complexity and tone of a covering letter is also important and should be tailored to the population being sampled. Advising the recipient of a cut-off date for return is recommended by some authors (Kanuk and Berenson 1975). Including a statement explaining the confidentiality of the information provided can reassure recipients that their personal details will not be made public. The sponsoring organisation can also influence a recipient's tendencies to respond, with differences reported for universities, public organisations and private companies (Fox *et al.* 1988; Turley 1999).

Questionnaire structure

The format, length and number of questions, the type of questions, the number of pages and even the colour of the paper used have been reported to affect the response rate of postal surveys (Freebairn 1967; Kanuk and Berenson 1975; Dillman 1978; Fox *et al.* 1988; Axford *et al.* 1997). A common criticism of postal surveys is their lack of flexibility and inability to capture deeper more qualitative information. Some questionnaires incorporate both closed ended questions and open-ended questions to accommodate this.

Incentives

Several studies have found that monetary and token incentives can increase response rates in some populations (Chebat and Cohen 1993; Gendall *et al.* 1998). In some cases, a financial incentive is thought to work as a gesture of good faith rather than a direct reimbursement for costs incurred (Dillman 1978). Not all populations are expected to value such monetary tokens. Other more effective incentives might be the promise of making the results of the study available to respondents.

Respondent contact after survey

Follow up letters and surveys are commonly used to increase response rates (Kanuk and Berenson 1975; Fox *et al.* 1988). However, some authors have expressed concern that this may induce forced responses which yield incorrect information (Auld 1971).

Coping with non-response and low response rates

Once a survey is completed and there has been a low response rate, it is possible to weight the responses to enable a more representative data set to be drawn up. A common way of weighting samples has been to consider the response speed of individuals. Those respondents that are slower to respond are thought to be more like non-respondents than early responders Dillman 1978.

Target contamination

Target contamination concerns the issue of which individual should complete a survey form sent to.an address where more than one person resides. This problem of which individual (e.g. husband or wife) within the sample unit targeted (e.g. a farm address) can reduce how representative the sample is. In some cases questionaries can also be "contaminated" as the respondent is influenced by other people or the survey is completed by more than one person (Dillman 1978).

OBTAINING ACCURATE INFORMATION FROM RESPONDENTS

Item non-response

A common problem with surveys is item non-response, where one or more individual questions are not answered by the respondent (Dillman 1978; Llewellyn *et al.* 2004). Careful wording of questions and addressing anonymity issues can assist in ameliorating these problems.

Measurement error or social desirability bias

In some circumstances survey respondents are reported to offer responses which are more socially acceptable than true (Dillman 1978). Kristiansen (2003) drew particular attention to the issue of weed identification as a key source of measurement error for weed surveys, an issue supported by other authors (Trotter 1998; Crossman and Weidenbach 2004).

Like item non-response, careful wording of questions and addressing anonymity issues can help overcome this problem. However, there will always be the possibility that respondent perceptions differ from what might be objectively measured. This issue is examined further in the survey validation section discussed later in this chapter.

GENERAL POSTAL SURVEY METHODOLOGY

To achieve the objectives set out for this project the postal questionnaire was developed to capture a range of information on the weed , farm and respondent characteristics. Methods specific to the four research objectives are described later in this chapter.

SURVEY DESIGN

The survey form was designed to obtain detailed information, but as a result this meant that a number of recipients would find the survey form difficult to complete. Consequently, a number of strategies were employed to encourage response. The survey form along with covering letter and all envelopes were marked with the University of New England logo and header. This was designed to increase the credibility of the questionnaire. The survey form was kept to four A4 size pages by folding an A3 sheet in half to give the impression of brevity. Yellow coloured paper was used for the response forms to make them stand out amongst other papers. An instructional paragraph was placed at the beginning of the questionnaire to direct recipients as to the way the form was to be completed. It was designed so that the person completing the questionnaire would be the main decision maker in consultation with individuals who might influence weed management. This was meant to avoid any possibility of target individual contamination (Dillman 1978) and dictate the target entity as the property on which the respondent spent the most time.

SECTION A

The questionnaire was divided into 4 sections (Appendix 1). Section A began with an open ended question asking recipients for their ideas and for information on control strategies that they had found successful. This open ended question was deliberately placed at the beginning of the survey. The wording of the question was designed to reaffirm the producer's experiences and attempted to place the recipient in the position of innovator, which was designed to reduce subordination issues (Dillman 1978). Section A also gathered background information on the respondent to provide a context in which different weed controls are applied. Discussions with producers during key informant interviews led me to believe that graziers were suspicious of the collection of personal information. In an attempt to lessen the influence of this possible barrier to response, a statement was included at the beginning of these questions to advise the respondent that this information was essential to ensure that the survey was representative of all graziers.

The specific questions used to gather background information were tailored to avoid non-response. Key informant interviews indicated that questions about age and education could cause particular consternation amongst some producers. Age was nevertheless considered an important variable and so rather than asking directly for the age of the respondent they were asked to provide the year they were born. Education was also considered a highly desirable variable so a question was specifically tailored to gain this information. Traditional questions about education often ask producers to nominate their highest level of education achieved listing an ascending list of formal scholastic achievements. This is known to be an irritation for many farmers, many of whom have little formal education. Rather than risk making farmers feel inadequate or subordinate, the question about primary and secondary education was dropped altogether. In its place a list of informal agricultural training programs (e.g. Prograze and Grazing for Profit) were listed along with more formal qualifications (e.g. Agricultural college and University degree). A space was provided so that respondents could list any training that they had undertaken but was not listed.

SECTION B

Section B (Appendix 1) aimed to gather information on the weeds of importance to graziers and how these had been changing over time. In addition, section B was designed to capture information on the controls being used by producers against weeds. To do this, a relatively complex structure was used that linked questions 1, 2 and 3 of section B of the questionnaire. Respondents were first asked to identify the most important pasture weeds on their property, ranking them in order of priority. In question 2, respondents were asked to advise whether they considered the impact of each weed had been increasing, stable or decreasing over the past five years. Question 3 asked producers to identify the control methods that they used against each of the weeds nominated in question 1. They were asked to distinguish between whether they considered the control successful or unsuccessful. Despite the relevance and importance of understanding what producers consider to be successful, further information was sought to validate these perceptions and determine if the successful controls were having a longer term influence. Linking the results found in question 2 of the postal survey and the long-term change in the impact of each weed species with the results gleaned from question 3 enabled an examination of how these two factors might be related. The information could then be used to determine if certain weed control strategies were associated with a decreasing or increasing weed impact over a longer period of time.

Question 3 of the questionnaire enabled respondents to identify the weed control methods that they used against each species. By allowing producers to identify more than one control method, the results could be used to investigate which combinations of weed control methods are commonly used. Further to this, these combinations could then be related to the change in impact of each species over time.

SECTION C

Questions 1 and 2 in section C (Appendix 1) of the postal survey, aimed to gather further background information on the respondent's use of quarantine methods and land use to enable a further understanding of the context in which weed controls might be used. Questions 3 and 4 of section C were designed to collect information on the current levels of weed infestation over the whole farm (question 3) and for one typical paddock (question 4). These two questions were included to provide a broader picture of the weed problem on each farm surveyed. This was undertaken as the species-specific questions in section B did not include a measure of the current density of each weed species. Whilst current species density information would have proven highly useful, it was excluded due to a lack of space on the questionnaire and the already complex level of the survey.

Questions 3 and 4 of section C were to be used to provide at least some indication of the extent and density of weeds on the respondent's property. Question 4 was later used as the basis to examine objective two of the thesis, the validity of producer perceptions and their ability to accurately self-report weed infestation levels on their property.

In the early stages of the analysis of results, questions 3 and 4 of section C were also used to create an index of overall farm weediness. This weediness index was compared with the various farm characteristics and use of weed control methods. Although the results showed some interesting trends, the analysis was discontinued in favour of the analysis of controls for individual weed species as presented in this thesis. This enabled a more detailed understanding of the unique controls used and integrated for each weed species. Further research into the weediness index data (particularly using clustering or self-organising maps) may be able to be used to uncover additional valuable information.

SECTION D

Questions 1, 2, 3 and 4 of section D (Appendix 1) of the postal survey provide further background information on the fertiliser use and grazing management strategies employed by respondents to support the contextualisation of results. Questions 1, 2 and 3 of section D of the questionnaire were designed to capture detailed information of the inputs to the farm system. This detailed information was to be used to allow calculation of specific nutrient inputs (particularly phosphorus) to examine soil fertility relationships. The responses provided by graziers included such a great variation in product names that this process was abandoned. Question 5 of section D was used to examine the challenges to adoption of spray grazing. Details of this section are discussed in detail later in this chapter.

PILOTING OF SURVEY

The survey form was piloted twice. The first pilot study involved testing various questions to determine what information could be gleaned. The producers contacted during the key informant process were used to undertake this process. From this pilot survey it was established that certain objectives outlined in the original project plan could not be achieved by postal survey. The second pilot study involved a larger mail-out to recipients selected from the telephone book, being listed as graziers. This pilot study helped refine the survey questions and establish an expected response rate of approximately 20%.

POPULATION SAMPLING STRATEGY

Sample bias was foreseen as a potential problem for this survey. The most representative survey gives all members of the population in question the opportunity to be included in the survey. To achieve this would require recipients to be selected from a list of all graziers in Australia. The only lists as comprehensive as these are held by government (Australian Bureau of Statistics) and industry (Meat and Livestock Australia) organisations and are either not publicly available or are too expensive. A commercial database was eventually used to obtain recipient addresses. The commercial database provider chosen was the marketing services and research company, Axiom Pty Ltd (North Sydney). This company was chosen as they held a large data base of producers and were able to target the grazing areas of Australia southern Australia.

COVERING LETTER AND OTHER INCLUSIONS

The covering letter attached to the survey (Appendix 2) was designed to encourage response. The letter was printed on university letter head, made an appeal to the recipient indicating that the results would assist both themselves and other farmers and emphasised the confidentiality of responses. Recipients were given the option of learning more about the project by reading background material to the project on the reverse of the cover letter. A response card (Appendix 3) was included in the mail-out providing recipients with the option to receive the results and to be added to the mailing list of a free research and development magazine (Meat and Livestock's Prograzier).

A reply-paid envelope was included with the survey form. The covering letter had the address printed directly onto it rather than using printed labels. Because of the potential legal repercussions of reporting certain noxious weed species, anonymity was offered to all respondents.

THE PHYSICAL MAIL OUT

The survey forms along with address cards and envelopes were printed at the University of New England's printery and then delivered to Axiom in Sydney. The covering letter was printed by Axiom as this included the recipient's address on it. Although complicated, this process was necessary as Axiom were unwilling to release their database of names and their in-house printing costs for the survey forms were too expensive. The reply-paid envelopes were addressed directly to me, so that a date of return could be recorded. The surveys were mailed out to 7,000 graziers throughout southern Australia in February 2004.

DATA INPUT AND STORAGE

Upon receipt of responses the returned envelopes were immediately stamped with the date. Later when these envelopes were opened, the questionnaires were also stamped with the date and all loose material included in the response was stapled to the survey form.

Data entry of the survey forms was undertaken using a Microsoft Excel spreadsheet. This sheet resembled the survey form so that data entry could be undertaken as quickly and accurately as possible. Also engineered into the survey form were a number of validation checks, which ensured that data being inputted were accurate. Considerable time was taken to construct this entry form, as incorrect entry of data could have compromised the accuracy of the results. The Excel spreadsheet produced data in univariate format and a macro was used to convert this information to a Microsoft Access database. Using the relational database tools available in Microsoft Access, tables were produced that could be analysed in the chosen statistical packages.

PRE-STATISTICAL CATEGORISATION

Prior to the commencement of formal statistical analysis, some categorisation of variables was undertaken.

INDUSTRY AND ENTERPRISE TYPE

The information provided on income sources allowed respondents to be classified into Australian and New Zealand Standard Industrial Classification (ANZSIC) enterprise categories (Australian Bureau of Statistics 1993). Only income from on-farm sources was taken into account when determining which classification a respondent would receive. Some respondents reported a proportion of their income coming from off-farm sources. However, in this study, off-farm income was ignored in identifying the type of agricultural production system. Table 3.1 shows the four main classifications that were used to group respondents. Some respondents failed to report their income distribution. In these cases livestock numbers and area of property under cropping, which were reported later in the survey, were used to classify them. In some cases, livestock numbers and area under cropping were not supplied. Respondents whose enterprise could not be determined were labelled as "unclassified". In rare cases, respondents reported income distribution that did not correspond with the livestock numbers and/or area under cropping information supplied. In these cases adjustments were made so that the ANZSIC classification accurately reported the livestock or cropping information reported by the respondent. There were some respondents that reported significant income (>50%) from industries outside those shown in Table 3.1. These included dairy, pigs, poultry, horticulture, horses and honey production. In some cases respondents also carried on business which fell into one of the ANZSIC codes describe in Table 3.1 and were ascribed this code (e.g. a fruit grower and beef cattle farmer was given the ANZSIC code of Beef cattle farming). In other cases respondents only carried out their non tabled enterprise and were reported as unclassified (e.g. dairy farming, horse breeding and honey production).

Table 3.1 ANZSIC codes and the description used to classify respondents

ANZSIC category (and number)	Description
Grain-sheep/beef cattle farming (0122)	Income received from cereal grain mixed with sheep farming or cereal grain mixed with beef cattle farming
Sheep-beef cattle farming (0123)	Income received from sheep farming and beef cattle farming
Sheep farming (0124)	Income received from sheep farming
Beef cattle farming (0125)	Income received from beef cattle farming

GEOGRAPHICAL CLASSIFICATION

Respondents were geographically referenced using the postcode of the property on which they reported. Each postcode was then allocated to an Interim Bio-geographic Regionalisation for Australia (IBRA) region (Figure 3.1). Not all postcodes fell neatly within the IBRA boundaries; where a postcode boundary overlapped an IBRA boundary the postcode was allocated to the IBRA region within which in predominantly fell. The IBRA regionalisation was decided upon because its underlying classification system relies on climate, geomorphology, landform and lithology to define boundaries (Cummings and Hardy 2000). Other weed research projects have included the use of IBRA regionalisation. For example, the list of Weeds of National Significance (WONS) is divided based on this geographical classification.

Having been allocated an IBRA region, respondents were further classified into larger geographical regions. Each IBRA region was allocated to one of five regions; northern, central, southern and western regions of south eastern Australia, with one further zone being made up of all responding IBRA regions from Western Australia.

The five regions were developed to align with the classification of pastures of Australia proposed by Moore (1975). The IBRA regions on the eastern side of Australia were initially allocated into two groups. Respondents either fell into the combined group of 1) temperate perennial pastures, or temperate perennial grass/annual legume pasture zone, or 2) the Mediterranean annual pasture zone. The Mediterranean annual pasture zone was labelled the "western region" for the purpose of this study. The temperate perennial pasture and temperate perennial grass / annual legume pasture zone was divided into a further three regions based on seasonality of rainfall based on the Commonwealth Bureau of Meteorology map shown in Figure 3.3. The IBRA regions were allocated to one of these three regions, being either the "northern region" representing summer dominant rainfall, "central region" representing a uniform rainfall and "southern region" representing a winter dominant rainfall. The IBRA bioregion of South Eastern Highlands (SEH) was divided in two at the NSW/Victorian state boundary so that Victorian respondents from the SEH fell into the southern pastoral zone and NSW respondents into the central pastoral zone. Due to a smaller number of respondents from Western Australia, all IBRA regions represented were conglomerated into one pastoral zone.

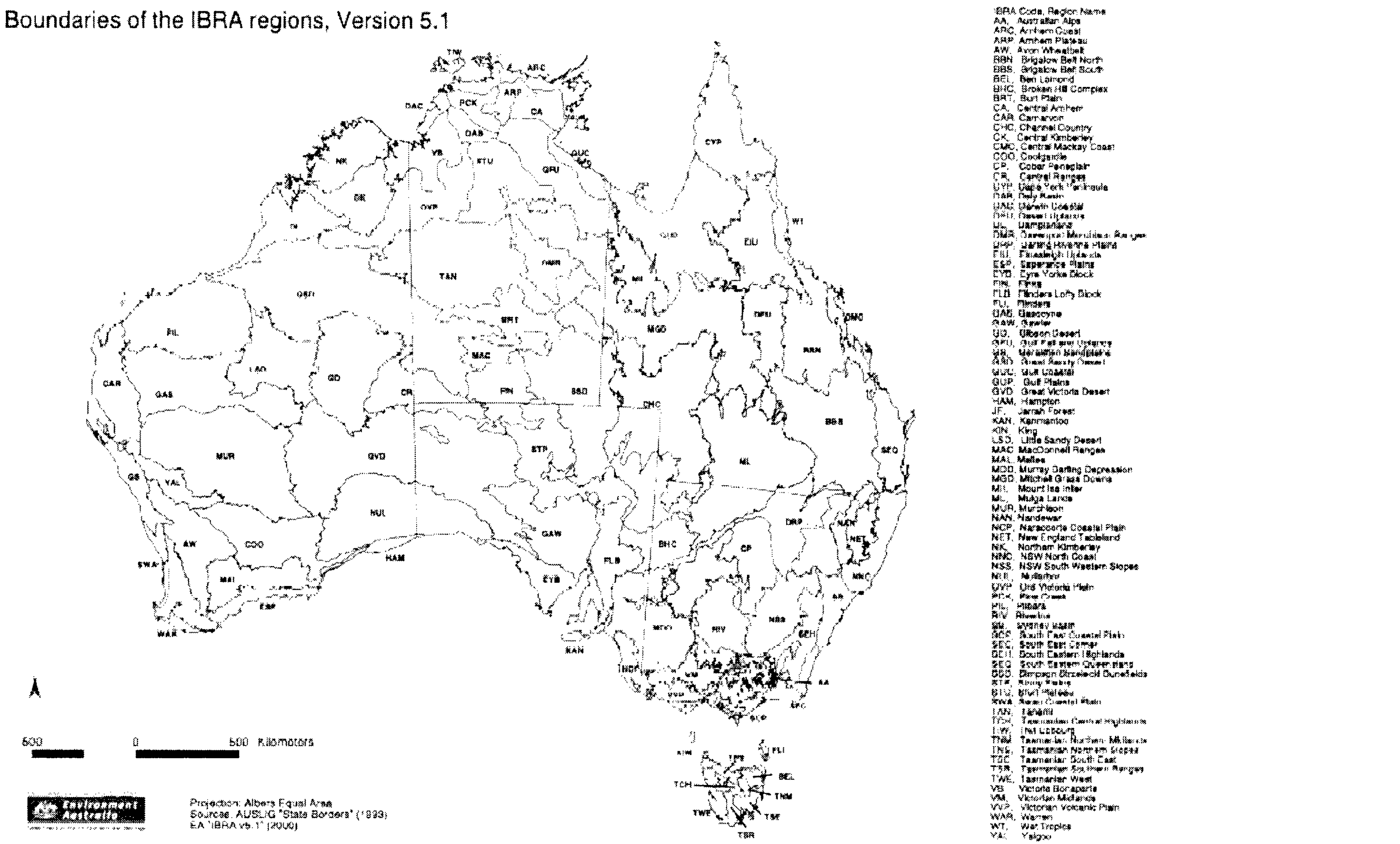

Figure 3.1 Boundaries of the IBRA regions (Source Australian Government Department of the Environment and Heritage 2005)

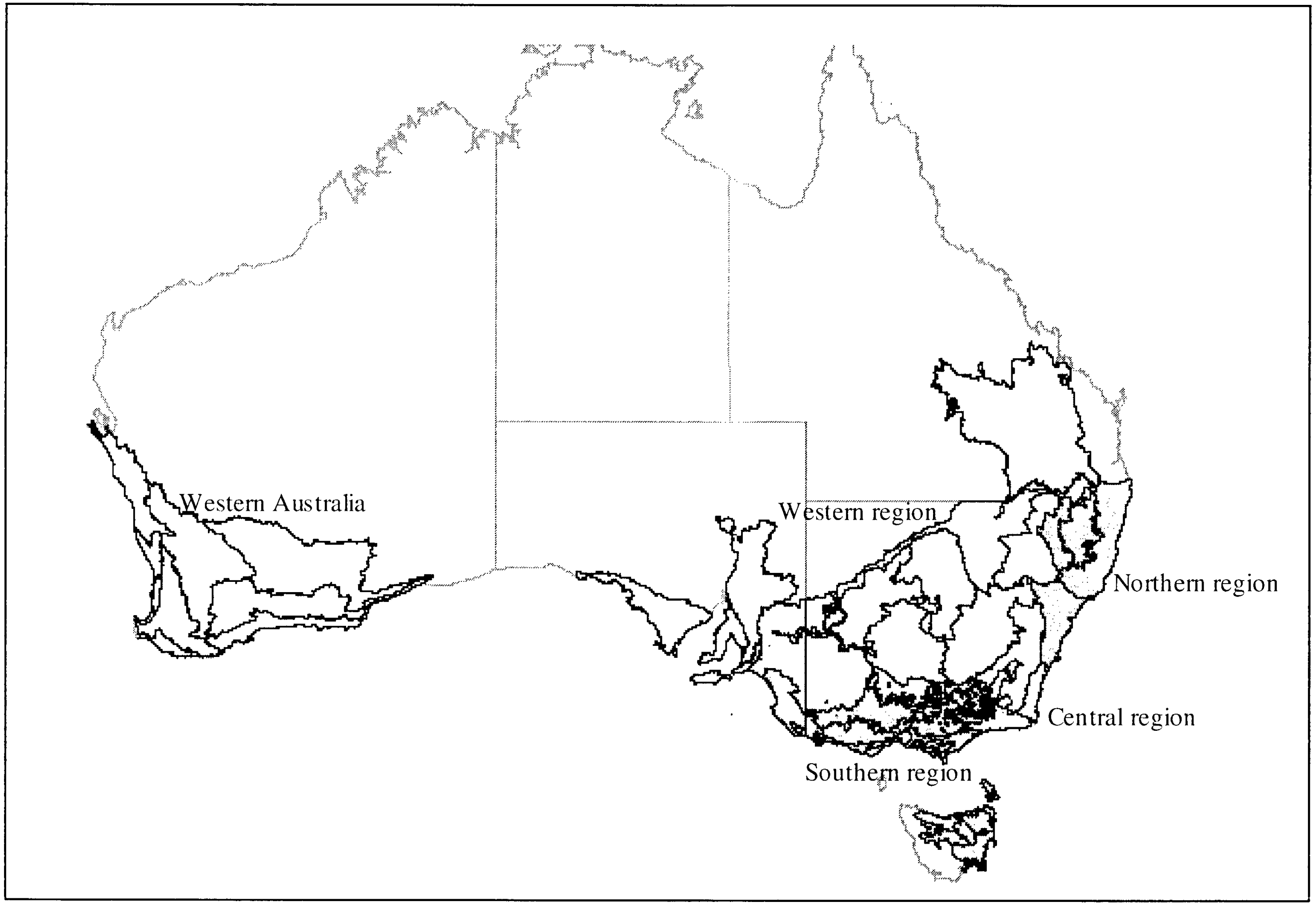

Figure 3.2 Regions developed for the analysis of postal survey results

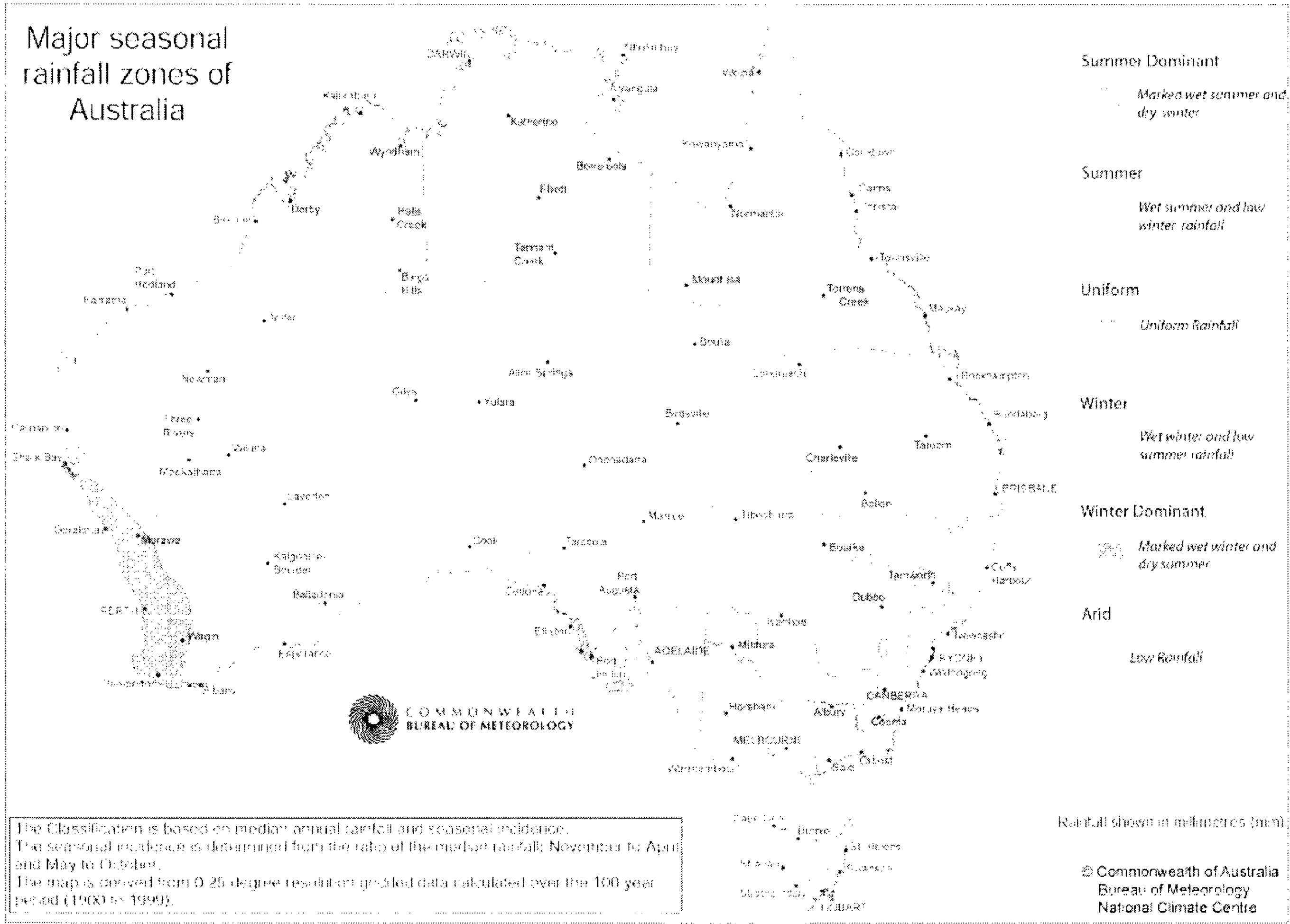

Figure 3.3 Major seasonal rainfall zones of Australia (Commonwealth Bureau of Meteorology 2005).

METHODOLOGIES AND ANALYSIS SPECIFIC TO EACH OBJECTIVE

The postal survey was used to gather information to meet three of the main objectives of this thesis: to determine producer perceptions of the most important pasture weeds (objective 2); to identify the best management practices for pasture weeds (objective 3); and, to identify the challenges to adoption of weed control methods (objective 4). The methods and analysis specific to each of these objectives are outlined in the following sections.

OBJECTIVE 1 – WEEDS OF SOUTHERN AUSTRALIAN PASTURES

The most important weeds of southern Australian pastures were determined by examining the responses to questions 1 and 2 of section B of the questionnaire. The most commonly reported weeds in each of the five pasture zones defined previously are presented in chapter 5.

OBECTIVE 3 – BEST MANAGEMENT PRACTICES

The third objective, determining the best management practices of weeds, was achieved for four weed species through asking six distinct questions: 1) Which controls do producers perceive to be successful? 2) Is the use of individual controls on a farm correlated with the long term change in weed problem? 3) If graziers use multiple control methods against weeds, what are the most frequently used combinations? 4) What is the context in which different combinations of controls are used? 5) Is there a correlation between the most frequently used combinations and the long term weed problem? and 6) Are graziers integrating multiple control methods in a strategic way to manage weeds? The first five of these questions were examined through the postal survey with the sixth being assessed by telephone interview (reported later in this chapter).

This process was undertaken for four weeds which were determined to be key species, capeweed (*Arctotheca calendula*), blackberry (*Rubus fruticosus* agg.*)*, barley grass (*Hordeum* spp.) and serrated tussock (*Nassella trichotoma*). These weeds were specifically chosen for further investigation as they were the most commonly reported species in the survey from each of the four principle functional weed groups (annual and perennial, grasses and broadleaf weeds).

1) WHICH CONTROLS DO PRODUCERS PERCEIVE TO BE SUCCESFUL?

The complex structure of section B of the postal survey enabled respondents to identify the controls methods they use against each weed species and whether they considered these successful or unsuccessful.

2) IS THE USE OF INDIVIDUAL CONTROLS ON A FARM CORRELATED WITH THE LONG TERM CHANGE IN WEED PROBLEM?

The control method information provided by respondents in question 3 of section B of the survey was linked to the reported change in weed problem status in question 2. This provided an indication of whether the use of control methods could be related to the change in each species.

3) IF GRAZIERS USE MULTIPLE CONTROL METHODS AGAINST WEEDS, WHAT ARE THE MOST FREQUENTLY USED COMBINATIONS? 4) WHAT IS THE CONTEXT IN WHICH DIFFERENT COMBINATIONS OF CONTROLS ARE USED?; 5) IS THERE A CORRELATION BETWEEN THE MOST FREQUENTLY USED COMBINATIONS AND THE LONG TERM WEED PROBLEM?

Most of the respondents listed more than one control method being applied against each weed. A series of analytical procedures was undertaken to determine the most common combinations of these control methods, the context in which they are used and correlation of the combinations of controls with the change in weed problem status.

Validation of individual responses

Although a great deal of care was taken to avoid item non-response, some respondents failed to complete the control part of section B of the survey. This meant that although they reported the occurrence and change in problem status of a weed species it appeared as if they had not applied any control method against it (they appeared to be non-active). They were not discounted from use for other sections of the survey results as the information they provided was valid and useful. However, they needed to be removed from consideration in this part of the survey as the information they provided was not valid. Non-valid respondents were excluded by identifying any that had left the control questions of section B of the survey blank for all weeds reported. The respondents remaining that attempted control of at least one species, and are defined as "active" respondents. Some of these active respondents reported no control method applied against certain weed species, These were the truly non-active respondents.

Exploratory categorical regression

Exploratory categorical regression was used to examine if weed occurrence or change could be predicted by weed controls or farm or farmer characteristics. The results of this analysis were not favourable with the r^2 for individual weed species regularly falling below 0.5. The low r^2 suggested that there were no simple linear relationships between weed occurrence and change and use of control methods or farm or farmer characteristics. Because the relationships between the variables of interest for all respondents proved to be weak, it was decided to examine if any relationships could be found within sub-groups of the sample through cluster analysis.

Categorical principle components analysis (CatPCA)

The weed control methods used by the respondents became the focus of the cluster analysis. However, because of the large number of control methods, a principle components analysis was first undertaken to reduce the number of variables. Principle components analysis reduces the number of variables in a data set by looking for correlations amongst variable rich data sets and reducing these to common factors or "principle components" (Punch 1998). Categorical principle components analysis (CatPCA) is a method recently developed by SPSS (SPSS inc. 2004) which enables ordinal and categorical data to be included in a principle components analysis. This process was particularly useful in this study as there were many possible control options that graziers might have used and these were all categorical.

Only those respondents using two or more controls against each weed species examined were included in this analysis. These respondents using two or more control methods were labelled "multi-active" respondents. The respondents that did not report any control methods were labelled "non-active" respondents. Those respondents using only one control method were labelled "single active".

In addition, control methods used by less than 10% and more than 90% of multi-active respondents were excluded from the CatPCA (Tabachnick and Fidell 1996). The inclusion of variables with a low rate of use can destabilise the CatPCA. The inclusion of variables with more than 90% reported use add little information to the CatPCA as nearly all respondents are using this method anyway. The CatPCA was undertaken using the statistical program SPSS (SPSS inc. 2004), and reduced multi-active respondent use of all the control methods reported in Section B of the postal survey to a point within two dimensions.

Clustering by partitioning around medoids (PAM)

The scores on the two dimensions generated through the CatPCA were then entered into a cluster analysis using the partitioning around medoids (PAM) clustering technique in the statistical program R (R Development Core Team 2005). PAM is a clustering technique involving iterative reallocation of cases amongst a given number of clusters until convergence to a solution that maximises cluster structure is achieved. This clustering process works by selecting an optimal number of representative individuals ("medoids") and builds clusters around these medoids (Kaufman and Rousseeuw 1990). The optimal number of clusters is determined by finding the solution with the highest average silhouette width. The silhouette width is a measure of the distance of an individual from the medoid (most representative individual). Each individual has a silhouette width, and these are averaged across all individuals to give the average silhouette width. The average silhouette width can also be calculated for each cluster to give an indication of the similarity of individuals within each cluster.

Statistical analysis of the clusters

Once the clusters of respondents were determined for each of the four key weeds, their use of control methods could be compared with the change in weed problem status. This would determine if there was any relationship between combinations of control methods, and the long term change in weed problem status. Including the control method use, the farm and farmer characteristics of each of the clusters was also examined to determine if these gave any contextual information.

For categorical variables, significant relationships were identified with a chi-square test for independence of factors. As many of the clusters contained small numbers of respondents, the Monte Carlo re-sampling technique with 10,000 replications was used (SPSS inc. 2004). A p-value of <0.05 was used to identify whether there was a significant relationship amongst variables, however a further more in depth technique was used to identify which responses were contributing to this significant relationship. The standardised residuals (SR) were used to identify which cells of the cross tabulation were contributing to the significant chi-square statistic. Individual results with a SR of greater than 2 or less than -2 were considered significant.

Continuous variables were first screened for outliers by generating Z scores and removing any cases with a Z score >4 (Tabachnick and Fidell 1996). For continuous variables an Analysis of Variance (ANOVA) was undertaken. Bonferroni post-hoc comparisons were undertaken to identify pairs of clusters making a significant contribution to an overall significant ANOVA.

OBJECTIVE 4 – THE CHALLENGES TO ADOPTION OF WEED CONTROLS

An examination of the challenges to adoption of control methods began with the postal survey and the questions asked in section D, question 5 (Appendix 1). Spray grazing was chosen as a case study because it is considered a relatively complex management technique that incorporates both chemical application and grazing management. In addition it has been acknowledged that despite being a successful control method it was not thought to be widely used (Ayres and Kemp 1998; Dowling *et al.* 2000). This combination of a complex, yet successful control method that appeared to be poorly adopted was thought to provide a potentially information-rich set of responses.

The issues relating to postal survey research have been discussed previously. However, this part of the survey posed some particular problems for which it is essential to provide some background. To obtain the information required this survey was designed with a combination of open ended questions and closed-ended categorical yes/no questions (Dillman 2000). As well as providing key information, the categorical yes/no questions functioned as filter questions. If a respondent answered a categorical question in a certain way then they were directed to another unique question which was dependent on their previous response.

Filter questions (also known as contingency or screening questions) can be quite complex and come with their own unique set of problems. It is recommended that filter questions contain no more than three levels, use graphics to move the respondent to the next question and if possible put questions on different pages (Trochim 2005). The wording of contingency questions is also a key issue with several studies revealing that they can influence the responses provided in subsequent questions (Bishop *et al.* 1983; Knauper 1998).

QUALITATIVE DATA ANALYSIS

Both quantitative and qualitative research methods have been employed in this thesis. Below is a brief review of the qualitative analytical procedures applied to the data collected in this section. There is a great deal written about qualitative data analysis and there is a variety of approaches with various applications (Marshall and Rossman 1989; Maykut and Morehouse 1994; Morse and Richards 2002; Somekh and Lewin 2005). This thesis generally follows the qualitative data analysis theory developed by Miles and Huberman (1994) and further simplified by Punch (1998). These authors describe a three stage process. The first stage is data reduction, the second is data display and the third involves drawing and verifying conclusions from the data with each stage interacting with the other.

Data reduction

Data reduction essentially involves summarising, labelling or coding the responses. This process continues throughout the study as concepts are formed and there is a need to further reduce the data. Coding can be divided into descriptive (*in vivo* or first order) and inferential (pattern, higher order or analytical). Descriptive coding is simply tagging the responses with a label that obviously describes them. Inferential coding makes more interpretations of the data than descriptive codes. Another form of data reduction involves "memoing" where the researcher records their ideas and theories as they progress through the coding phase.

Data display

Data display involves the presentation of the products of data reduction and also continues through out the analytical process as higher level data reduction produces new concepts requiring presentation. Data display can take many forms including tables, graphs and net works.

Drawing and verifying conclusions

Drawing and verifying of conclusions occurs throughout the analytical process as themes and concepts become apparent. The process of data reduction and display cements these ideas into verifiable conclusions.

QUESTION STRUCTURE

Examination Of the issues of adoption and problems with the use of spray grazing was achieved by asking the non-adopters directly and indirectly by examining the problems that users of spray grazing had encountered. Filter questions were used to isolate those respondents that had not used or trialled spray grazing. These respondents were then posed the direct question "Are there any particular reasons you have not trialled or used spray grazing on your property?" This is a very direct question that could be construed as implying the non-user of spray grazing as somehow inferior and is likely to be affected by response bias (Dillman 2000; Bertrand and Mullainathan 2001). In asking this question I aimed to obtain producers' own perceptions of why they had not implemented spray grazing. These direct producer self-perceptions can provide valuable insight (Llewellyn *et al.* 2004). However, because of the potential for response bias, additional questions were added to the survey to examine the problems that producers who had trialled or used spray grazing had encountered whilst implementing it. Filter questions were used to divide these producers into those that perceived spray grazing to be successful and those that perceived spray grazing to be unsuccessful.

These two groups were also questioned as to their intention to use spray grazing in the future. It was hoped that this would provide information on the different issues and problems encountered by those producers who although having used or trialled spray grazing had decided to abandon it (non-adopters).

OVERCOMING THE PROBLEMS OF FILTER QUESTIONS

As described in the review, filter questions can provide some unique problems. During the development of this survey several different ways were trialled in an effort to elicit the required information. While the number of levels of questions is recommended to be less than three (Trochim 2005) and an attempt was made during initial survey development to reduce the number of levels, fewer levels did not allow the capture of the necessary information so minimisation of levels was abandoned. Although trialled, graphical arrows (Trochim 2005) were also abandoned during development due to a lack of space on the survey form.

The questions asked were relatively direct in comparison with the other parts of the survey and so they were considered to pose the most risk in terms of causing non-response. Because of this feature these questions were placed at the very end of the survey form. In this way, if a respondent did experience difficulty, the balance of the survey was already completed.

DATA ANALYSIS AND PRESENTATION

The categorical yes/no questions were recorded and are presented as a proportion of the respondents within each level of question. In some cases respondents provided a written response which was commonly "maybe" or "unsure". Rather than ignoring these responses they have been included as an additional response category. In hindsight this possible response should have been incorporated into the questionnaire.

DESCRIPTIVE CODING PROCESS

The responses to the open-ended questions were first categorised using a descriptive coding process (Miles and Huberman 1994; Punch 1998). Due to the open-ended nature of some of the questions, more than one response could be reported for each question. A database was established in Microsoft Access to handle the original responses and the codes. Each response could have up to three individual descriptive codes assigned to it.

The data were analysed using the multiple response functions in SPSS (SPSS inc. 2004). The proportion of respondents within each question level reporting each descriptive code are presented. In addition, samples of original responses are presented for those descriptive codes reported by 5% or more of the relevant respondents. A cross tabulation (chi-square) of the reasons given for failure, problems encountered in use and intention for future use of spray grazing formal statistical analysis was not undertaken due to the complexity of multiple response answers and the low number of respondents reporting an intention to discontinue use of spray grazing.

INFERENTIAL CODING PROCESS

Once the tables of descriptive codes were constructed, an inferential coding process was applied to the results. The inferential codes were developed from the review of literature and are described in Table 2.7. Not all descriptive codes could easily be ascribed an inferential code. In some cases the descriptive codes were left as "unidentified" for those that did not seem to fit any of the possible inferential options. In some isolated cases descriptive codes seemed to cross over two inferential codes; in this case both inferential codes were ascribed.

The key perceptions were drawn out from the postal survey results using an index scoring process. This is outlined in detail in the focus group methodology.

3.3 ON-FARM VISITS

On-farm visits were used to examine objective 2 of this thesis- the validity of producer perceptions. The aim of this process was to assess the ability of producers to accurately report the weed situation on their property. This part of the study was to determine whether the information provided by producers in survey form accurately represented the weed status of their properties. This study only begins to uncover the complexity of validation of producer perceptions; however it does reveal some valuable trends and information.

A validation test was devised to assess the ability of producers to accurately report the weed status of their property. This test involved case study paddock assessments where producers selected a representative part of an average paddock and reported the composition of weeds and desirable plants in this area. This area was then sampled using a 400 point quadrat technique to determine the percent composition of the grasses, legumes and weeds present to make comparisons with the predictions of the respondent.

REVIEW OF RELEVANT LITERATURE

THE PROBLEM

Very little work appears to have been undertaken in the area of validating the perceptions of producers with regard to the weed situation on their property.

There have been many postal surveys undertaken which have requested information on the extent, density and distribution of various weed species from Australian landholders Hamilton *et al.* 1990; Stansbury and Scott 1999; McLaren *et al.* 2002a; Shelton *et al.* 2003; McLaren *et al.* 2004. The array of information collected is extensive and ranges in complexity from simple occurrence of species, to those surveys requiring detailed estimations of area of land infested at a range of densities. Much of the data from these and other similar surveys have been used to draw conclusions, and gone to direct research and support significant economic analysis. None of these surveys have included research into the accuracy of the information provided by the respondents. Little if any of this information appears to have been validated by ground truthing. Without this validation major questions must still linger about the accuracy of farmer's ability to identify and quantify weed species present on their property.

Vere (1995) stated that "useful economic analysis of weeds can only be based on reliable data relating to extent and distribution, impacts on production, spread potential and clearly defined control strategies. There are few such comprehensive data for most Australian weeds which explains why economic analysis has long been considered to be an important deficiency in weed science". Further, this author goes on to suggest that "perceptions of data accuracy have major bearing on the acceptance of the results of economic analysis. In acceptance terms, these problems are considered to be more important than concerns about the validity of the economic methods." Because of the need for accuracy in all fields of research it is essential that an understanding of the variation between respondent perceptions and reality be discerned. Vere (1995) highlights one important area of possible error when he stated that "determining the areas by degree of infestation appears to be the greatest problem with accuracy". With reference to surveys of government weed control authorities. Vere (1995) suggested that the accuracy of surveys in attaining extent, density and distribution data was questionable. No comment was made on the ability of landholders to accurately report weed infestations by area and degree.

ATTEMPTS AT VALIDATION IN AGRICULTURAL RESEARCH

Some papers alluded to a validation process or undertaking a systematic ground truthing, however, few have explored the relationship between the perceptions of landholders and those systematically recorded in an objective physical survey.

In their Australian survey of weeds of winter cropping systems, Jones *et al.* (2000) reported undertaking a validation study by field work. The results only make comparisons between the number of respondents to the postal survey identifying each weed as present or absent and the paddocks subjected to field survey. Jones *et al.* (2000) prove that the paddocks selected for field survey are a representative sample of their postal survey (10% response rate). However, this does not prove that the producer perceptions of extent and density of weeds initially collected in their postal survey are any more reliable.

In their weed survey, Lemerle *et al.* (1996) make comparisons between field survey data and information collected by postal survey. In this case the frequency of occurrence of weeds in cropping paddocks from a field survey, compared favourably with the frequency of reported occurrence by farmers and agronomists. The sample unit was comprised of farmers who were compared by regions. This information proved useful in understanding the relationship between occurrence and perception on a broad regional scale but again did not examine the relationship between individual farmer perception and actual weed extent and density. In their research on box-ironbark remnant vegetation in southern Australia, Hamilton *et al.* (2004) used a postal survey and follow up validation process, to examine the ability of landholders to accurately report habitat quality indicators. In their survey they asked landholders to self assess a number of habitat indicators with responses made on a Likert type scale. The questions focussed on the frequency of occurrence of a number vegetation classes and tree sizes. These responses were weighted and an overall score for habitat quality calculated. A sample of the survey respondents was selected for validation. An ecologist visited each property and undertook the same assessment as the landholders. The results showed that the landholder assessments correlated significantly with the assessment undertaken by the trained ecologist ($P<0.01$, $R^2=0.892$). This study has demonstrated a degree of validity in landholder responses. However, the type of information being sought, habitat quality indicators and the way in which it was processed into an overall habitat quality score provides a somewhat unclear picture. Producers were asked to report in four categories (none, few, some and many), and the abundance of various habitat indicators which were mostly vegetation types (e.g. old trees, medium trees, small trees, prickly shrubs, other shrubs, native grasses, weeds, wood on ground etc). A more complete picture of landholders' ability to report accurate information could be obtained from a review of each individual category with the ecologist's assessment to see how the self reported abundance information correlates with the objective assessment.

Doney and Packer (2001) undertook a postal survey and ground truthing of landholder perceptions in their study of the impact of deer on grain crops in the United Kingdom. Their survey asked producers to report the species of deer present on their property and estimate the economic damage caused by these animals. Two years after collecting the data a field study was undertaken to examine the validity of the information provided by the respondents. They reported that "respondents were generally accurate in the density and species of deer reported". The data showed that 80% of farmers accurately reported the species present on their property, whilst 20% failed to accurately report them. They went on to suggest that respondents were poor at estimating the economic damage caused by deer. The authors did however suggest that this could be explained by the time lapse of two years between questionnaire and validation process. The authors commented that "the process was not without its drawbacks. It was necessary to balance the best scientific practice with the practical arrangements of visiting a number of farms over a short period, and gaining permission to access the crops". In this statement they highlight some of the difficulties involved in validation type studies. The authors further highlight the difficulties of validation studies as there is an "inevitable compromise between 'best scientific practice' and a practical method" when collecting data.

Murphy and Lodge (2002) investigated the relationship between visual estimates of ground cover, canopy cover and several objective measurements. In their study, four individuals gave estimations by visual assessment of 60 quadrats of both ground cover (any non-soil material covering the ground) and canopy cover (any herbage greater then 5cm high). The same quadrats were subjected to three types of objective assessment including, point quadrat, mapped area and digital image analysis. For ground cover, the authors suggested that analysis of the results indicated that human visual assessment tended to underestimate the ground cover through the mid range of 20-80%, whilst they were more accurate at the extreme ends of the range. Whilst a polynomial expression described the relationship between visual and objective estimates, overall the data appeared to suggest that visual assessment underestimates the amount of ground cover and hence overestimates the amount of bare ground. The authors suggested that this overestimation is likely to be related to the ability of the human eye to "look through pasture" to identify areas of bare ground leading to an overestimation of bare ground.

A greater degree of variation was found between individual visual estimates of canopy cover (R^2=0.42) than for ground cover (R^2=0.70). Murphy and Lodge (2002) suggest that this may be due to the two questions being asked of the assessor, firstly, to determine the height of the vegetation as greater than 5cm (to be counted as canopy cover), and secondly the area of canopy cover vegetation in the quadrat. They convincingly suggest that the two step process results in greater variation.

Canopy cover was only objectively assessed using the mapped area technique. A highly correlated linear relationship (R^2=0.90) was detected between mean visual assessment and the mapped area canopy assessment. Two outliers are specifically mentioned as causing problems, these both possessing a wiregrass tussocks with tall diffuse canopies. This suggested that visual assessment can be accurate in providing objective canopy cover assessments; however, the large variation between individuals must be taken into account when assessing the usefulness of this measurement tool. Murphy and Lodge (2002) conclude that visual assessment is a good measure of ground cover to within 10% accuracy and is suitable for land management research measuring changes to this degree of accuracy.

CONCLUSIONS FROM LITERATURE

Survey data is the prime input on which much economic analysis of weeds was undertaken and forms the basis for many scientific research projects. Any improvement in accuracy or the ability to understand the degree of error involved must greatly improve the validity of such studies.

In addition to this, an understanding of landholder abilities to accurately assess their own pasture would be of great benefit to producers themselves. Accurate assessment of their pasture for its degree of weediness would allow landholders to compare weed management systems and potentially, if models were available, estimate losses due to weed infestation. Accurate reporting of the weed levels on properties could trigger the implementation of control methods based on weed density thresholds.

METHODOLOGY

Much of the postal survey data are focussed on a respondent's reported change in weed infestation. Because of the complexity in devising a methodology that tests the ability of producers to accurately report change in weed status and because little work had been done in this area before, it was decided to examine the ability of producers to accurately report weed infestation at a single point in time as a proxy measure of their ability to accurately report change in weed status. Although having limitations, the absence of any prior research in this area and the constraints of time and resources supported this approach.

SELECTION OF RESPONDENTS

The producers selected for this assessment were those reporting at least one or more weed species in the postal survey as a decreasing problem. They were considered to be successful weed managers for at least one species. All producers were selected from the New England Tablelands region of Northern New South Wales to reduce travelling time for the researcher.

RESPONDENT INTERVIEW

In the period from November 2004 to January 2005 eight of these producers were intensively interviewed and their properties surveyed to gain information a range of farm and weed characteristics. The farmers took part in an on-farm, face-to-face interview that took place at their residence prior to any paddock assessments.

During this interview producers were asked to identify an average paddock which was representative of the major pasture type found on their property. They were then requested to select an area within this paddock which measured approximately 50 metres by 50 metres, representative of the selected paddock. The aim of this questioning was to obtain a sample paddock most representative of the property as a whole and the particular pasture which dominates the farm. Preston (2004) reported that a similar technique was used to identify and survey paddocks for ryegrass (*Lolium rigidum*) resistance in South Australia (Hawthorn-Jackson *et al.*). Daly *et al.* (1999) also used a similar methodology in their examination of producer perceptions of pasture persistence.

Producers were then asked to provide an estimate of the botanical composition of this area by ground cover. An explanation of ground cover was provided before they gave their response. This explanation at its most basic consisted of the following statement. "Think of a one metre square, if you looked down from on top and a plant takes up 10 by 10 cm then it is taking up 1% of that square". Most farmers understood this request with some requiring further discussion to ensure they knew what was being asked of them. Whilst the term "ground cover" was used with producers, they were in effect being asked to provide canopy cover estimations as ground cover is predominantly used to describe any sort of non soil material covering a given area. Canopy cover is predominantly used to describe vegetative material covering a given area. The producer was then requested to provide their estimate of the composition of the area by canopy cover of the following categories. These categories were the same as used in the postal survey except for the inclusion of a bare ground option.

1. Perennial pasture grasses

2. Annual pasture grasses

3. Grass weeds

4. Broadleaf weeds

5. Bare ground

6. Other

This information was recorded by the interviewer in an on-farm interview booklet.

An assumption was made that the producers would be making their estimates of weeds based on the presence and density of the species that they had listed in the postal survey. This assumption later proved to cause some difficulty in interpreting the results.

FIELD ASSESSMENT

At the conclusion of the face-to-face interview the paddock and specific area nominated by the producer was subject to a vegetative survey, to determine an objective composition.

Within the area nominated a "W" shaped transect pattern was followed (Figure 3.4) as used by Jones *et al.* (2000) and similar to the "M" transect of Dellow *et al.* (2002). This pattern gave a total of four 50 metre transects. The "W" transect was chosen as it allowed an easy and cheap demarcation of transect lines with permanent marking posts. The posts used were 1800mm long fibre glass stakes, which are safer than steel posts or short wooden pegs when left in the paddock. At the time of sampling a string line was laid along each transect with markers at 50cm intervals. This gave 100 points along each transect and a total of 400 points for the total sample. These markers were used as guides for the point quadrat. Measurements were taken on a first hit basis using a single point quadrat equivalent to the modified step point method described by Cunningham (1975) and used by Croft *et al.* (2002). The single point quadrat consisted of a pointed needle suspended above the pasture canopy in a tripod frame (Figure 3.5). The pointed needle was pushed downwards until it made contact with the first piece of vegetation or object. In high pasture swards the legs of the tripod could be extended so that the needle began above the canopy. The tripod frame described avoided any trampling effects that may occur when using a step point method.

All data were collected was entered into a Microsoft Excel spreadsheet and stored in a Microsoft Access data base.

PRESENTATION OF RESULTS

The results are presented as a percentage of the 400 points taken in each "W" transect. In most cases, plants could be identified to a species level, however, many could only be identified to genus level and some as either annual or perennial grasses or functional groups. The results have been grouped into the categories of pasture grass species, pasture legume species, broadleaf weeds, grass weeds and other.

Pasture grass species included all grass species recorded except the grass weeds *Vulpia* spp. Several other grass species, which were reported by producers in the postal survey as weeds were recorded in the point quadrat survey. These included swamp foxtail (*Pennisetum* spp.) Parramatta grass (*Sporobolis* spp.), annual brome species (*Bromus* spp.) and spear grasses (*Austrostipa* spp.). Except for one case, none of these species were identified as weeds by the producers interviewed, so for the purposes of this analysis they have been included as pasture grasses rather than grass weeds. The exception is the inclusion of one specific *Austrostipa* sp. (bamboo spear grass) nominated by respondent 820 which was present on the property as only small isolated incursions and not found in the case study area.

Pasture legume species included all legumes found in the point quadrat survey. These included white clover (*Trifolium repens)*, red clover (*Trifolium pratense*), subterranean clover (*Trifolium subterraneum*) and a number of native legumes and medics.

Broadleaf weeds included all dicotyledonous species recorded (other than those desirable legume species) as well as bracken fern (*Pteridium esculentum)* and rushes (*Juncus* spp.). Although rushes are monocotyledonous, they were included in broadleaf species as they do fit into the alternative of grass weeds. Plant species which fell outside the list of plants identified by producers as weeds have been included in this section to demonstrate the issues related to producers' definitions of weedy species.

Grass weeds included only *Vulpia* spp. This was the only grass weed nominated by any respondents as potentially occurring in the case study areas.

Other records taken included any bare ground points, unidentifiable litter and uninformative records. Unidentifiable litter included all records of litter that could not be identified. If litter was identified it was included under its species. Uninformative records included points such as dung, rocks and sticks which were considered irrelevant to this study.

ADJUSTMENT OF POINT QUADRAT RESULTS

To understand better how accurately producers can assess their pastures in terms of canopy cover an adjusted composition was developed in line with the assumption that producers were only providing estimates for canopy cover of the weeds listed in their postal survey. In the development of this adjusted composition I hypothesised that producers do not recognise all the weed species present in their paddocks but only observe and report those species which they consider a problem sufficient to warrant listing in their postal survey. In effect an assumption was made that for each producer only those species that were listed amongst the top ten weed species on their postal survey form were included in the adjusted composition leaving all other species out. In addition to this all the records listed as bare ground, litter and uninformative records were excluded. As an exception were the two respondents who included an estimation of bare ground, for whom the point quadrat results were included in the analysis.

Across all respondents the species which were commonly excluded from the adjusted composition included crumble weeds (*Crassula* spp.), cud weeds (*Gnaphallium* spp.), flat weed (*Hypochoeris radicata)*, plantain (*Plantago* spp.), rushes (*Juncus* spp.), dock weeds (*Rumex* spp.), species in the *Cyperaceae* family., *Oxalis* spp., and kidney weed *(Dichondra repens). Vulpia* spp. was excluded for all but two of the respondents who had listed it in their postal survey.

The results were then adjusted so that all records deemed extraneous were removed and percentages calculated as a proportion of the new totals. These results are presented in the "adjusted composition" columns of Table 4.1 through to Table 4.8.

STATISTICAL ANALYSIS

Inspection of the histograms for the adjusted percentage broadleaf weeds and percentage grass weeds as estimated by transect and visually by farmers showed the distributions were skewed and departed substantially from a normal distribution. In view of the failure to meet distributional assumptions and the small sample, the Wilcoxon signed rank test with Bonferroni correction was used for comparing the adjusted point quadrat results and the estimates provided by farmers.

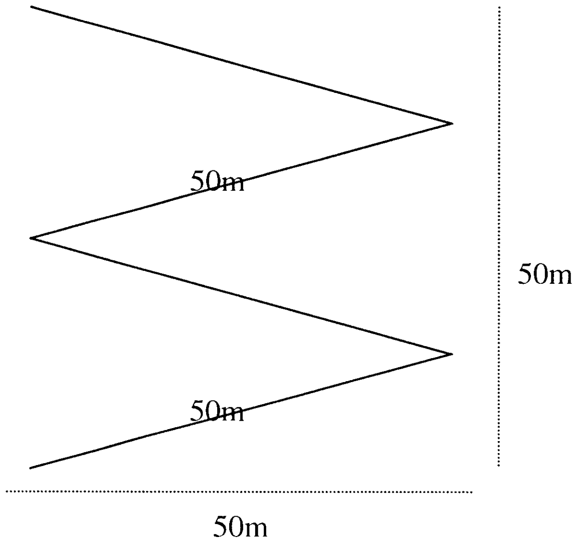

Figure 3.4 The "W" transect used to sample the case study paddocks

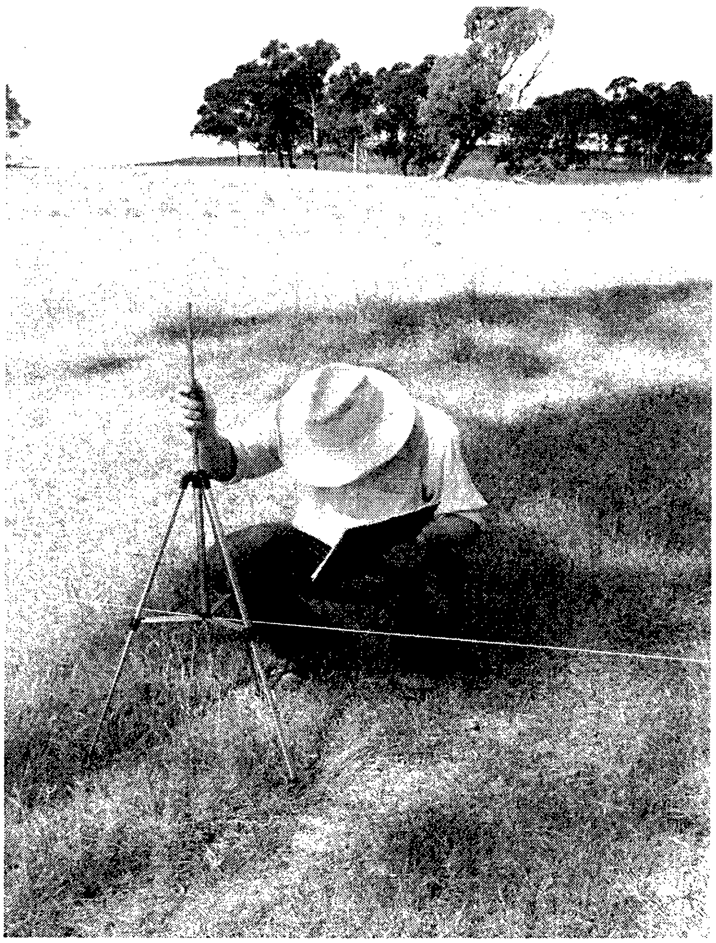

Figure 3.5 the point quadrat sampling device

3.4 TELEPHONE INTERVIEWS

Telephone interviews were used as a follow up to the postal questionnaire. The postal survey revealed that respondents used weed controls in combination, but not how or why. The objectives of the telephone interview were to: 1) determine if graziers are integrating weed controls in a strategic way; and 2) establish how individual producers combine the controls they use.

A telephone survey can be a quick and cheap means of gaining information. This method of research is particularly popular amongst market researchers. The telephone interview has some significant benefits over the postal survey, as questions can be clarified and the required information gathered relatively quickly. The telephone survey can capture both quantitative and qualitative data enabling the exploration of issues in depth, a characteristic which is exploited in this research. In comparison with face to face interviews, costs are much lower. In addition larger, more geographically diverse populations can be surveyed (Dillman 1978).

Obviously, this survey technique depends completely on the targeted sample possessing and being able to use a telephone. It also depends on the availability of the targeted sample and as a result many telephone surveys have to be conducted at specific times of the day to reach the desired participants. In early years of telephone technology very high response rates were achieved (Dillman 1978), however, in today's society, telephone surveys have lost their novelty and are generally regarded as a nuisance by the general public who will readily decline the interview.

Thus, obtaining a representative sample of the target population can be a particular problem in telephone surveys. There are various means of ameliorating this issue. However, in this study

I specifically selected the target audience and so this is not an issue. Obtaining a response is also a significant problem for telephone survey research. The inability to contact people or interview refusals are the primary cause of non-response in telephone interviews. Some of the problems with mail surveys also plague telephone surveys including item non-response and response error which can be particularly affected by social desirability bias.

METHODOLOGY

The aim of the telephone interview was to gain more detailed information from respondents on how they use and potentially integrate the various control methods that they had nominated.

STRUCTURE OF THE TELEPHONE INTERVIEW

The telephone survey followed a semi-structured interview process (Punch 1998; Morse and Richards 2002). The interviewer used a prompting sheet to ask specific questions, with the responses used to create discussion with the producer to elucidate any further details that may have been relevant to the question. The key points of each response were recorded on paper and then an overall report was typed at the conclusion of each interview.

Each respondent selected for telephone interview was contacted by telephone, usually during the day to advise them that they had filled out the postal survey and that further information was desired from them. The respondent was advised of the weed on which information required, in particular the level of infestation and how they controlled it. If they agreed to be interviewed a suitable day and time was arranged to call them back.

Initial contact during the daytime was effective as the potential respondents rarely had time to talk. However, it gave them some time to think over the weed and the weed control methods they used. When they were called back it appeared that many of the respondents had given the weed and its control methods some thought. There were some respondents that were initially advised at night and undertook the interview immediately. These interviews seemed more difficult as the respondent did not seem as comfortable nor able to provide detailed information. It is advisable and recommended that researchers using telephone surveys in the future, use a pre-notification call to assist in relaxing the respondent and obtaining better quality information. The telephone interviews were conducted after 6pm on week nights. Depending on the particular respondent interviews went for between ten minutes to over one hour.

QUESTIONS ASKED

A sample of the questions asked in the telephone interview are found in the Appendix 4. These questions were designed to prompt the respondent to provide as much detail about how they use each control method as possible. The first part of the telephone survey was designed to glean information on the type of infestation being experienced by the producer and how this had been changing (presented in full in Appendix 4). The second part of the telephone survey was designed to glean as much detail as possible about the control methods that the respondent used against the nominated weed (examples presented in Appendix 4).

SELECTION OF RESPONDENTS

The respondents selected for telephone interview were chosen on the basis of their control method use characteristics. The PAM clustering technique described earlier involved the identification of representative objects, or medoids within the data set and then clusters were constructed by assigning other objects to their nearest medoid (Kaufman and Rousseeuw 1990). The multi-active respondents falling on the coordinates of the medoid for each cluster were selected for further investigation by telephone interview.

In some cases, where clusters were not strongly defined, only one respondent might fall on the medoid coordinates. In this case, to obtain further respondents to interview, individuals immediately adjacent to the medoid were selected. This was done by calculating the linear distance between all respondents and the medoid coordinates and selecting those objects with the shortest distance. Representatives from each of the "single-active" and "non-active" groups for each weed were also selected for telephone interview.

TELEPHONE INTERVIEW PRESENTATION OF RESULTS

The results from each telephone interview were recorded in statements, based around each control method reported by the respondent. To summarise these extensive statements a model was devised to demonstrate the relationship between the various controls methods and their impact on the targeted weed. This form of visual presentation is commonly used in qualitative research (Punch 1998) and provides a unique way of visualising how producers integrate weed management controls.

The diagrammatic presentation developed (Figure 3.6) shows a simple competitive relationship between the weed and desirable pastures species, a model proposed by Huwer *et al.* (2002). In addition to this the model of weed population growth proposed by Sheppard (2000) was modified to demonstrate where in the weed's life cycle each control method was targeted. Surrounding the weed and desirable species icons are all the possible control methods that are available to a grazier to manage each weed. The lifecycle shows the three major life stages of a weed, seeds (S), immature plants (I) and mature plants (M). There are five limiting processes in the life cycle, these are, seed survival (Ss), germination of seeds to produce immature plants (G), establishment of immature plants to mature plants (E), survival of mature plants over years (Sm) and the reproduction of mature plants to produce seeds (R).

If a respondent regularly uses a control method, it is highlighted in black and an arrow points to the area to which this control is targeted. If a control has been used only in the past or is used only sporadically the control icon is highlighted in dark grey. For pro-active control methods the arrow points to the desirable pasture species icon. This indicates that this control method is designed to encourage the desirable species to out compete the weed. For reactive control methods the arrow will point to the icon representing the weed species. In addition, the reactive arrow will point to a particular part of the weed's lifecycle shown within the weed species icon. In some cases control methods will be strategically combined to manage the weed. In this case the arrows proceeding from the control icons will join and an additional arrow will start from this point of amalgamation to demonstrate how this integration of controls targets the weed or promotes the desirable species.

At the bottom of each model is information provided by the respondent as to the current extent and density of this weed species on their property. This is shown in the circular chart on the left. The overall impact on the property of this weed, the change in extent and the change in density over the past five years are also given.

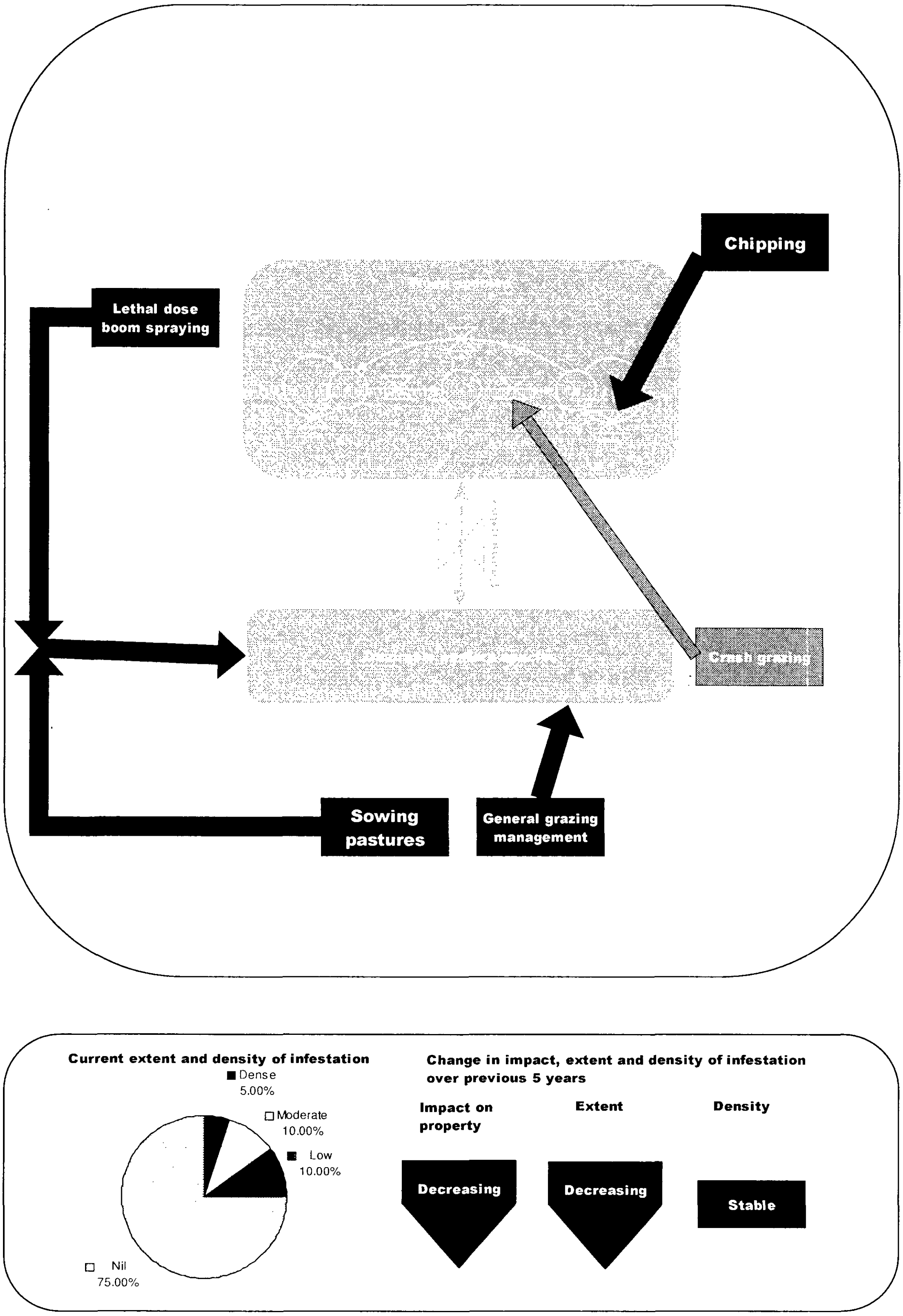

Figure 3.6 an example of the model used to present the results of the telephone interviews on integration of weed controls.

3.5 FOCUS GROUPS

The aim of the focus group studies was to expand on the information obtained through the postal survey addressing objective 4 of this thesis identifying the challenges to adoption of weed control methods. Two of the four weed species examined in chapter 5 were selected to assess the challenges for adoption of control methods. Whereas the postal survey on spray grazing focussed on the problems with the technology, the second and third case studies involving focus groups also aimed to elucidate the social reasons for non-adoption.

A REVIEW OF RELEVANT LITERATURE

WHAT IS FOCUS GROUP RESEARCH?

Focus group research involves a facilitated discussion amongst a group of selected participants. The discussion is designed to obtain the perceptions of participants on a defined topic. The perceptions and responses provided are influenced by the interaction of individuals within the group, revealing issues that might not be made apparent by other research methods (Krueger 1988; Morgan 1988; Dick 1998; Punch 1998).

WHY UNDERTAKE FOCUS GROUP RESEARCH?

Focus groups can provide great insight on an issue as the responses given are less likely to be influenced by the questions being asked compared with other survey forms. Indeed, Krueger (1988) insists that this contrast with individual surveys with pre-defined questions was the reason the focus groups were developed by social researchers. Other advantages of focus groups include the relative low cost and speed with which the results can be obtained (Krueger 1988; Punch 1998; Woodhead *et al.* 2000; Barbour and Schostak 2005). There are some disadvantages to focus group research including the potential for groups to go off topic in the discussion and difficulties in analysing the results. Organising the individuals to attend a focus group can also provide problems (Krueger 1988).

THE APPLICATION OF FOCUS GROUPS IN AGRICULTURAL RESEARCH

Focus groups are most commonly used in social science, education, political science and public health (Morgan 1996). Within these areas of study, focus groups have regularly been incorporated into research being applied to agricultural related issues (King *et al.* 2000; Teixeira 2004b; Athanasiov *et al.* 2005; Chang and Zepeda 2005; Zepeda and Kim 2006). To a lessor extent, focus groups have been used to examine the limitations to adoption of agricultural technologies (Eberle *et al.* 2004) and rarely to the extension issues of weed management (Sell *et al.* 2000).

MAJOR ISSUES WITH FOCUS GROUP RESEARCH

The planning of the focus group is a key determining factor in its success and several authors have outlined procedures for organising, conducting and reporting focus group research (Krueger 1988; Marshall and Rossman 1989).

The selection of participants plays an important role in the success of a focus group (Krueger 1988). The selection procedure used in this study was similar to the "elite interviewing" process proposed by Marshall and Rossman (1989) where the participants are chosen on the basis of their experience in the area of interest. The number of participants is also important with smaller numbers recommended for topics expected to generate high levels of participant involvement and higher numbers for more neutral topics (Morgan 1996).

Another key issue in focus group research is the development of appropriate questions and a structure in which they are presented to the group (Krueger 1988). Focus groups vary in the range of structure applied during the meeting. Some focus groups have little structure and participants are allowed to dictate the direction of the questioning and conversation. Other focus groups could be considered highly structured with a distinct order of events or set of questions being asked of participants (Dick 1998; Punch 1998). The focus group research undertaken as part of this study falls between these two extremes and could be defined as semi-structured.

There is extensive literature on the analysis of qualitative results for research focus groups. The methods range in complexity from the simple presentation of the quotations of participants, data reduction and coding through to computer analysis of content of transcriptions (Marshall and Rossman 1989).

Focus groups are increasingly being used in combination with other quantitative and qualitative research methods. In some cases, they are used as precursors to more formal interviews and in other instances they are used after surveys to "flesh out" the results (Punch 1998; Woodhead *et al.* 2000).

FOCUS GROUP METHODOLOGY

SELECTION OF PARTICIPANTS

The blackberry focus group was targeted on the Northern Tablelands of New South Wales. The postal survey results indicated that there were many respondents reporting this weed in the Armidale area and so the focus group was held in this town. The Central Tablelands of New South Wales were targeted for the serrated tussock focus group. The focus group was undertaken in Goulburn as many of the respondents to the postal survey from this town reported the presence of serrated tussock on their property.

Local weed authority personnel were contacted in Armidale and Goulburn to help identify active and motivated weed managers for the species in question. Only producers within a reasonable distance of the town in which the focus group was to be held were contacted to avoid having people travelling long distances. Many producers contacted expressed interest in the focus groups but were unable to attend due to other commitments. Each focus group consisted of four producers. Three producers were selected with large commercial properties and one producer was selected with a smaller land holding representing the growing number of "life-style" landholders. Numbers were kept low as it was considered the participants would be more motivated to discuss issues (Morgan 1996) whilst larger groups would take a longer time to complete the meeting.

FOCUS GROUP STRUCTURE

The focus group structure was initially developed as a six-stage process. The strategy was designed to engage the participants, avoid them developing any pessimistic feelings and enable them to think broadly about the issues through providing visual cues. This optimal focus group strategy is given in Appendix 5. Unfortunately, the piloting of the focus group revealed that there was insufficient time to achieve all these steps. As a consequence, the focus group was cut down to a three stage process (Table 3.2).

Each focus group began with a presentation of the general results and best management practices found through the postal survey for that particular species. This process, also used by Woodhead *et al.* (2000) and Teixeira (2004a), helped engage the participants as they were asked to comment on the results as they were presented. They were particularly asked to provide any information that they considered key to the success of the control method. These notes were written under the heading of each control method on a white board.

After the participants had reviewed the individual results they were asked to identify what they considered to be the good and bad features of each of the individual control methods. This process was developed from work being undertaken by Lyndall Thompson investigating on-farm approaches and barriers to the adoption of integrated parasite management of sheep (Thompson 2006). The responses provided by participants were written on sticky notes and stuck to a white board on which all controls were listed.

The nature of the focus groups resulted in producers reporting both key issues and good and bad features throughout the discussion. Where possible the moderator summarised these and placed them on the white board. In addition, a scribe was employed to take notes during the meeting to avoid any out of context information being lost.

As was expected, during the discussions it became apparent that many of the individual control methods were being integrated in particular combinations and in specific circumstances. Once the details and features of the individual control methods had been discussed the participants were asked what they considered to be the reasons that people in their area had not been using or applying the various control methods and integrated strategies that had been talked about.

Table 3.2 A summary of the focus group methodology used

Stage	Details	Researcher statement	Purpose
1) Presentation of survey results to date	An initial presentation of the best management practices found through the postal survey was undertaken.		This process engaged the participants as they began discussing the value of results and control methods during this presentation.
2) The good and bad of individual control methods.	The producers were then asked to identify the good and bad features of each of the control methods.	"For each of the individual control methods can you identify some good and bad features of each"	Whilst the bad features or limitations were all that was desired, enabling producers to identify good features kept the tone of discussion balanced and not sliding into pessimism.
3) Limitations to integrated strategies identified.	Producers were then asked to identify the reasons why a typical producer in this area might not be able or willing to implement the integrated strategies.	"We have examined a whole range of individual control methods and talked about their integration. What do you think are the reasons that people in your region do not apply these control methods?"	To identify the issues that might be related to adoption of integrated weed management strategies.

IDENTIFYING THE KEY PRODUCER PERCEPTIONS

To gain an understanding of the challenges that are most commonly perceived as a problem by producers, an index was calculated for each inferential code for the results provided in both focus groups and the postal survey responses. The top five most commonly reported inferential codes for non-adopters, successful adopters, unsuccessful adopters, successful dis-adopters and unsuccessful dis-adopters were allocated an index score from 5 to 1, the most common receiving a score of 5, and the 5th most common a score of 1. These scores were then averaged to give a score out of five.

The issues reported by participants in the two focus groups were treated similarly. Although it would have been useful, time restrictions meant that a producer ranking process could not be applied during the focus groups. Consequently, the number of times an inferential code was reported in both the individual controls and integration parts of the focus group was summed. The same ranking process was used for the spray grazing section and an index score generated using the same technique as for the focus groups. This produced an index of the commonality or reporting of each inferential code for the spray grazing responses.

Whilst this process identified the most common perceptions, its limitations must be acknowledged. If the same questions were to be asked of different control methods or weed species the results may have been quite different. Nevertheless, comparison of the results for the two very different weed species (a perennial grass and a woody shrub) help in identifying common perceptions across weeds as well as those that differ between species.

4 Validity of producer perceptions

This project has sought to harvest the local knowledge held by producers. To do this, producers were asked to provide a range of information in a number of surveys and focus groups. As much of this information was self reported producer perceptions it was considered important to understand how accurate the information provided actually was. Specifically, this chapter aimed to examine the validity of producer perceptions by examining a subset of the results of the postal survey. As outlined in chapter 3 several respondents to the postal survey were interviewed on their property to see if they could accurately report the weeds of an area of their property. The results of the observed composition of the eight case study paddocks and the predictions made by producers are presented from Table 4.1 to Table 4.8.

CONFLICT BETWEEN RESEARCHER AND PRODUCER DEFINITION OF WEEDY SPECIES

What was apparent when the point quadrat results were compared with the predictions made by respondents was that the general definition of a weed proposed by the researcher and that held by the producer were conflicting. *Plantago* spp. (plantain/ribwort), for example, recognised weeds in texts, are rarely considered undesirable by producers and are in many instances sown and encouraged as a valuable feed source. Additionally, many of the species found using the point quadrat transects were not commonly reported as weeds although they make a significant contribution to the canopy cover of the pastures surveyed.

The most noticeable and recurrent difference between the respondent predictions and point quadrat results was the variation in the species of plants listed under broadleaf weeds. Plants such as crumble weeds (*Crassula* spp.), cud weeds (*Gnaphalium* spp.) and flat weed (*Hypochoeris radicata*) were commonly reported in the point quadrat survey of the case study paddocks however few of the 934 respondents to the postal survey reported them as weeds and only under an extreme infestation did one of the producers involved in this study indicate that crumble weeds and cud weeds were undesirable plants. Work by Lemerle *et al.* (1996) also suggested that crumble weed and flat weed can be overlooked although frequently occurring in paddocks. These species are not commonly identified by agronomists, with farmers typically being able to identify even less weeds than agronomists.

VULPIA SPP. *PREDICTIONS AND POINT QUADRAT RESULTS*

Only two of the interviewed farmers (SRN's 688 and 892) reported vulpia (*Vulpia* spp.) as a weed in their postal survey and they were accurate to within 1% (Table 4.4 and Table 4.7) in their estimation of vulpia ground cover. In a case of extremes, one of these producers (SRN 892) reported no vulpia and the other (SRN 688) reported 40%.

During the face to face interview a further two farmers (SRNs 12, 85) provided estimates for grass weeds and specifically referred to vulpia. These two producers did not list vulpia as a weed in their postal survey. However, they appeared to be prompted by the question which asked for an estimation of grass weeds. These producers gave the impression that they were uncomfortable in providing an estimate of canopy cover of vulpia as they considered it more of a guess than for other categories. Respondent 12 provided an estimate that fell outside the point quadrat results by 6% however discussions in the field revealed that they were unable to accurately identify this weed and so this result must be treated with caution. Respondent 85 provided a combined estimate for broadleaf and grass weeds so that a comparison was not possible. Another producer (SRN 86) failed to report vulpia infestation of 10% canopy cover as found in the point quadrat survey (Table 4.8). Further discussions with producers not listing vulpia in their postal survey indicated that they considered it a less important weed, which although present on their farm did not warrant being listed in the same category as the species they had reported.

The overall impression is that producers had difficulty in identifying and quantifying vulpia as a weed unless they considered it important enough to have listed it as a weed in their postal survey.

BARE GROUND PREDICTIONS AND POINT QUADRAT RESULTS

Only two of the eight producers surveyed suggested that there may be bare ground present in their pastures. One producer (SRN 820) accurately predicted around 5% whilst the other (SRN 688) in a difficult paddock situation predicted 40% and the point quadrat returned 13.0%. Of the eight paddocks surveyed, the lowest proportion of bare ground by the point quadrat was 2.8% and the highest 13.0%. The remaining six respondents failed to identify bare ground in their pastures. This may partly be explained by the point quadrat sampling device, which in its vertical descent occasionally struck bare soil even in swards of high biomass. The producer generally views the pasture from an acute angle which would decrease the appearance of the small areas of bare soil recorded using the point quadrat. This has been taken into account in developing an adjusted composition.

INDIVIDUAL COMPARISON OF RESPONDENT PREDICTIONS WITH OBSERVED AND ADJUSTED POINT QUADRAT RESULTS

Table 4.1 shows the predicted, observed and adjusted pasture composition of respondent 12. This respondent's initial prediction that 95% of canopy cover was grass was well outside the 63.7% obtained from the field sampling. This error came primarily out of the underestimation of minor broadleaf weeds and vulpia (Figure 4.1 shows an extensive infestation of minor broadleaf weeds). This producer did not list vulpia amongst their weeds in the postal survey and although predicting 2% vulpia, it can be assumed that this was an uninformed guess, as discussed previously. None of the weeds listed by the respondent in their postal survey form were recorded in the point quadrat survey. Therefore using the respondent's definition of weeds as shown in the adjusted composition column the predicted value of 1% broadleaf weeds is within 1% of the point quadrat results. The respondent predicted legume of 2% which was within 1% of that recorded in the vegetative survey.

Table 4.1 Observed, adjusted and predicted pasture composition of respondent 12's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**63.7**	**97.3**	**95**	**2**
Pasture legume species	**Total**	**1.8**	**2.7**	**2**	**1**
Broadleaf weed species	*Crassula* spp.	2.5	0.0		
	Gnaphalium spp.	1.0	0.0		
	Hypochoeris radicata	12.5	0.0		
	Juncus spp.	1.8	0.0		
	Plantago spp.	1.0	0.0		
	Rumex spp. (docks)	0.2	0.0		
	Cyperaceae	0.2	0.0		
	Unknown species	0.8	0.0		
	Total	**20.0**	**0.0**	**1**	**1**
Grass weed species	***Vulpia* spp.**	**8.0**	**0.0**	**2**	**2**
Bare ground	**Total**	**4.2**			
Other records	Unknown litter	0.8			
	Uninformative record	1.5			
	Total	**2.3**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

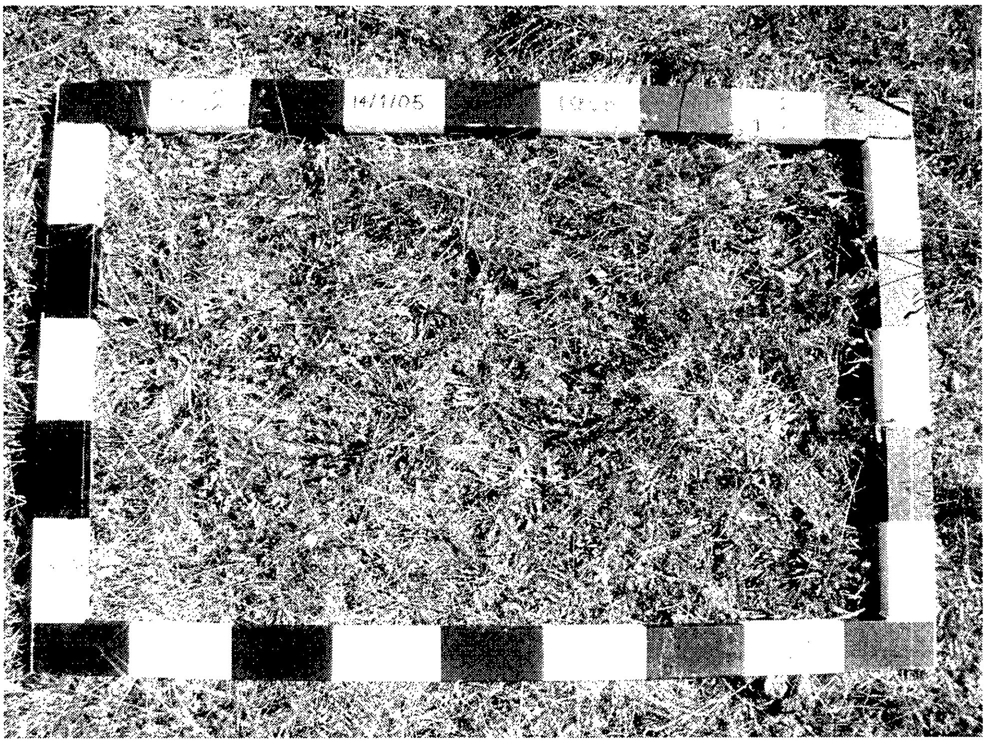

Figure 4.1 A photo quadrat of respondent 12's case study paddock representative area revealing the high density of broadleaf weed infestation.

The predictions of respondent 19 (Table 4.2) are within 5% of the adjusted composition for pasture grasses and legumes. This respondent reported kidney weed (*Dicondra repens*) and saffron thistle (*Carthamus lanatus*) as weeds in their postal survey response. However, they failed to predict their presence in the field. Several broadleaf species not reported in the postal survey made significant contributions to the canopy cover but also appear to have gone unnoticed by the producer. Vulpia. was neither predicted by the respondent nor recorded in the vegetative survey.

Table 4.2 Observed, adjusted and predicted pasture composition of respondent 19's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**80.0**	**93.0**	**95**	**2**
Pasture legume species	**Total**	**3.8**	**4.4**	**5**	**1**
Broadleaf weed species	*Carduus pycnocephalus* and *tenuiflorus*	0.2	0.0		
	Cirsium vulgare	2.5	0.0		
	Crassula spp.	0.2	0.0		
	Gnaphalium spp.	0.2	0.0		
	Erodium spp.	0.2	0.0		
	Hypochoeris radicata	1.0	0.0		
	Dichondra repens	1.2	1.4		
	Oxalis spp.	0.2	0.0		
	Carthamus lanatus	1.0	1.2		
	Unknown species	4.5	0.0		
	Total	**11.5**	**2.6**	**0**	**3**
Grass weed species	***Vulpia* spp.**	**0.0**	**0.0**	**0**	**0**
Bare ground	**Total**	**3.8**			
Other	Uninformative record	**1.0**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

The predictions made by respondent 666 were more representative of the observed composition rather than the adjusted (Table 4.3). The difference between the respondent's estimations and the adjusted composition was 10% or greater for pasture grass species and broadleaf weeds. None of the weeds reported in this farmers' postal survey were found in the point quadrat results. Despite this, the respondent still estimated a broadleaf weed canopy cover of 10%. There were a number of possible explanations for this. Firstly the estimate figure of 10% was only 2.2% outside the observed composition which may suggest that this respondent was including the minor broadleaf species in their estimate. Alternatively, the respondent may have simply made an error in their estimation of broadleaf weed species. As none of the weed species named in this respondent's postal survey were present in the case study area, it is possible that this respondent was referring to spear thistle (*Cirsium vulgare*) when making these estimates. Furthermore a large number of mature spear thistle plants were present on and adjacent to the case study area (Figure 4.2). Spear thistle only contributed 0.8% of the canopy cover according to the point quadrat survey however their height, maturity and prominence may have led to the respondent overemphasising them.

Table 4.3 Observed, adjusted and predicted pasture composition of respondent 666's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**84.2**	**99.4**	**85**	**14**
Pasture legume species	**Total**	**0.5**	**0.6**	**5**	**4**
Broadleaf weed species	*Cirsium vulgare*	0.8	0.0		
	Crassula spp.	3.5	0.0		
	Conyza spp.	0.2	0.0		
	Oxalis spp.	2.5	0.0		
	Rumex spp. (docks)	0.2	0.0		
	Unknown species	0.5	0.0		
	Total	**7.8**	**0.0**	**10**	**10**
Grass weed species	***Vulpia* spp.**	**1.0**	**0.0**	**0**	**0**
Bare ground		**5.0**			
Other	Unknown litter	1.0			
	Uninformative record	0.5			
	Total	**1.5**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

Figure 4.2 Field photograph of respondent 666's case study paddock with tall spear thistle prominent.

The predictions made by respondent 688 (Table 4.4) were different from many other respondents, as the pasture type chosen was a sown improved pasture, recently over grazed and had become infested with annual broadleaf and grass weeds (Figure 4.3). This respondent accurately predicted a large (40%) canopy cover of *Vulpia* spp. Additionally, pasture legumes were accurately estimated to within 1%. This respondent was the only one to list crumble weeds (*Crassula* spp.) and cud weeds (*Gnaphalium* spp.) amongst their problem species in their postal survey. Their predicted broadleaf weed percentage was accurate to within 4.5% of the adjusted composition. The greatest variation of adjusted composition from predicted composition was bare ground and pasture grass species. This respondent greatly underestimated the proportion of ground covered by desirable grasses and over estimated bare ground.

Table 4.4 Observed, adjusted and predicted pasture composition of respondent 688's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**29.2**	**29.9**	**10**	**20**
Pasture legume species	**Total**	**2.5**	**2.6**	**2**	**1**
Broadleaf weed species	*Crassula* spp.	2.2	2.3		
	Gnaphalium spp.	10.0	10.2		
	Oxalis spp.	0.5	0.0		
	Total	**12.8**	**12.5**	**8**	**4**
Grass weeds	***Vulpia* spp.**	**40.8**	**41.8**	**40**	**2**
Bare ground	**Total**	**13.0**	**13.3**	**40**	**27**
Other	**Uninformative record**	**1.8**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

Figure 4.3 Photo quadrat of respondent 688's case study paddock infested with annual broadleaf and grass weeds.

Except for an overestimation of pasture legumes by 10% (and subsequent underestimation of grasses) the estimates made by respondent 820 were within 1% of the point quadrat results (Table 4.5). None of the species recorded in the point quadrat survey were reported by the respondent as weeds in the postal survey. The prediction of 0.5% for broadleaf and grass weed species correlates favourably with the 0.0% adjusted composition but it is obvious that bracken fern (*Pteridium esculentum*) was excluded from the respondent's predictions as it made up a large (8.5%) proportion of the observed composition. The estimates of 0.5% for these categories were given more as a concession at the time of interview with the respondent suggesting that there probably wouldn't be any weeds there. The high level of uninformative records represents a large proportion of fallen timber, as the field site was located in a heavily forested area.

Table 4.5 Observed, adjusted and predicted pasture composition of respondent 820's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**76.0**	**94.1**	**84**	**10**
Pasture legume species	**Total**	**0.0**	**0.0**	**10**	**10**
Broadleaf weed species	*Pteridium esculentum*	8.5	0.0		
	Cirsium vulgare	0.2	0.0		
	Eucalyptus spp.	1.5	0.0		
	Hypochoeris radicata	1.2	0.0		
	Unknown species	0.8	0.0		
	Total	**12.2**	**0.0**	**0.5**	**0.5**
Grass weed species	**Total**	**0.0**	**0.0**	**0.5**	**0.5**
Bare ground	**Total**	**4.8**	**5.9**	**5**	**1**
Other	**Uninformative record**	**7.0**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

Broadleaf and grass weeds were estimated together by respondent 85 (Table 4.6). Although not listing vulpia as a weed in their postal survey, this respondent did specifically refer to and provide an estimate for this weed as part of the total 9% predicted for both broadleaf and grass weeds. The respondent expected some level of broadleaf weed infestation, however, the point quadrat survey found none of the weeds named in the postal survey. This farmer may have simply made an error and overestimated the broadleaf weed infestation or been including the minor broadleaf weed species in their estimation. If this producer was including minor broadleaf species then the prediction of 9% combined weeds was equal to the observed composition total of 9% if grass weeds and minor broadleaf weeds were combined.

Table 4.6 Observed, adjusted and predicted pasture composition of respondent 85's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**84.2**	**100.0**	**90**	**10**
Pasture legume species	**Total**	**0.0**	**0.0**	1	1
Broadleaf weed species	*Cirsium vulgare*	0.2	0.0		
	Crassula spp.	0.5	0.0		
	Gnaphalium spp.	0.5	0.0		
	Hypochoeris radicata	3.5	0.0		
	Conyza spp.	0.2	0.0		
	Dichondra repens	0.2	0.0		
	Plantago spp.	0.5	0.0		
	Cyperus spp.	0.8	0.0		
	Total	**6.5**	**0.0**		
			}	**9**	**9**
Grass weed species	***Vulpia* spp.**	**2.5**	**0.0**		
Bare ground		**3.8**			
Other	**Uninformative record**	**3.0**			

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

Respondent 892 (Table 4.7) demonstrated a good ability to predict the composition of their case study paddock. Pasture grasses were predicted to within 5% of the adjusted composition and pasture legumes to within 1% of adjusted composition. Matt rush (*Lomandra* spp.) was the only weed named in the postal survey that was reported in the point quadrat results. Its observed canopy cover was only 0.5% against a prediction of a total 5% broadleaf weeds. Whilst matt rush is not a dicot, its was included in broadleaf weeds as producers perceive it as such. Again, this farmer may have simply made an error and overestimated the broadleaf weed infestation or been including the minor broadleaf weed species in their estimation. If this producer was including minor species then the estimate of 5% is only 3.2% outside the observed composition of 8.2%.

Table 4.7 Observed, adjusted and predicted pasture composition of respondent 892's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**79.8**	**89.2**	**85**	**4**
Pasture legumes	**Total**	**9.2**	**10.3**	**10**	**0**

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Broadleaf weed species	*Acaena* spp.	0.2	0.0		
	Crassula spp.	1.0	0.0		
	Hypochoeris radicata	0.2	0.0		
	Conyza spp.	1.0	0.0		
	Hydrocotyle laxiflora	1.2	0.0		
	Malva parviflora	0.8	0.0		
	Lomandra spp.	0.5	0.6		
	Plantago spp.	1.2	0.0		
	Cyperus spp.	1.2	0.0		
	Asperula spp.	0.5	0.0		
	Unknown species	0.2	0.0		
	Total	**8.2**	**0.6**	**5**	**4**
Grass weed species	**Total**	**0.0**	**0.0**	**0**	**0**
Bare ground		**2.8**			
Total		**100.0**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondent's predicted composition and the adjusted composition rounded to nearest 1 percent.

The estimations made by respondent 86 were all within 1% of the adjusted composition (Table 4.8). This respondent did not list vulpia as a weed in their postal survey despite 9.3% of the case study area being infested with this weed. This suggests that vulpia is not perceived as a significant weed to this producer.

Table 4.8 Observed adjusted and predicted pasture composition of respondent 86's case study paddock.

Component		Observed composition (%)[1]	Adjusted composition (%)[2]	Respondent predicted composition (%)	Difference (%)[3]
Pasture grass species	**Total**	**82.8**	**99.4**	**99**	**0**
Pasture legume species	**Total**	**0.5**	**0.6**	**0**	**1**
Broadleaf weed species	*Cirsium vulgare*	1.0	0.0		
	Crassula spp.	1.0	0.0		
	Gnaphalium spp.	0.3	0.0		
	Hypochoeris radicata	0.3	0.0		
	Dichondra repens	0.3	0.0		
	Unknown species	0.5	0.0		
	Total	**3.3**	**0.0**	**1**	**1**
Grass weed species	***Vulpia* spp.**	**9.3**	**0.0**	**0**	**0**
Bare ground		**3.3**			
Other	**Uninformative record**	**1.0**			
Total		**100.1**	**100.0**	**100**	

[1]The results of the point quadrat transect. [2]Based on the assumption that producers only provide estimates for canopy cover for the weeds listed in their postal survey. Bare ground, litter and uninformative records were also excluded. [3]Absolute difference between the respondents predicted composition and the adjusted composition rounded to nearest 1 percent.

OVERALL ABILITY OF PRODUCERS TO ACCURATELY REPORT WEED INFESTATION

Table 4.9 shows that there was no significant difference between the adjusted point quadrat results and farmer estimates of the percentage of broadleaf (p=0.273) and grass weeds (p=0.500) in the validation paddock. Complete analytical output from SPSS is reported in Appendix 14. The differences between medians and the differences between means are both in the order of several percent, suggesting that farmers' visual estimates of weed incidence in pastures are reasonably accurate, particularly if the percentage of weeds is relatively high. The visual estimates may be relatively less accurate if the percentage of weeds in pasture is low.

The differences above were shown not to be significant, but it must be acknowledged that this was a relatively small sample of producers and a more accurate estimate of population differences would be obtained with a larger sample. Nevertheless the differences are substantively small and is reasonable to conclude that farmers' visual estimates of weed incidence in pastures are reasonably accurate.

Overall, the producers in this group were accurate to within 10% in their estimations of the adjusted broadleaf weed composition and six of the eight producers were within 5% (Table 4.10). Although the differences between producer estimates and the adjusted composition for grass weeds was less than 2% many respondents failed to identify the grass weeds present. It is notable that the predictions of the two respondents who had reported this vulpia in their postal survey were both within 1% of the point quadrat results. Although it cannot be confirmed with any certainty it is possible that once respondents can identify a grass weed they may be able to accurately quantify it. Seven of the eight farmers were accurate to within 4% in their estimations of pasture legume composition (Table 4.10).

The relatively high level of accuracy demonstrated by landholders in prediction of pasture legume composition was less likely to have been influenced by the error in definition of weeds as previously discussed. There was very little difference between producer and researcher definitions of legumes. This suggests that landholders, if questioned in a more in-depth study, particularly examining one easily discernable weed species may be even more accurate with their assessments.

Table 4.9 Descriptive statistics and exact Wilcoxon signed ranks test for adjusted transect and farmer estimates of percentage of broadleaf and grass weeds.

Measure	Mean	Standard Error of mean	Median
% broadleaf weeds - adjusted transect	2.00	1.48	0.00[1]
% broadleaf weeds - farmer estimate	3.75	1.33	2.75[1]
Absolute difference - broadleaf weeds	3.50	1.08	3.50
% grass weeds - adjusted transect	5.25	5.25	0.00[2]
% grass weeds - farmer estimate	5.88	4.91	0.25[2]
Absolute difference - grass weeds	1.13	0.57	0.25

[1] Exact paired-sample Wilcoxon signed ranks test for equality of adjusted transect and farmer estimate medians for percentage of broadleaf weeds $p = 0.273$.

[2] Exact paired-sample Wilcoxon signed ranks test for equality of adjusted transect and farmer estimate medians for percentage of grass weeds $p = 0.500$.

Table 4.10 The percentage difference between the adjusted composition[1] and respondent predicted composition for the four major categories of vegetation.

Respondent	Pasture grass species (%)	Pasture legume species (%)	Broadleaf weed species (%)	Grass weeds species (%)
12	2	1	1	2
19	2	1	3	0
666	14	4	10	0
688	20	1	4	2
820	10	10	0.5	0.5
85	10	1	9[2]	
892	4	0	4	0
86	0	1	1	0

[1]The adjusted composition excludes uninformative records, bare ground and adjusts for non-listed broadleaf weeds and grass species.

[2]The Respondent 85 estimated a combination of 9% for both broadleaf and grass weeds. Adjusted composition for both was 0% giving the difference of 9%.

CONCLUSIONS

From this preliminary study the majority of producers appear able to accurately estimate weed canopy cover to within 5% in their own paddocks, although several shortcomings were identified in the methodology and further study and refinements are required to authenticate these findings.

The original purpose of this study was to test producer's ability to accurately report the weed situation on their property. Because the postal survey questions focused on the change in individual weed status, this test was devised as a proxy measure and correlation between producer ability to accurately report their weed situation at one point in time and their perception of change in infestation is unknown. However, if a producer can accurately report their point in time infestation then more credence can be given to their ability to report the difference between infestations at one time compared with another.

It would be helpful to be able to extend this standard of accuracy to other producers. However, these were not a random group of producers and because of the refinements required in methodology, generalising the results to the whole population must be treated with caution. Nevertheless, the results do suggest that a degree of confidence can be applied to the results of the postal survey for some weeds, and particularly for the four key weeds that are the focus of the best management practices. In contrast, it is suggested that the results for vulpia may need to be treated with more caution, as this study revealed some producers failed to accurately identify and quantify the level of infestation of this weed.

The adjusted composition from which comparisons with producer estimations have been drawn were developed as a result of the assumption that producers were referring to only those weed species named in their postal survey and not taking into account the possibility that additional minor weeds may have been included by the farmer. This problem was compounded when species which are not normally considered as important weeds made up significant proportions of the canopy cover (up to 20%) and those species which farmers considered problematic enough to list as weeds in the postal survey made up little if any of the canopy cover. Although surveys such as Dellow *et al.* (2002) indicated that the minor broadleaf weed species such as flat weed (*Hypochaeris radicata)* and cud weed (*Gnaphalium* spp.) were present in the perennial pasture zone at similar biomass levels to weeds such as spear thistle (*Cirsium vulgare*) and saffron thistle (*Carthamus lanatus),* I did not expect the minor species to be recorded at such high levels in field assessments. The lower level of major weeds could have been anticipated from the fact that these producers were selected for being good weed managers. Their selection was however, based on a decreasing infestation, not on a known level of infestation.

Future studies will need to take into account these issues when attempting to ascertain the ability of producers to accurately report weed infestations. Studies that focus on one weed species only are likely to be the easiest and most accurate. It may be enlightening to compare the ability of producers to identify and quantify a weed that is important to them against a weed of lesser importance. Additionally, the scientific and economic communities would benefit greatly from a study into the ability of producers to accurately report weeds at varying densities. Information is required on whether landholders are more able to quantify high level infestations compared with low level infestations. Ultimately, further trials may be able to examine the ability of producers to accurately report the change in weed infestations over time. This assessment of self reporting would have a great influence on many scientific and economic studies.

Furthermore, understanding the ability of landholders to accurately self report their weed situation and developing tools to assist them, will have significant implications for future areas of pasture weed science. Currently, landholder assessments of the impact and subsequent cost of weeds appear to be rarely based on economic thresholds. The development of a tool to enable producers to turn a self reported weed extent and density into an economic cost could greatly increase the economically rational control of weeds.