

# Factors affecting adoption in the grazing industry

Findings from a survey of properties in the Burdekin and Fitzroy Catchments



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# **Key Findings**

- Grazing management and business management involves a complex interaction between biophysical, climatic, markets, and social factors. To understand if there were any key characteristics for adoption of best management practices, and therefore improved delivery of extension activities this study investigated determinants of adopting grazing BMPs in the Fitzroy and Burdekin.
- There is heterogeneity across graziers, their properties and their management practices; because of this the previous empirical literature has struggled to find significant determinants or drivers of adoption.
- The research found very little and weak evidence of correlation between graziers' characteristics and their management practices using a number of statistical approaches. Highlighting the complexity of developing strategies for increased adoption.
- The survey was firstly designed to collect information regarding grazing management practices. Therefore to gain a more informed understanding of the characteristics and drivers for adoption a number of modifications are required.
- Improved survey design would allow insights to be gained regarding the drivers and adoption. Design modifications include:
  - The scope of the survey i.e. including questions that elicit more information about graziers, their properties and their management practices.
  - The quality of the survey i.e. increasing response rate and reducing missing answers.
  - Turing the focus of the survey towards the adoption diffusion process i.e. the inclusion of questions pertaining to the rate and extent of adoption, as well questions that elicit subjective beliefs about individual management practices.

## **Executive Summary**

The declining health of the Great Barrier Reef from increased sediment and nutrient pollutant loads has resulted in a suite of programs and policies to improve management practices in both the sugarcane and grazing sector. A range of support mechanisms have been implemented to reduce these emissions including the Reef Water Quality Protection Plan (2013) which focuses on providing support mechanisms to increase landholder adoption of best management practices. Improved water quality from grazing lands relies on ongoing and high levels of adoption of better management practices by landholders. A key mechanism is extension which relies on understanding drivers and barriers of adoption to improve water quality improvements outcomes.

Extension can facilitate or accelerate voluntary change by reducing or changing the effort and time landholders need to spend in searching for information and acquiring skills. In other words, extension can assist in the dissemination of innovations through a population of potential adaptors more rapidly than would otherwise be the case (Pannell et al. 2009)

The focus of this report is on the grazing sector in the Fitzroy and Burdekin catchments, where the key issue is sediment reductions. While previous research has identified some key drivers and barriers to adoption of more sustainable management practices in the grazing sector, the findings are often contradictory and/or inconclusive. This study aims to provide insights for an improved extension delivery strategy by focusing on a selection of core management practices to provide a more detailed understanding of adoption drivers.

Three primary property characteristics were examined and their correlation with the core management practices analysed. The key findings of this paper are consistent with much of the agricultural adoption literature. The analysis revealed only weak evidence for the existence of significant relationships between graziers' and their management practices. Furthermore of those relationships that were found to be

significant, none could be described as robust. Ultimately, the results of the analysis are best described as inconclusive, as the dataset and analysis conducted reflects key challenges identified in the literature.

This report provides a number of recommendations for the future analysis of management practice adoption in the grazing industry. It also highlights some key findings from the literature and applies them to the adoption of best management practices and improved extension strategies. The report also highlights the deficiencies within the data set used due to the intent of the survey being for a different purpose.

## Introduction

The declining health of the Great Barrier Reef has been attributed to the increase of sediments, nutrients and pesticide pollutants entering the Great Barrier Reef lagoon from adjacent catchments (Greiner *et al*, 2008; Karfs *et al*, 2009 Brodie et al. 2011). Sediment has been identified as a primary concern because of its ability to inhibit the growth and survival of corals and sea grasses by reducing light availability and limiting photosynthesis (Kroon and Waterhouse 2012).

The grazing industry has been identified as the dominant contributor of increased sediment runoff, with grazing pressure reducing protective vegetative cover and exposing vulnerable bare ground to large rainfall events (Thorburn, 2013). Given the significant area (77 per cent of the total) of grazing in the Burdekin and Fitzroy catchments, reducing pollutant loads from the grazing industry in these two catchments has been priority for both State and Federal funding (Queensland, 2013c).

To reduce pollutants entering the Reef, the Reef Water Quality Protection Plan (Reef Plan) was developed and subsequently endorsed by the Prime Minister and Queensland Premier in October 2003 and updated in 2009 and 2013. (Queensland., 2009). The Reef Plan is a collaborative program of coordinated projects and partnerships designed to improve the quality of water entering into the Great Barrier Reef though improved grazing land management. Reef Plan created a number of targets and actions to achieve by 2018. Action 5 of the Reef Plan outlines key deliverables that include "report(ing) annually by industry sector on the uptake of improved land management practices". In satisfying this key deliverable the Department of Agriculture, Fisheries and Forestry (DAFF) developed the Grazing Management Practice Adoption Survey to identify and rank a grazing property's management practices.

The purpose of the Grazing Management Practice Adoption Survey was to collect information and data pertaining to grazing land management, but also to use the opportunity to collect demographic, herd management and extension data within the Great Barrier Reef catchments. The primary objective of the survey was to determine how producers are impacting on the current benchmarks of Reef Plan with respect to their ability to adopt improved land management practices in order to improve reef water quality reducing sediment and nutrient run-off.

The Grazing Management Practice Adoption Survey provides the opportunity for DAFF to identify areas in which research, development and extension can be better provided, focussed and implemented in order to increase the adoption of improved management practices to meet both the immediate and long term goals of the Reef Water Quality Protection Plan.

Using graziers' responses to the Grazing Management Practice Adoption Survey, this report investigates whether any significant relationships exist between graziers' and their current management practices. Using the responses from the survey three separate variables were investigated. Specifically, are any of the following grazier or property characteristics:

- Experience,
- Property Size, or
- Business Structure

Correlated with any of the following grazing management practice issues:

- What graziers base their average carrying capacity on?
- What controls graziers have of grazing on river and creek frontages and wetlands?
- How graziers account for differing ages and sizes of their cattle when assessing stocking rates?
- How graziers manage stocking rates?
- How graziers manage for end of season ground cover.
- What grazing strategies graziers employ to better maintain areas of land that are in declining condition.

This report focusses on graziers within the Fitzroy and Burdekin catchments and management practice issues that affect Great Barrier Reef water quality. The purpose of this paper is to improve the current understanding of graziers' management practice decisions with the intention of developing a more efficient and effective agricultural extension strategy.

## **Methods**

In the first part of this paper a review of the relevant literature is presented, focussing on Reef Plan and its actions, as well as the issue of adoption in agriculture. The case study is then described, comparing and contrasting the Fitzroy and Burdekin catchments. The statistical methodology is then discussed, as well as the explanatory variables and survey responses. An analysis of the survey data is then undertaken using a visual inspection of the individual relationships and the estimation of relevant correlation statistics. The strongest of these relationships are then tested further by estimating binary response models and utilising model-specification tests. Finally the results of the analysis are presented and discussed including predicted probabilities generated from the binary response model regression.

## Background

The Great Barrier Reef is the largest coral reef ecosystem in the world, spanning 2,300 kilometres along the Queensland coast. The coral reefs, numbering almost 3000 in total, represent about 10 per cent of all the coral reef areas in the world. Coupled with its obvious intrinsic value, the contribution of the Great Barrier Reef to the Australian economy is estimated to be \$6.1 billion annually (Access Economics 2005). The Great Barrier Reef receives runoff from 35 major catchments which drain 424,000 square kilometres of coastal Queensland. Poor water quality from catchment runoff affects the health of the reef, causing degradation of inshore reefs and sea grass beds and is thought to be a significant contributor to crown-of-thorns starfish outbreaks.

Grazing is the dominant land user within the Great Barrier Reef catchments occupying 77 per cent of the total agricultural land. The impact of poor water quality from grazing lands entering into the Great Barrier Reef has been identified as a significant contributor to the decline in the health of the Great Barrier Reef (Brodie et al., 2003; Fumas, 2003). In order to improve the quality of water entering the Great Barrier Reef a number of programs and projects have been designed. Among the initiatives is the Reef Plan, which is designed to improve the quality of water in the

Great Barrier Reef through improved land management in Reef catchments (Queensland . 2009).

Initially established in 2003, the Reef Plan was updated in 2009 and again in 2013 with details of specific actions and deliverables to be completed by 2018. A key strategy (Action 5) of the Reef Plan was the construction of a set of grazing 'best management practices' which were developed in consultation with graziers and other industry professionals. This initiative is framed in an "ABCD" ratings hierarchy and aims to ensure a sustainable, profitable beef industry by managing the land in a manner that maximises water quality and minimises the delivery of nutrients and sediments to aquatic systems (Coughlin et al., 2006).

The ABCD grazing management practice framework is characterised by its: adaptability to different kinds of ecosystems on various scales; provision of practical guidelines on what to do and why; sustaining the integrity of particular ecosystems; and, that it represent a working consensus among other practitioners, managers and researchers (Greiner *et al.*, 2008). The grazing practices framework aligns practices of varying levels of control, impact and complexity with eight core management principles:

- 1. Objectively determine long term carrying capacity.
- 2. Match stocking rate to forage availability.
- 3. Strategically use fire to achieve management and ecological outcomes.
- 4. Strategically manage weeds and feral animals to achieve productivity and ecological outcomes.
- 5. Strategically use sown pastures to achieve productivity and resource condition outcomes.
- 6. Locate and maintain property roads and firebreaks.
- 7. Prevent and stabilise erosion areas including gullies, stream banks, and hill slopes.
- 8. Manage records.

In using the grazing ABCD framework to assess management practices, the above principles are weighted to reflect their relative potential impacts upon land condition.

For example practices aligned with carrying capacity and stocking rates (principles 1 and 2 respectively) are weighted as contributing 60 per cent of the total ABCD value to an individual assessment. Graziers' who adhere closely to the above core management practices are therefore more likely to be rated higher within the ABCD framework, while those who employ few of the principles are likely to be rated relatively lower within the ABCD framework.

Graziers with "A" class practices are considered as likely to maintain land in very good condition or improve land in lesser condition. Those with "B" class practices are likely to maintain land in good condition or improve land in lesser condition. "C" class practices may maintain land in fair condition or gradually improve land in poor condition. While those with management practices classed as "D" are likely to degrade land to poor condition.

Increasing the relative number of "A" or "B" classed graziers is a priority for Reef Plan as the initiative aims to improve the Great Barrier Reef's water quality through the adoption of improved management practices. However promoting adoption within the agricultural industries has historically proved extremely challenging. In principle the rate and extent of adoption is influenced by the characteristics of the practices or technology, as well as those of the landholders and their properties. However efforts to clearly establish this link have largely failed. There is at present an exhaustive body of literature on agricultural adoption the results of which indicate that it is an extremely case specific issue issue that is subject to a vast and complex array of drivers and barriers.

Extension services have operated as a key policy mechanism for promoting the adoption of improved management practices within Australia's agricultural industries. By increasing the dissemination of information, providing skills and education or reducing the effort required by landholders to implement the change Extension aims to facilitate or accelerate voluntary change.

The Grazing Management Practice Survey presents an opportunity to identify areas in which Extension and adoption services can be improved. Analysing graziers and their current management practices will improve the current understanding of management practice adoption decisions. This information should in turn aid Extension services in improving efficiency and effectiveness by enabling an improved targeting of effort and resources.

## **Case Study**

This paper focuses on the Fitzroy and Burdekin catchments which are the two largest regions within the Great Barrier Reef Catchment, occupying 37 per cent and 33 per cent of the total catchment area respectively (Queensland. 2013c)



### Figure 1 The Fitzroy region and the Great Barrier Reef

The Fitzroy catchment covers 15.6 million hectares and is the largest region draining into the Great Barrier Reef lagoon. Grazing is the predominant use of land (77 per cent), and the Fitzroy region itself contributes a quarter of the total annual average anthropogenic sediment load reaching the Great Barrier Reef lagoon. As of June 2010, 49 per cent of graziers' in the Fitzroy region were employing "C" or "D" classed practices. This equates to some 1,710 graziers that occupy an area of approximately 5.8 million hectares and indicates that there is considerable scope to increase the adoption of improved management practices for sediment pollutant reduction in the Fitzroy region (Queensland, 2011a; 2013a; 2013c).

#### Figure 2 The Burdekin region and Great Barrier Reef



The Burdekin region covers approximately 14.1 million hectares and is drained largely by the Burdekin River system. The main agricultural land use for the region is also grazing, which occupies approximately 90 per cent of the agricultural land. The Burdekin contributes 46 per cent of the Great Barrier Reef's average annual anthropogenic sediment load, the largest of all the regions. In June 2010 there were an estimated 827 landholders grazing cattle on 12.8 million hectares of land in the Burdekin region, with 44 per cent of these graziers' employing "C" or "D" classed management practices. This result indicates that there is also considerable scope to increase the adoption of improved management practices for sediment pollutant reduction in the Burdekin region (Queensland, T. S. o. 2011a; 2013a; 2013c)

Reflecting their relative size and importance the Burdekin and Fitzroy catchments had the greatest proportion of respondents in the Grazing Management Practice Survey. The survey contained a large number of missing values; as such these observations were omitted from the analysis in this paper. The total number of remaining respondent graziers was 88, 52 of which were from the Burdekin catchment, while the remaining 36 were from the Fitzroy catchment.

#### Figure 3. Properties surveyed by location of river catchment

river catchment the property is located within	Freq.	Percent	Cum.
BUR FIT	52 36	59.09 40.91	59.09 100.00
Total	88	100.00	

## **Grazier and Property Characteristics**

The grazing management practice adoption survey asks over 100 questions of the responding graziers. A number of these questions asked graziers to describe some of their individual grazier and property characteristics, which could be grouped into three core characteristic groups: business scale, business experience and business structure. For each of these groups a representative variable or survey response was chosen, which are described in more detail below.

Business structure is hypothesised to affect adoption decisions in a number of ways. For example the structure of a graziers' business might influence adoption decisions through a graziers' 'locus of power'. Individuals who have a strong belief in their own ability to influence the circumstances of their lives are described as having an 'internal locus of control' and those who possess this trait are less likely to experience stress during their decision making. The theory therefore suggests graziers who have a business structure with an 'internal locus of control' might experience more freedom and control in adoption based decisions and therefore be more likely to adopt (Pannell *et al.*, 2006).

For the independent variable describing a property's Business Structure (labelled throughout this analysis as **businessstructure**) graziers' responses to survey question 66 "*What best describes your business structure*?" were chosen. Unlike the other two explanatory variables in this analysis **businessstructure** is a nominally discrete variable, in that responses to the question take on individual values which have no specific order. Figure 4 describes the breakdown in responses: the majority of grazing properties across the two catchments consider themselves in partnerships (49 per cent), roughly a quarter of businesses are run by companies, while 17 per cent of businesses are sole traders.



#### Figure 4. Summary statistics for the variable Business Structure

The second independent variable included in this analysis is Business Scale. Conventional theory suggests that properties with larger scale operations might be more willing to invest in new technologies and practices, particularly if there is a need for extensive capital investment (Knowler and Bradshaw, 2007). The log of responses to survey question 67: "*What is the size of your property?*" were used to describe the scale of a property's business (**Insize**). Responses to question 67 were chosen largely because it is likely to be the most accurate of the responses for scale related questions from the survey, other possible scale variables considered included number cattle run on a property and number cattle sales for a property.

The level of experience of a grazier is the last explanatory variable included in this paper's analysis. Experience is often included in adoption based literature and is hypothesised as one of many human capital variables to positively affect rates of adoption. This relationship might exist for a number of reasons, for example: graziers with relatively more experience are potentially exposed to more ideas, they have greater experience making decisions and in effectively using information (Prokopy *et al.*, 2008; Caswell *et al.* 2001). The log of responses to question 72: "How long has the property been under its current ownership?" are used to describe Business Experience, and labelled throughout this report as **Inowner**.

Variable	Obs	Mean	Std. Dev.	Min	Мах
lnsize	88	9.680327	1.016385	7.377759	12.73651
lnowner	88	2.950062	1.179645	0	5.02388



Property size and the length of property ownership variables can be considered to have roughly log-normal distributions. The log of property size has a mean of 9.68, a standard deviation of 1.02 and minimum and maximum values of 7.38 and 12.74 respectively. While the log of length of property ownership has a mean of 2.95, a standard deviation of 1.179, and minimum and maximum values of 0 and 5.02 respectively.

## **Grazing Management Practices**

This paper analyses responses to 6 of surveys questions which were selected for their respective significant in the weighting of the ABCD grazing management practice framework. Each of these management practices are addressed as individual questions the DAFF survey and graziers were required to respond with one of a four possible answers. These responses, numbered 1 to 4 can be viewed as ordered metrically or ordered categorically given that the responses indicate a relative ranking (usually low to high) that matches to a corresponding level on the ABCD grazing management practices framework.

The first of the survey responses analysed were from question 8: "What do you base your average carrying capacity on?". A summary of the graziers' responses are presented below in Figure 6.

#### Figure 6. Summary of Responses to Question 8



Response 1 ("*Historical experience and/or anecdotal advice not documented*") received the greatest share of responses (35 per cent), roughly a quarter of respondents answered with response 2 ("*Long term stock and stocking rate records documented in diaries, paddock records etc.*") and 3 respectively ("*Objective measure of safe stocking rate calculations, including property map and based on historical data, subjective assessment of resource condition*") while response 4 ("*Documented records, including property map and safe stocking rate calculations based on land type, property infrastructure and objective assessments of land condition*") received the smallest share of responses with 15 per cent.

The second of the survey responses analysed were from question 11: "What control do you have of grazing on river and creek frontages and wetland areas?". A summary of the graziers' responses are presented below in Figure 10.



#### Figure 7. Summary of Responses to Question 11

There was a fairly even spread across the 5 responses for question 11, with response 4 "Fenced as much as practically possible/'cost effective, use off-stream water points throughout, use moderate stocking rates and regular wet season spelling, use fire and chemicals for week control" the most frequent. While response 3 "Fenced frontage country and mostly have off-stream watering points. Ensure frontages are stock moderately and occasionally wet season spell" was the least frequent with 15 per cent of total responses.

Interestingly 20 per cent of respondents stated that that didn't have any significant areas of river and creek frontage or wetlands. Those that responded question 11 with response 5 indicate that the question is not applicable to them. As such these observations are dropped from the analysis of question 11, the new restricted frequency table and histogram are displayed below in Figure 11.





The relative proportion between responses remains unchanged; however the individual responses' share of the total consequently increases. As can be seen from the summary above response 4 received the greater share of responses (34 per cent) and answer 3 received the fewest responses with 19 per cent.

The third of the survey responses analysed were from question 12a: "How do you account for the differing age and size of your cattle when assessing stocking rates?". A summary of the graziers' responses are presented below in Figure 15.

#### Figure 9. Summary of Responses to Question 12.a.



An overwhelming majority of respondents (52 per cent) answered with response 2 ("Numbers in each paddock recorded annually. Use common sense and rules of thumb to account for effects of animal class and size/age") followed by response 3 (25 per cent) ("Numbers in each paddock recorded at each muster. Use AE or LSU to account for different animal class and size/age.") and response 4 (17 per cent) ("Numbers in each paddock recorded every time there is a change in numbers within a paddock. Use AE or LSU to account for different animal class and size/age."), while response 1 ("Numbers recorded annually. Effects of animal class and size/age"), while response 1 ("Numbers recorded annually. Effects of animal class and size/age"), received only 6 per cent of responses.

The fourth of the survey responses analysed were from question 14: "How do you manage stocking rates?". A summary of the graziers' responses are presented below in Figure 19.







An overwhelming majority of respondents (80 per cent) answered with response 3 ("Use long term experience to look at stock numbers and pasture available in each paddock after the wet season. Cattle numbers adjusted to ensure adequate residual pasture and groundcover at break of season"), followed by response 2 (11 per cent) ("Broad assessment of whole property for pasture available and cattle numbers before dry season starts or soon after."). While answers 1 ("Usually do a whole of property assessment of feed supply and cattle numbers before dry season starts or soon after.") and 4 ("Routinely use forage budgets and paddock/stock records for each paddock and adjust cattle number to ensure adequate residual pasture and groundcover at break of season") were the least frequent responses, each with roughly 5 per cent of total responses.

The fifth of the survey responses analysed were from question 15: "How do you manage for end of season ground cover?". A summary of the graziers' responses are presented below in Figure 23.



#### Figure 11. Summary of question 15 responses

An overwhelming majority of respondents (44 per cent) answered with response 3 ("*Regularly monitor ground cover and manage grazing to keep it above 50 per cent at break of season*") followed by response 2 (36 per cent) ("*Observe amount of pasture and groundcover at the end of the dry season and try to keep enough residual pasture for stock*") and response 4 (14 per cent) ("*Regularly observe groundcover, density of 3P grasses and land condition and have installed photo monitoring sites. Aim to maintain paddock and ground cover specific to region, rainfall and land type*").

While answer 1 ("*Don't actively manage groundcover*") was the least frequent response, with roughly 6 per cent of total responses.

The sixth of the survey responses analysed were from question 24: "What grazing strategies do you employ to better maintain areas of land that are in decline?". A summary of the graziers' responses are presented below in Figure 11.





An overwhelming majority of respondents (48 per cent) answered with response 3 ("*I* adjust stocking rates and frequently use rotational grazing.") followed by response 4 (31 per cent) ("*I* adjust stocking rates, fence for stock control and frequently use rotational grazing.") While answers 1 ("*I* have set stocking") and 2 ("Stocking rates are not adjusted and I occasionally use rotational grazing") were the least frequent responses, both with roughly 10 per cent of total responses.

# Methodology

The tests for significant relationships undertaken in this report between the survey responses and property characteristics first involved visual analysis of the relationships and estimation of the respective correlation coefficients. The variable **businessstructure** and each of the survey responses are ordered categorically, as such Pearson's Chi-square<sup>1</sup> and Fisher's exact<sup>2</sup> tests were estimated for tests

<sup>&</sup>lt;sup>1</sup> <u>Pearson, Karl</u> (1900). <u>"On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can be reasonably supposed to have arisen from random sampling". *Philosophical Magazine Series* 5 50 (302): 157–175.</u>

<sup>&</sup>lt;sup>2</sup> Fisher, R. A. (1922). "On the interpretation of  $\chi^2$  from contingency tables, and the calculation of P". *Journal of the Royal Statistical Society* 85 (1): 87–94.

between the two variables<sup>3</sup>. Because the **Insize** and **Inowner** variables are continuous tests of their relationship with the individual categorically ordered survey responses must be done via polyserial correlation<sup>4</sup>, which describes the relationship between categorically ordered and continuous variables.

The Pearson's Chi-square and Fisher's exact tests are conducted with the null hypothesis that no relationship exists between the two variables. Once conducted p-values can be estimated which indicate the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. When the *p*-value is less than the predetermined significance level which is often 0.05 the null hypothesis is rejected, here this indicates that a significant relationship exists between the variable **businessstructure** and the individual management practice being examined.

The polyserial correlation coefficients are interpreted in the same way an ordinary correlation coefficient is, with values having a range between -1 and 1. Values approaching -1 indicates a strong negative relationship: an increase in one variable coincides with a decrease in the other. While values approaching 1 indicates a strong positive relationship: an increase in one variable coincides with an increase in the other. The absolute value of the polyserial correlation coefficient indicates the relative strength of the relationship with values close to 0 indicating a weak relationship, while values close to 1 or -1 indicate a significantly stronger relationship between the two variables.

The strongest of the initially examined relationships are then investigated further. The vast majority of the empirical adoption literature analyses potential relationships between adoption decisions and selected independent variables by employing some form of a logistic regression model. This form of analysis employs a binary value representing the level of adoption as the dependent variable, for example the decision to adopt some technology or practice on a property might be represented by

<sup>&</sup>lt;sup>3</sup> While p-values for both tests are reported Fishers' exact test is preferred when sample sizes are small. The results of both tests across all the analysed relationships are

<sup>&</sup>lt;sup>4</sup> For more on polyserial correlation see Cox, N. R (1974). Estimation of the correlation between a continuous and discrete variable. Biometrics, *30*, 171-178

a 1 while the decision to not adopt is represented by a 0. The property or landholder characteristics being analysed are then included as the logistic model's explanatory variables. Using standard t-tests each of the individual variables can then be tested for their statistical significance in predicting the value of the explanatory variable, or the level of adoption.

The baseline logistic regression model is derived directly from the logistic function described here in equation 1, which is a sigmoid function of Z that has a restricted range between 0 and 1.

$$f(Z) = \frac{e^{Z}}{e^{Z} + 1} = \frac{1}{1 + e^{-Z}}$$
(1)

Z itself is a function of the explanatory variables

$$Z = \beta_1 + \beta_2 X + \dots + \beta_k X_k$$
<sup>(2)</sup>

As *Z* approaches infinity  $e^{-Z}$  goes to 0 and f(Z) approaches its upper boundary of 1. Conversely as *Z* approaches minus infinity  $e^{-Z}$  goes to 1 and f(Z) approaches its lower boundary of 0.

This report follows the adoption literature but given this report's underlying assumption that the survey responses are ordered categorically an ordered logit model is employed. The ordered logit model is a straightforward extension of the baseline logistic model described above and is primarily used when the response has multiple categories that are ordered<sup>5</sup> (Greene *et al.*, 2003).

Unfortunately the estimated coefficients of the function Z do not have any direct intuitive interpretation. However by taking their exponentiation the coefficients then describe proportional odds ratios, which describe the marginal effect of the explanatory variables on the probability of answering with a certain response. If k is the level of the response variable, odds ratios are constructed by comparing the observations which are in groups greater than k against those which are in groups less than or equal to k. The interpretation of the relevant coefficient would therefore be that for a one unit change in the explanatory variable, the odds for cases in a

<sup>&</sup>lt;sup>5</sup> If we drop the assumption of ordered or ranked responses and estimate the model with a multinomial logit the observed change in results in negligible.

group that is greater than k versus less than or equal to k are the proportional odds times larger.<sup>6</sup>

The ordered logit model is first estimated including all three of the property characteristics as explanatory variables, this is the null model. Once estimate t-tests are then performed to determine the statistical significance of the model's estimated coefficients. A statistically significant estimated coefficient indicates a relationship exists between the property characteristic tested and the management practice in focus. For those estimated coefficients that are insignificant Likelihood Ratio and Wald tests are then performed. This is done to assess if insignificant variables can be omitted from the null model to improve the overall fit of the model. Given the similarity of the two tests only the Likelihood Ratio test is described below with the results reported in detail later.

The likelihood ratio test, described by equation 3 is obtained by first regressing the null model and computing its respective likelihood statistic. The previously insignificant variables are then omitted from the null model to make the restricted model. The restricted model is also regressed and its likelihood statistic obtained. A ratio of the two likelihood statistics is formed and the log is taken to form the test statistic.

$$LR = -2\ln\left(\frac{\text{null model likelihood}}{\text{restricted model likelihood}}\right)$$
(3)

The null hypothesis for the likelihood ratio test is that the restricted model is the "true" model against an alternative that it is the null model that is in fact "true". In order to test the null hypothesis the computed likelihood ratio test statistic compared to the relevant critical values for a given significance level. The resulting test statistic is distributed chi-squared, with degrees of freedom equal to the number of parameters that are constrained. Once the true model is established predicted probabilities are then estimated and discussed.

<sup>&</sup>lt;sup>6</sup> See <u>http://www.ats.ucla.edu/stat/mult\_pkg/faq/general/odds\_ratio.htm</u> for more detail on how to interpret logit odd ratios.

# **Preliminary Analysis Results**

The results from the preliminary analysis are grouped by property characteristic and discussed below. Here the relationship between the variables representing the management practices and property characteristics are analysed through the use of scatter-plots and correlation statistics.

## **Property Size**

Figure 13 describes the results from the estimated polyserial correlation coefficients which describe the relationship between **Insize** and the individual survey responses Figure 14 visually displays six scatter-plots in individual panels where the individual panels graph the respective survey response against **Insize**.

Correlation with log of farm size												
Management Practice Issue	Estimated Statistic	Estimated Standard Error										
Average Carrying Capacity (Q8)	0.23895495	0.11125524										
Frontage Control (Q11)	0.20306356	0.11947406										
Age and Size of Cattle (Q12a)	0.05876275	0.1485375										
Stocking Rates (Q14)	0.04077994	0.13590933										
End of Season Cover (Q15)	-0.02381499	0.11678891										
Declining Land Strategy (Q24)	0.03083502	0.12291028										

Figure 13	. Polyserial	Correlation	Estimates:	Survey	responses	against	Log of	Property	Size
i iguio io	. i oiyoonan	oonolation	Eotimatoo.	<b>Gai 10</b>	rooponooo	agamot	-09 0.	roporty	0120

Of the six investigated relationships, none appear to exhibit a strong visual relationship with the size of a property. This result is substantiated by the estimated polyserial correlation coefficients all of which are very close to zero, indicating neither a overt positive or negative correlation. However the estimated coefficients for questions 8 (0.24) and 11 (0.20) are significantly larger (between 4 and 7 times larger) than the other four relationships, indicating that they are likely the strongest of

candidates for a significant relationship between the log of property size and the survey responses.



Figure 14. Scatter Plots: Survey responses against Log of Property Size

## **Experience of the Property Operator**

Figure 15 displays six scatter-plots in individual panels where the individual panels graph the respective survey response against **Inowner**. Figure 16 describes the results from the estimated polyserial correlation coefficients which describe the relationship between **Inowner** and the individual survey responses.



Figure 15. Scatter Plots: Survey responses against Log of Experience

Correlation with log of experience													
Management Practice	Estimated Statistic	Estimated Standard											
Issue		Error											
Average Carrying Capacity (Q8)	0.04097761	0.12884095											
Frontage Control (Q11)	-0.04632223	0.13274563											
Age and Size of Cattle (Q12a)	0.12338848	0.12430016											
Stocking Rates (Q14)	0.34058858	0.10972359											
End of Season Cover (Q15)	-0.01272801	0.12534847											
Declining Land Strategy (Q24)	-0.02747282	0.1227325											

Figure 16. Polyserial Correlation Estimates: Survey responses against Log of Experience

Of the six investigated relationships, only one appears to exhibit a strong visual relationship with the length of property ownership. Responses to Question 14 appear to be visually correlated with the length of property ownership, and this appears to be driven primarily by the increasing frequency of response 3 as the length of property ownership increases. The relative strength of this relationship is supported by a comparatively strong coefficient of polyserial correlation (0.34). Again in terms of absolute magnitude all of the polyserial values presented in Figure 10 are relatively small. However the value corresponding to question 14 coupled with its apparent visual relationship indicates the possibility of a significant relationship with the log of length of property ownership.

## **Business Structure**

Figure 18 describes the results from correlation tests examining relationship between individual survey responses and the respective property's business structure. Figure 17 displays six scatter-plots in individual panels where the size of the individual points reflects the frequency of occurrence.

The visual representation of the relationship between the structure of a property's business and its responses to the management practice questions reveals very little. This apparent lack of relationship is reinforced by the results from the estimated

correlation statistics. For all six survey responses the p-values of both the Pearson's Chi-square and Fisher's exact tests are relatively large, with the smallest (0.477) estimated from Pearson's Chi-square test of question 8 responses. All of the estimated p-values are significantly larger than the 10 per cent significance level critical value of 0.10. As such the null hypothesis that the row variable is independent of the column variable cannot be rejected at any reasonable level of significance. Each of the six questions responses must therefore be concluded to be independent of a property's business structure.

Figure 17. Pearson's and Fisher's Exact tests: Survey responses against Business Structure Ouestion 11 Ouestion 8

		~~	COULOIL	0.			× – – – – – – – – – – – – – – – – – – –	a control			
q66 What best describes the structure of your business?	q8 What do yo 1	u base you capacity 2	r average ca on? 3	rrying 4	Total	q66 What best describes the structure of your business?	q11 What cont river and c 1	rol do you zreek front 2	have of graz ages and wet 3	ing on land 4	Total
1 2 3 4	9 13 6 2	3 9 7 3	2 14 4 1	1 7 4 1	15 43 21 7	1 2 3 4	3 9 4 0	3 6 5 2	1 6 5 2	5 11 8 1	12 32 22 5
Total Pe	30 arson chi2(9) = 'isher's exact =	22 8.5841	21 Pr = 0.477 0.544	13	86	Total	16 earson chi2(9) =	16 = 5.1341	14 Pr = 0.822	25	71
							Fisher's exact =	=	0.861		

#### Question 12a

Question 14

q66 What best describes the structure of your	q12a How do y and size of	ou account your cattl	for differen e when assess	t age ing		q14 How do you manage stocking rates?	q66 What best 1	: describes your bus in 2	the structure ess? 3	≥ of 4	Total
business? 1 2 3 4	1 1 2 0 1	2 7 13 10 3	3 1 10 6 1	4	Total 10 31 18 7	1 2 3 4	0 2 12 0	2 6 32 3	2 2 19 0	0 0 6 1	4 10 69 4
Total Pe	4 earson chi2(9) = fisher's exact =	33 6.9034	18 Pr = 0.647 0.586	11	66	Total Pe F	14 earson chi2(9) = Tisher's exact =	43 : 7.0177	23 Pr = 0.635 0.756	7	87

Question 15.

q66 What best describes the structure of your business?

	q15 How do you	manage en cover?	d of season	ground		q66 What best describes the structure of your	q24 What graz to better ma	ing strate intain are	gies do you en as of land th:	nploy at	
,	1	2	3	4	Total	business?	1	2	3	4	Total
2	0 3 2 0	9 13 8 2	4 21 10 4	2 6 3 1	15 43 23 7	1 2 3 4	3 3 2 1	1 3 4 0	7 20 8 3	3 11 8 3	14 37 22 7
	5	32	39	12	88	Total	9	8	38	25	80
P (	arson chi2(9) = 'isher's exact =	6.1548	Pr = 0.724 0.780			Pe	arson chi2(9) = 'isher's exact =	6.0865	Pr = 0.731 0.760		

Question 24



Figure 18. Scatter Plot: Survey responses against Business Structure

The results from the correlation analysis conducted here indicate that none of the survey responses have a strong relationship with any of the grazier and property characteristic variables investigated. The majority of estimated correlations lie between +/- 0.05, indicating that on average there is very low correlation between any two of the variables. The strongest relationship appears to be between the variable **stockingrates** (responses to q14) and **Inowner** (log of ownership length), with an estimated correlation of 0.341. **avcarrycapacity** (responses to q8) and **Insize** (log of property size) has the next highest correlation with 0.239 and then

followed by **frontagecontrol** (responses to q11) and **Insize**, with an estimated polyseries correlation of 0.203. While none of these three correlations can be described as strong, the next section of this report investigates them further in order to robustly test the strength of the possible relationships.

## **Regression Analysis**

At best the results from the preliminary analysis conducted in the previous section finds very little evidence of significant correlations between any of the combinations of variables examined. However a case could be made for the possible existence of significant relationships between the following three variable pairs:

- Length of Experience (and to a lesser extent property size) and responses to Question 14.
- Property Size and responses to Question 8.
- Property Size and responses to Question 11.

In the following three parts of this section the above three relationships are individually investigated in order to robustly test the strength of these possible relationships. Results from the logistic regressions of the three individual management practices against the full set of property characteristics are reported. As are t-tests which are performed to establish the statistical significance of the explanatory variables' estimated coefficients. Likelihood Ratio and Wald tests are also performed to test the overall fit of the models and predicted probabilities are estimated and discussed

## Length of Property Ownership and responses to Question 14

In order to determine the significance of a relationship between property ownership length and how that property manages its stocking rates, question 14 responses were first regressed against all three demographic variables using an ordered logit model, the output of which is displayed below in Figure 19.

Figure 19. Estimated Question 14 ordered logit model

. ologit stock	ingrates lnsi	ze businesss	structure	lnowner			
Iteration 0: log likelihood = -62.264452 Iteration 1: log likelihood = -58.975207 Iteration 2: log likelihood = -58.792159 Iteration 3: log likelihood = -58.791516 Iteration 4: log likelihood = -58.791516							
Ordered logist	ic regressior	ı		Numbe LR ch	r of obs	= =	87 6.95
		_		Prob	> chi2	=	0.0736
Log likelihood	1 = -58.791516	; 		Pseud	o R2	=	0.0558
stockingra~s	Coef.	Std. Err.	z	P> z	[95% C	onf.	Interval]
lnsize	.0342708	.2687313	0.13	0.899	49243	29	. 5609745
businessst~e	.1819707	.3375397	0.54	0.590	47959	49	.8435362
lnowner	.5638654	.226231	2.49	0.013	.12046	08	1.00727
/cut1	8432941	2.73379			-6.2014	25	4.514836
/cut2	.6082039	2.7036			-4.6907	55	5.907163
/cut3	5.654343	2.815187			.13667	86	11.17201

The estimated model can therefore be written as:

$$\log \frac{\hat{p}_i}{1 - \hat{p}_i} = 0.0342708 \text{ Insize} + 0.1819707 \text{ business structure} + 0.5638654 \text{ Inowner}$$
(4)

Exponentiating both sides of equation 4 transforms the equation into proportional odds ratios which can be more readily interpreted.

$$\frac{\hat{p}_i}{1-\hat{p}_i} = \exp(0.0342708 \text{lnsize}) \cdot \exp(0.1819707 \text{businessstructure}) \cdot \dots$$
$$\dots \cdot \exp(0.5638654 \text{lnowner})$$
(5)

A one unit change in the explanatory variable **Insize** increases the proportional odds ratio by a multiplicative factor of exp(0.342708) or 1.0349, all else held constant. Thus for a one unit increase in the **Insize** there would be a 3.5 per cent chance of responding with a higher ordered response or a better classed management practice. Likewise a one unit increase in **Inowner** implies a 76 per cent chance of responding with a higher ordered response. While a one unit increase in the **businessstructure** yields a 20 per cent chance of responding with a higher ordered responding with a higher ordered respondence.

Performing standard t-ratio test on the estimated coefficients of the ordered logit model shows that of the three explanatory variables only **Inowner** is statistically significant. **Inowner's** estimated t-statistic of 2.49 has a corresponding p-value of 0.013, much smaller than the 5% significance level critical value of 0.05. While the p-values for **Insize** and **businessstructure** (0.899 and 0.59 respectively) are much larger than any reasonable significance level's critical value. These results indicate that the length a property has been under the same ownership may indeed affect how a grazier manages their stocking rates. However it also appears unlikely that

the size of a property or how a property's business is structured significantly affects how stocking rates are managed.

Nested model specification tests are now performed on the ordered logit model described in equation 4. Each of the individual variables are omitted in turn and Likelihood Ratio and Wald tests are performed to investigate whether the overall specification of the model improves. Given the insignificance from the t-ratio tests of the variables **businessstructure** and **Insize** their omission should improve the model, while omitting the significant variable **Inowner** will likely worsen the model's specification.

Figure 20 describes the respective likelihood ratio test statistics and respective p-values from the three individual tests. When **businessstructure** and **Insize** are individually omitted from the null model (equation 4) Likelihood Ratio tests yield p-values of 0.5890 and 0.8985 respectively. Both of these values far greater than the 5 per cent significance level critical value of 0.05, as such the null hypothesis that the restricted model is the true model cannot be rejected in either case. Consequently the specification of the null model might be improved by dropping either **businessstructure** or **Insize**. Omitting **Inowner** from the null model results in a p-value from the likelihood ratio test of 0.0110. This is significantly smaller than the critical value of 0.05 indicating that the specification of the null model is not improved by omitting **Inowner**.

Omitted Variable	Likeliho	od Ratio Test	Wald Test		
	Chi2	p-value	Chi2	p-value	
log of experience	6.46	0.011	6.21	0.0127	
log of property size	0.02	0.8985	0.02	0.8985	
business structure	0.26	0.589	0.02	0.5898	

#### Figure 20. Likelihood ratio and Wald tests of variable significance

The tests performed above indicate that **businessstructure** and **Insize** are statistically insignificant in determining how graziers manage their stocking rates, while **Inowner** is in fact the only statistically significant variable. Lastly the likelihood ratio and Wald tests are again performed this time testing the significance of a

restricted model that has both **businessstructure** and **Insize** omitted from the null model.

The restricted ordered logit model is estimated and the output for the described regression is displayed below in Figure 21. Again **Inowner** is statistically significant with a t-ratio test statistic of 2.52 and a corresponding p-value 0.012. The estimated coefficient for **Inowner** is relatively unchanged at 0.5674506 which corresponds to a proportional odds ratio of 1.7637. This can be interpreted as given a one unit increase in **Inowner** there is a 76 per cent chance of the grazier answering with a higher ordered response.

. ologit stockingrates Inowner Iteration 0: log likelihood = -62.264452 Iteration 1: log likelihood = -59.125815 Iteration 2: log likelihood = -58.958403 Iteration 3: log likelihood = -58.957931 Ordered logistic regression Number of obs = 8 LR chi2(1) = 6.6 Prob > chi2 = 0.013 stockingra-s Coef. Std. Err. z P> z  [95% Conf. Interval Inowner .5674506 .2250672 2.52 0.012 .1263269 1.00857 /cut1 -1.566136 .73612 -3.008905123367 /cut3 4.905154 .9420994 3.058673 6.75163									
Iteration 0: log likelihood = -62.264452 Iteration 1: log likelihood = -59.125815 Iteration 3: log likelihood = -58.957931 Iteration 4: log likelihood = -58.957931 Ordered logistic regression Log likelihood = -58.957931 Stockingra~s Coef. Std. Err. z P> z  [95% conf. Interval Inowner .5674506 .2250672 2.52 0.012 .1263269 1.00857 /cut1 -1.566136 .73612 -3.008905123367 /cut21134083 .633983 -1.355979 1.20917 /cut3 4.905154 .9420994 3.058679 3.7518	. ologit stockingrates lnowner								
Ordered logistic regression         Number of obs = 8 LR chi2(1) = 6.6 Prob > chi2 = 0.010 Pseudo R2 = 0.053           tog likelihood = -58.957931         Prob > chi2 = 0.010 Pseudo R2 = 0.053           stockingra~s         Coef. Std. Err. z         P> z          [95% Conf. Interval]           Inowner         .5674506         .2250672         2.52         0.012         .1263269         1.00857           /cut1         -1.566136         .73612         -3.008905        123367           /cut2        1134083         .633983         -1.355992         1.12917           /cut3         4.905154         .942094         3.058673         6.75163	Iteration 0: Iteration 1: Iteration 2: Iteration 3: Iteration 4:	log likeliho log likeliho log likeliho log likeliho log likeliho							
stockingra~s         Coef.         Std.         Err.         z         P> z          [95% Conf.         Interval           Inowner         .5674506         .2250672         2.52         0.012         .1263269         1.00857           /cut1         -1.566136         .73612         -3.008905        123367           /cut2        1134083         .633983         -1.355992         1.12917           /cut3         4.905154         .9420994         3.058673         6.75163	Ordered logist Log likelihood	Ordered logistic regression Log likelihood = -58.957931					= = =	87 6.61 0.0101 0.0531	
Inowner         .5674506         .2250672         2.52         0.012         .1263269         1.00857           /cut1         -1.566136         .73612         -3.008905        123367           /cut2        1134083         .6339833         -1.355992         1.12917           /cut3         4.905154         .9420994         3.058675         6.75163	stockingra~s	Coef.	Std. Err.	z	P>   z	[95% C	onf.	Interval]	
/cut1 -1.566136 .73612 -3.008905123367 /cut21134083 .633983 -1.355992 1.12917 /cut3 4.9905154 .9420994 3.058673 6.75163	lnowner	.5674506	.2250672	2.52	0.012	.12632	69	1.008574	
	/cut1 /cut2 /cut3	-1.566136 1134083 4.905154	.73612 .633983 .9420994			-3.0089 -1.3559 3.0586	05 92 73	1233679 1.129176 6.751635	

Figure 21. Estimated Restricted Ordered Logit Model Question 14

Likelihood-ratio and Wald tests are then performed to investigate if the overall fit of the null model is improved by omitting both **businessstructure** and **Insize** simultaneously.

#### Figure 22. Restricted Ordered Logit Model Tests

Omitted Variables	Likelihoo	d Ratio Test	Wald Test		
Omitted Variables	Chi2	p-value	Chi2	p-value	
log of property size					
and	0.33	0.8467	0.33	0.8472	
business structure					

Simultaneously omitting both the **businessstructure** and **Insize** results in a likelihood ratio p-value of 0.8467, a result which indicates the null hypothesis cannot be rejected. Consequently the specification of the null model is improved with the omission of **Insize** and **businessstructure**. This result can be interpreted as

confirmation that there is significant evidence that how a grazier manages its stocking rates is affected by how long a property is under the same ownership.

The probability of a particular response occurring can then be predicted from the single explanatory variable version of the restricted model, the results of which are graphed below in figure 23. Each case is estimated as a binary outcome where 1 represents graziers selecting that specific response, while 0 indicates answering with any other response.





For responses 1, 2 and 4 the probability of occurrence is very low for all values of **Inowner**. As length of ownership increases the probability of response 1 or 2 being selected decreases to virtually zero, while the probability of response 4 occurring increases but only slightly in terms of magnitude. The probability of response 3 occurring however is relatively high for all lengths of ownership and increases as **Inowner** increases.

While the above regression and predictions are both clear and neat, regressing a

dependent variable against a single explanatory variable is often unadvisable. This is particularly true in the case of adoption based analysis. Performing univariate analysis subjects the model to the possibility of omitted variable bias and furthermore omitting potential explanatory variables such as **Insize** and **businessstructure** will fail to capture important information that might drive respondents' answers despite their apparent insignificance (Vanclay 1987, Pannell *et al* 2006).

Given the serious problems associated with univariate analysis, the original null model is again regressed and the relative predicted probabilities are estimated and discussed in detail below. As Figure 24 shows, the inclusion of **Insize** and **businessstructure** retains the overall shape and predictions of the restricted model produced in figure 23. However there is a greater degree of variability within each of the predicted response probabilities driven by the inclusion of **Insize** and **businessstructure**.



Figure 24 Unrestricted model predicted probabilities against Business Experience

The probability of response 1 occurring from the unrestricted model appears relatively unchanged when compared to the predicted probability from the restricted

model, with the steady decline observed in the single explanatory variable regression still prominent. The probability of response 2 occurring now appears slightly greater for all levels of **Inowner** when comparing the results from both models. While there appears to be a noticeable increase in the probability of response 3 occurring at lower levels of **Inowner** the gradient of response 3's predicted probabilities is noticeably flatter. The probability of response 4 occurring increases as **Inowner** increases in much the same manner as in the restricted model, however the magnitude of the increase is slightly smaller.





The size of a property has almost no effect on the probability of occurrence for each of question 14's individual responses; this is particularly true for responses 1 and 4. Both response 2 and 3 exhibit a relatively high degree of variability; however on average both appear relatively inert to changes in **Insize**.

Comparing the responses to question 14 across the four business structure types, the probability of responses 1, 2 and 4 occurring is relatively low regardless of business structure, while response 3 is clearly the most likely of responses to occur

across the four types of business structure. However responses 2 and 3 exhibit a far greater degree of variability in probability of occurrence across the four business structure types than that of responses 1 or 4.



Figure 26. Unrestricted model predicted probabilities against Business Structure

The evidence suggests that property's management of its stocking rates has a statistically significant relationship with the length of time a property has been under its current ownership. However the size of that particular property and how its business is structured does not have a significant affect. Based on the estimated predicted probabilities properties which have been under their current owner for only a short period of time are equally likely to manage its stocking rates using "*long term experience*" or any other method. As property ownership length increase the evidence suggests that graziers tend to rely even more heavily on their own experience in determining long term stocking rates.

### **Property Size and responses to Question 8**

In order to determine the significance of a relationship between the size of a property and what a property bases its average carrying capacity on, question 8 responses were regressed against all three demographic variables. An ordered logit model was employed and all three property characteristics were utilised as explanatory variables, the output of which is displayed below in Figure 27.

. orogit avea	Τγταρατιτή Π	ISIZE DUSTILES	SSCIUCCI	ure mowine			
Iteration 0: Iteration 1: Iteration 2: Iteration 3:	log likeliho log likeliho log likeliho log likeliho	bod = -115.7 bod = -113.1 bod = -113.09 bod = -113.09	7557 1073 9936 9936				
Ordered logist	cic regression	n		Number LR ch Prob >	of obs 2(3) ≻ chi2	; = = =	86 5.31 0.150
Log likelihood	d = -113.09930	5		Pseudo	R2	=	0.0229
Log likelihood avcarrycap~y	t = -113.09936 Coef.	Std. Err.	z	Pseudo P> z	[95%	= Conf.	0.0229 Interval
Log likelihood avcarrycap~y Insize businessst~e Inowner	Coef. .3860894 .2078876 .0715826	5 Std. Err. .1974459 .2373043 .1721919	z 1.96 0.88 0.42	Pseudo P> z  0.051 0.381 0.678	[95% 0008 2572 2659	= Conf. 3974 202 0074	0.0229 Interval .7730763 .6729954 .4090729

Figure 27. Estimated Question 8 ordered logit model

The estimated model in proportional odds ratios can be written formally as:

$$\frac{p_i}{1 - \hat{p}_i} = \exp(0.3860894 \text{lnsize}) \cdot \exp(0.2078876 \text{business structure}) \cdot \dots \\ \dots \cdot \exp(0.0715826 \text{lnowner})$$
(6)

All else held constant, the estimated equation can now be interpreted: a one unit change in **Insize** increases the proportional odds ratio by a multiplicative factor of exp(0.3860894) or 1.47122. Thus for a one unit increase in the **Insize** there would be a 47 per cent chance of responding with a higher ordered response or in other words a 47 per cent chance of employing a better classed management practice. Likewise a one unit increase in **Inowner** implies a 7 per cent chance of a grazier giving a higher ordered response. While a one unit increase in the **businessstructure** yields a 23 per cent chance of answering with a higher ordered response.

The estimated coefficients are then tested for statistical significance using t-ratio tests. Property size is the lone explanatory variable that is estimated to be statistically significant and only at the 10 per cent significance level with an estimated t-statistic of 1.96 and corresponding p-value of 0.051. The p-values for **businessstructure** and **Inowner** are significantly larger in magnitude and are estimated at 0.381 and 0.678 respectively, larger than critical values for any reasonable level of significance. These results indicate that the size of a property

may indeed affect how a grazier manages their stocking rates. However it also appears unlikely that the length of property ownership or how a property's business is structured significantly affects what a property bases its average carrying capacity on.

Nested model specification tests are now performed on the ordered logit model described in equation 6. Each of the individual variables are omitted in turn and Likelihood Ratio and Wald tests are used to investigate whether the overall specification of the model improves. Given the insignificance from the t-ratio tests of the variables **businessstructure** and **Inowner** their omission should improve the model, while omitting the significant variable **Insize** will likely worsen the model's specification. The results from the tests are described below in Figure 28.

#### Figure 28. Unrestricted multinomial logit model tests

Omitted Variable	Likeliho	od Ratio Test	Wald Test		
	Chi2	p-value	Chi2	p-value	
log of experience	0.07	0.6772	0.17	0.6776	
log of property size	3.92	0.0476	3.82	0.0505	
business structure	0.77	0.3798	0.77	0.3810	

When **businessstructure** and **Inowner** are individually omitted from the null model (equation 6) Likelihood Ratio tests yield p-values of 0.3798 and 0.6772 respectively. Both of these values far greater than the 5 per cent significance level critical value of 0.05, as such the null hypothesis that the restricted model is the true model cannot be rejected in either case. Consequently the specification of the null model might be improved by dropping either **businessstructure** or **Inowner**. Omitting **Insize** from the null model results in a p-value from the likelihood ratio test of 0.0476 which is less than the 5 per cent critical value of 0.05, this indicates that the specification of the null model is not improved by omitting **Insize**.

The likelihood ratio test is again performed this time testing the statistical significance of omitting both **businessstructure** and **Insize** from the null model described in equation 6. Figure 29 describes the results from the restricted ordered logit model

which regresses responses to question 8 solely against **Insize** and the subsequent likelihood ratio test.

Omitted Variables	Likelihood	d Ratio Test	Wald Test		
Omitted Variables	Chi2	p-value	Chi2	p-value	
log of property size					
and	1.00	0.6056	1.00	0.6075	
business structure					

### Figure 29. Restricted Question 8 ordered logit and LR test.

Simultaneously omitting both the **businessstructure** and **Inowner** results in a likelihood ratio p-value of 0.6056, a result which indicates the null hypothesis cannot be rejected. Consequently the specification of the null model is improved with the omission of **Inowner** and **businessstructure**. This result can be interpreted as confirmation that there is significant evidence that what a grazier bases their average carrying capacity on is affected by the size of their property.

Predicted probabilities for each of question 8's responses produced by the restricted ordered logit model can be estimated and are displayed below in figure 30. Univariate analysis again produces very smooth and neat predicted probabilities.

Figure 30. Predicted probabilities of Restricted model Question 14



There are clear trends in each of the predicted probabilities. As property size increases response 1 observes the biggest change in probability, with a large decrease from around 60 per cent at low property sizes to less than 20 per cent at the highest property sizes. While the probability of responses 3 and 4 occurring increases from very low to moderately low, as property size increases. The probability of response 2 occurring has a slight inverted U-shape but overall the can be considered relatively constant at 20 per cent across all property sizes.

Given the previous mentioned reservations with univariate regression the remaining independent variables variable are once again included. The ordered logit model is again estimated and predicted probabilities are estimated and displayed below in figures 31 to 33.

Figure 31. Predicted probabilities of unrestricted model Question 14



As figure 31 describes, including the initially insignificant variables **Inowner** and **businessstructure** keeps the overall shape and probability levels of the restricted model but includes greater variability into the predictions. In fact for each of the individual responses and with the exception of greater variability, the probability of occurring appears relatively unchanged when graphed against **Insize**.

# Figure 32. Predicted probabilities of Unrestricted model Question 14 against Business Experience



When graphed against **Inowner** the average probability of occurrence for all four responses appear to be relatively inert to changes in **Inowner**. The probability of response 1 exhibits the most variation, while response 2 is the least variant. In summary the length of ownership of a property appears to have little to no effect on the magnitude of the probability of any of the individual responses occurring, but may contribute some variability.

Figure 33. Predicted probabilities of Unrestricted model Question 14 against Business Structure



When graphed against **businessstructure** again response 2 appears to be inert its changes. Responses 3 and 4 both appear to have a low probability of occurring for all types of business structure with roughly similar variances. The probability of response 1 occurring has the largest variances across all business structures and the predicted probabilities appear to decrease as **businessstructure** moves from responses 1 to 4.

The evidence suggests that what a property bases its average carrying capacity on has a statistically significant relationship with the size of that particular property. However the length of time a property has been under its current ownership and how its business is structured does not have a significant affect. Based on the estimated predicted probabilities properties smaller in size are more likely to employ "historical experience and/or anecdotal advice not document" in determining how to base their average carrying capacity. As property sizes increase reliance on this method decreases and properties become more likely to use "objective measure of safe stocking rate calculations" or "Documented records, including property map and safe stocking rate calculations based on land type, property infrastructure and objective assessments of land condition". Interestingly the proportion of respondents who use

"Long term stock and stocking rate records documented in diaries, paddock records etc" is constant across all property sizes, ownership lengths and business structures.

## **Property Size and Responses to Question 11.**

The last relationship to be examined is between the size of a property and the graziers' control of grazing on river and creek frontages as well as wetland areas. In order to determine the significance of this relationship responses to question 11 are regressed against all three characteristic variables in an ordered logit model, the output of which is displayed below in figure 34.

Figure 34. Unrestricted ordered logit Question 11

. * Business S . ologit front	Structure, Pro tagecontrol li	operty Size a nsize busine	and Ownei ssstructi	r Length ure lnown	er		
Iteration 0: Iteration 1: Iteration 2: Iteration 3:	log likeliho log likeliho log likeliho log likeliho log likeliho	<pre>bod = -96.50 bod = -95.11 bod = -95.11 bod = -95.11</pre>	8734 1497 3274 3274				
Ordered logist	tic regression	ı		Numbe LR ch	r of obs i2(3)	= =	71 2.79
Log likelihood	d = -95.113274	1		Prob Pseud	> CH12 0 R2	=	0.0145
frontageco~1	Coef.	Std. Err.	z	P> z	[95% c	onf.	Interval]
lnsize businessst~e lnowner	.3520031 .0431958 064486	.2242154 .2557465 .1812707	1.57 0.17 -0.36	0.116 0.866 0.722	08745 45805 419	09 82 77	.7914572 .5444497 .2907981

The estimated model in proportional odds ratios can be written formally as:

$$\frac{\hat{p}_i}{1-\hat{p}_i} = \exp(0.3520031 \text{nsize}) \exp(0.0431958 \text{businessstructure}) \bullet \dots$$
$$\dots \bullet \exp(-0.064486 \text{lnowner})$$

All else being held constant, the estimated equation can now be interpreted: a one unit change in **Insize** increases the proportional odds ratio by a multiplicative factor of exp(0.3520031) or 1.42191. Thus for a one unit increase in the **Insize** there would be a 42 per cent chance of responding with a higher ordered response or in other words a 42 per cent chance of employing a better classed management practice. Likewise a one unit increase in **Inowner** implies a 4 per cent chance of a grazier giving a higher ordered response. While a one unit increase in the

(7)

**businessstructure** yields a 6 per cent chance of answering with a lower ordered response.

The estimated coefficients are then tested for statistical significance using t-ratio tests. In this case none of the explanatory variables appear to be significant at the 10 per cent level. This result indicates it is unlikely that a property's size, its length of ownership or how its business is structured significantly affects the property's control of grazing on river and creek frontages as well as wetland areas.

Nested model specification tests are now performed on the ordered logit model described in equation 7. Each of the individual variables are omitted in turn and Likelihood Ratio and Wald tests are used to investigate whether the overall specification of the model improves. The results from the tests are described below in figure 35. In all three cases the null hypothesis can not be rejected. This result indicates each of the individual coefficients are not significantly different from zero and as such the specification of the model is improved by omitting any one of the explanatory variables.

Omitted Variable	Likeliho	ood Ratio Test	Wald Test		
	Chi2	p-value	Chi2	p-value	
log of experience	0.13	0.7216	0.13	0.7220	
log of property size	2.52	0.1124	2.46	0.1164	
business structure	0.03	0.8659	0.03	0.8659	

Figure 35. Question 11 Unrestricted model likelihood ratio tests

The evidence therefore suggests that neither the size of a property, the length of its ownership or how its businesses is structured affects how graziers respond to question 11. The implication here is that none of the explanatory variables in this analysis performs well in explaining how a property controls grazing on river and creek frontages as well as wetland areas. Despite the lack of statistical significance for any of the explanatory variables the predicted probabilities are still able to be estimated and are discussed below in figures 36 to 38.

#### Figure 36. Predicted Probabilities against Property Size



Property size appears to affect the probability of occurrence with trends of varying strength visible across each of the responses. As property size increases the probability of response 1 decreases, from around 40 per cent to around 10 per cent. The probability of response 2 occurring decreases very slightly as property size increases, while the probability of response 3 occurring rises equally as slightly. Lastly the probability of response 4 occurring increases as property size decreases.

In contrast the length of ownership does not appear to affect the probability of a response to question 11. The probability of responses 2 and 3 occurring appear to be particularly inert to changes in length of ownership, while the probabilities of responses 1 and 4 exhibit greater variance. However the average probability of responses 1 and 4 also appear relatively constant across the range of ownership lengths.

#### Figure 37. Predicted Probabilities against Business Experience



Figure 38. Predicted Probabilities against Business Structure



The different types of business structure also appears to exhibit little affect on the individual probability of a responses occurring. Specifically the probability of

responses 2 and 3 occurring is low regardless of business structure, and both have very little variance. While responses 1 and 4 also have a reasonably low average probability of occurrence they are associated with a much greater degree of variability.

In summary the evidence suggests how a property controls grazing on river and creek frontages as well as wetland areas is not significant affected by any of the explanatory variables included in this analysis. Of particular note is the failure of the analysis conducted here to detect a strong and robust relationship with the size of a property. Of the three correlations identified in the preliminary analysis as having potentially significant relationship this was the weakest. When compared with all the considered relationship the correlation between how a property controls grazing on river and creek frontages as well as wetland areas and property size was relatively strong. It therefore seems unlikely that any analysis of the remaining relationships would yield statistically significant results.

## **Discussion and Conclusions**

This report aimed to further inform the characteristics for adoption and therefore allow the development of an improved extension strategy for water quality improvements from grazing lands. Using correlation analysis and logistic regression techniques, this research analysed graziers' responses and investigated whether there were any significant relationships between graziers' and their management practices.

This paper chose key demographic information and management practices and performed an initial broad analysis. Unfortunately at best there was only weak evidence pointing towards some significant correlations between some of the variables. In order to robustly test the possible relationships the strongest of those initially analysed were investigated further, with logistic regression and model specification tests performed. Statistically significant relationships were discovered in both multivariate and univariate analyses. However none of these relationships could be described as robust and given the problems associated with performing univariate analysis, the results obtained are ultimately best described as incomplete.

This research highlights the complexity of increasing adoption over a short time period and to achieve water quality improvements. The literature highlights the general principles to be followed to assist in the promotion of natural resource management (Vanclay 2004, Pannell 2011). This research was unable to find any strongly significant and robust relationships in the analysis of grazier's management practices in the Fitzroy and Burdekin catchments. While this result was surprising, it is consistent with a large subset of the relevant literature. The Grazing Management Adoption survey, the results of which this paper analysed, was designed specifically to meet action 5 of the Reef Plan: "*to report annually by industry sector on the uptake of improved land management practices*" (Queensland. 2009). Ultimately the survey successfully delivers action 5 in providing a clear picture of who has adopted what grazing management practices. However if the questions of: "When?", "Where?", "How?" and most importantly: "Why management practices are adopted?" are to be answered, significant changes are need to the structure and content of DAFF's Grazing Management Adoption Survey.

There are three main ways in which the analysis could be improved on in the future. Firstly, while the analysis conducted in this paper approaches the problem using multivariate analysis, it includes a maximum of three explanatory variables: Business Structure, Property Size and Business Experience. The results are therefore based on only a small subset of explanatory variables, significantly less than the possibly significant variables presented in Appendix 1 (Lindner 1987).

Secondly, much of the relevant literature employs the use of a binary dependent variable which discards much of the potentially available information, thereby reducing the power of any statistical tests (Lindner 1987). The survey responses employed in this paper's analysis effectively include four degrees of adoption; as such the tests performed in this paper are consequently less likely to suffer from low power. However it should be noted that there is significant scope for improvement in regards to information about the rate, timing and interest in adoption.

A lack of significance attributed to the dynamic learning process underpinning adoption has also attracted much criticism in the literature. Ignorance of the dynamic

learning processes underway paints an incomplete picture of adoption behaviour; given the differing levels of knowledge at any moment in time between landholders. This problem can be avoided, for example, by waiting until the diffusion process is complete, analysis of the adoption/rejection decision can then proceed on the basis that all producers are fully and equally informed (Lindner 1987). The analysis of this paper however does not concern frontier technologies or practices; in fact the management practices outlined in the ABCD framework were constructed in a consultative fashion with graziers and other prominent people in the industry. The argument could therefore be made that landholders are equally well informed about the individual grazing management practices and as such the diffusion process is already complete.

Finally, there exists a lack of understanding about how landholders value adoptable innovations in the empirical literature (Lindner 1987). The analysis conducted here is also subject to this criticism, because survey responses used in this paper's analysis fail in every capacity to describe how graziers' value of the individual management practices. This problem might be rectified by following O'Mara (1971) for example, who elicits subjective beliefs about an innovation's productivity, and analyses adoption decisions with respect to these subjective beliefs.

This paper recommends a number of specific changes including: A much larger and more robust array of grazier and property characteristic questions; the inclusion of questions pertaining to the rate and extent of adoption, as well as other time-framing questions; questions that elicit subjective beliefs about individual management practices; as well as general methods that increase the response rate and minimise missing data.

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# Appendix 1: Predicted probabilities by response number



**Question 14 – Stocking Rates** 









**Question 8 – Average Carrying Capacity** 









**Question 11 – Frontage Control** 





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