10-2015

Valuable Behavioural Phenotypes in Australian Farm Dogs

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Australian Government
Rural Industries Research and Development Corporation

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October 2015

RIRDC Publication No. 15/081

Australian Government

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Front cover photo credit: Lorraine Williams

October 2015

RIRDC Publication No 15/081
RIRDC Project No: PRJ-007806

ISBN 978-1-74254-827-2
ISSN 1440-6845

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Publication No. 15/081
Project No. PRJ-007806

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Electronically published by RIRDC in October 2015
Print-on-demand by Union Offset Printing, Canberra at www.rirdc.gov.au
or phone 1300 634 313

Foreword

Despite widespread acknowledgment of the important contribution the Australian livestock working dog makes to livestock industries and the rural economy, many aspects that influence dog performance and breeding and selection success have not been previously quantified. To optimise dog performance and success rates, and thus minimise so-called wastage, research is required to provide evidence-based information of direct relevance to those who breed, train, handle, work and trial livestock working dogs.

This industry collaborative project was designed to address a number of knowledge gaps. Information collected from over 800 dog owners relating to over 4000 dogs gave an overview of the livestock working dog industry.

The study revealed that dogs typically work for 5 hours a day, 5 days a week during the peak period of shearing. Dogs typically travel over 40 km per day and reach maximum speeds of 37 km per hour.

An estimation of the economic worth of the livestock working dog revealed a 5.2-fold return on investment. Putting a number value on the significant contribution of dogs to farm labour justifies focusing resources into optimising their use.

Optimising dog performance requires that we understand husbandry, training and management techniques. This research identified management factors and handler attributes that are related to the success of dogs in the workplace.

As part of this project, the pedigrees of over 80 000 Working Kelpies were collated. The research showed heritability estimates indicating that many of the traits that working dog breeders and handlers value have strongly inherited components. These estimates indicate the expected effectiveness of a selective breeding program and can be used to generate estimated breeding values. This will help breeders to better select breeding dogs and identify kennels that have similar breeding goals to their own.

The study has not only already contributed much new information about kelpies, their special qualities and how to get the best of out of them, but has also put in place a process for assessing dogs on their performance and breeding potential. This has laid a strong foundation for ongoing research and development that will continue to deliver ever more detailed information to interested parties.

This project was funded by Meat and Livestock Australia (MLA) and the Rural Industries Research and Development Corporation (RIRDC) with invaluable in-kind support from the Working Kelpie Council of Australia (WKC). The authors are grateful for the opportunity to significantly advance the knowledge of what many see as a national treasure: the Australian Working Kelpie.

This report is an addition to RIRDC's diverse range of over 2000 research publications and it forms part of our New, Developing and Maturing Animal Industries RD&E program, which aims to enhance industry success through targeted industry-specific RD&E.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

About the Authors

Professor Paul McGreevy is one of only three veterinarians recognised worldwide by the RCVS as Specialists in Veterinary Behavioural Medicine. He has written 6 books, 30 chapters and over 180 articles in peer reviewed journals. His team has recently achieved significant success in revealing the nature of canine cognition and identifying early behavioural (and morphological) traits associated with success in puppies undergoing training for guide work. He is on the expert panel of the UK's Dog Breeding Advisory Council.

Professor Claire Wade is Professor of Animal Genetics and Computational Biology. Claire is developing a programme in medical and behavioural genetics with particular focus on the horse and the dog. In recent years her canine focus has included playing key roles in the analysis leading to the Canine Genome Sequence, the development of three canine gene-mapping arrays and the mapping of several genes for canine diseases leading thus far to three commercially available genetic tests for genetic diseases. She has current projects exploring the genetics of separation-related distress disorder, aggression, deafness, congenital birth defects, and pigmentation in the dog.

Liz Arnott graduated from the University of Sydney in 2003. She began her veterinary career as a mixed animal practitioner on the mid-north coast of New South Wales. Following a year of practice in the United Kingdom, she took a veterinary position in Tamworth focusing on small animal medicine. Liz was awarded a Masters in Small Animal Practice from Murdoch University and achieved membership to the Australian College of Veterinary Scientists in 2011. Working in rural New South Wales for many years has given her a great appreciation of the working partnership between farmers and their dogs.

Jonathan Early graduated in Veterinary Science from the University of Sydney in 2005. It was during his undergraduate training that he developed a particular interest in animal behaviour and welfare. Since graduation he has worked in mixed practice in Victoria, small animal and exotics practice in Hobart, Tasmania and locumed across England. Prior to beginning his PhD in livestock working dogs, Jonathan worked in the Animal Health Policy Branch within the Australian Government Department of Agriculture, Fisheries and Forestry in Canberra. He recently attained his membership of the Australian and New Zealand College of Veterinary Scientists in Veterinary Behaviour.

Acknowledgments

This project was funded by Meat and Livestock Australia (MLA) and the Rural Industries Research and Development Corporation (RIRDC) with invaluable in-kind support from the Working Kelpie Council of Australia (WKC).

The authors would like to thank many supporters and volunteers for their assistance through this project. Julie Bird (RIRDC) and Alex Ball (Meat and Livestock Australia) have provided guidance, advice and above all leadership. The WKC kindly formed a steering committee, under the leadership of Don Robertson, which shared wisdom and experience to ensure we adopted the relevant terminology and considered traits of relevance to the industry. We also acknowledge the Working Kelpie breeders across Australia who have made us welcome and supported our endeavours. They include Scott Amon, Ken Atherton, Anthony Attard, Tim Austin, Stephen Burgun, Carl Carlon, Lance Clifford, Peter Crowe, Gordon Curtis, Peter Darmody, Cameron and Danielle Douglas, Mitch Duffy, John Gedye, Victor Hazlett, Noel Hocking, Rex and Kay Hocking, Kevin Howell, Michael Johnson, Jan Lowing, Neal Lynch, David Lyndsay, Bill Luff, Jim Marshall, Mary McCrabb, Moira McDowell, Gary Milgate, Sarah Mortimer, Kim and Michael Parish, Eric Smyth, Frank Powter, Matt Sherwood, Dale Thompson, Tony Parsons, Michael Ryan, Gary White, Nancy Withers and the Casterton Kelpie auction committee.

Barbara Cooper has been a pillar of support and we acknowledge that the current body of work would not have been possible without her. Michelle Hyde has provided invaluable editorial assistance for this report.

Other contacts from beyond the world of the Working Kelpie are also warmly thanked. They include Kerrie Challenger, Vicki Priestley, Tully Williams, Tony Mulvihill and Charlie Cover, the Australian Working Stock Dog Magazine and generous support from the Royal Agricultural Society Foundation

Contents

Tables

Figures

Executive Summary

What is the report about? What were the objectives?

This report presents findings regarding the ways to optimise the performance of livestock working dogs in Australia. The methods available to optimise dog performance include both environmental and genetic factors. The objectives of this study were to identify objective measures of desirable behavioural phenotypes in Australian livestock working dogs and explore genetic parameters of these 'quality of working life' traits within the Kelpie breed. The document reports on genotyping that reveals gene-behaviour associations and describes heritability estimates that underpin a database for potential estimated breeding value (EBV) calculations.

Who is the report targeted at?

This report is aimed at industry producers who breed, train, handle, work and trial livestock working dogs. The aim of this project was to provide information of direct relevance to livestock working dog breeders, handlers and trainers in a bid to optimise the performance and selection of livestock working dogs, and so reduce wastage rates, and increase profitability and welfare.

Background

It is widely acknowledged that livestock working dogs make a profound contribution to Australia's livestock industries and the rural economy. The working dog also holds a firm place in folklore that reflects its companionship and loyalty. Despite this, there are significant gaps in our knowledge relating to livestock working dogs. Much of the information that underpins current breeding and training decisions is only anecdotal.

Methods used / Where are the relevant industries located in Australia?

To address these knowledge gaps, the research project collected data on over 4000 dogs using The Farm Dog Survey, which gathered information from over 800 livestock working dog owners around Australia. The survey was designed to collect information relating to a wide range of livestock working dog usage and management factors, as well as characteristics of dog owners and handlers. The target audience for the survey was all livestock working dog owners and handlers in Australia. The sample survey we obtained is similar to the Australian farming population when considering several demographic characteristics such as gender, age and geographic location. The results and findings obtained are relevant to producers Australia-wide and are of sufficient quality to inform heritability estimates. Using the Working Kelpie pedigree, that represents over 80 000 dogs, we have devised methods that underpin a database for EBV calculations.

Results/key findings

A number of questions were asked via surveys and face-to-face interviews to obtain information that addresses the critical knowledge gaps. One fundamental question asked was about the type and scale of dogs' contribution to the producers' workload. The study identified the working behaviours of most value to producers and found that owners were generally good assessors of the ability of their own dogs' core attributes. Valuable information relating to how hard farm dogs work during peak periods, such as shearing was obtained. Preliminary results suggest that yard trial scores reflect important aspects of paddock performance, are useful in understanding dog's efficiency in yard work and suggest that high-scoring dogs may cause less stress to sheep.

Another fundamental question relates to the environmental factors associated with success rates of livestock working dogs. Dogs that are not successful are culled from work and breeding programs and represent costly wastage. This is not only a problem of economics but also of animal welfare. The study identified important management factors and handler attributes that influence the success of dogs

in the workplace. Significant associations were identified between success rate and seven variables: dog breed; housing method; trial participation; age of the dog at acquisition; electric collar use; hypothetical maximum treatment expenditure; and the conscientiousness score of an owner's personality. These findings serve to emphasise the impact of the handler on a dog's success in the workplace and should inform extension programs that emerge from the current project.

A major focus of the project was investigation of the genetic factors that underpin working dog success. The producer-focused collaborative research project asked how dogs can be selected and bred to produce the best dogs for the job. Addressing this challenge required identification of the traits of interest, and then measuring these traits. Livestock working dog behavioural traits encompass those traits specific to livestock work and displayed predominantly by livestock working breeds, and general personality traits evident in all breeds of dogs. To quantify these traits in Australian dogs, an assessment form was devised that facilitates collection of data on the behavioural phenotypes of large numbers of livestock working dogs. The Livestock Working (Herding) Dog Assessment Form was designed and validated for both personality and livestock working (herding) behaviour traits, using a comparison with the results of direct measures of behaviour. Beyond this project, it is anticipated the form will be of use in benchmarking dogs for breeding purposes and as a national working dog recording scheme for a genetic evaluation system.

Heritability, the expression of the extent to which relatives will resemble each other, is an important property of traits of interest to dog breeders. Heritability estimates identify potential targets for selection because they reflect the expected effectiveness of a selective breeding program. That said, genetic progress is a function of both the heritability of the trait and the variation within the trait, so variation is just as important as the heritability. However, neither heritability nor variation will have any effect unless there is selection, and the selection intensity directly affects progress. Acknowledging the necessity of selection for genetic improvement is important when considering wastage, which is a recurring theme in the current report.

This study provides encouraging preliminary evidence that important economic behaviours in livestock working dogs can be described by heritable indices. Many of these preliminary estimates are of an order that suggest that these traits may be suitable to form part of a selective breeding program for behaviour in livestock working dogs. The preliminary genotyping study also exposed differences in genomic selection signals in 'Working' and 'non-working' Kelpies. This revealed that while livestock working dog breeders may be selecting primarily for traits such as stock sense and boldness, they are actually favouring dogs that have high levels of resilience and are able to continue to work in hostile environments. The 'non-working' Kelpie is valued as a companion dog and appears to be primarily selected for body shape and structure.

The study used the results obtained from The Farm Dog Survey to estimate the costs associated with acquiring, training and maintaining livestock working dogs, and an estimate of the work they typically perform, to estimate the economic value of livestock working dogs. The study revealed that livestock working dogs typically provided their owners with a five-fold return on investment.

Implications and recommendations for relevant producers

The project has adopted a rigorous scientific approach to reveal a number of important new findings and provide the groundwork needed to provide extension work of huge benefit to livestock producers. It is recommended that the industry acknowledges the value of the traits reported here and use the indicative heritability estimates for personality and herding traits in breeding plans. Producers can use this report to assist in decision-making on selection and breeding that allows cost savings and productivity improvements, whilst also demonstrating increased social responsibility and improved animal welfare practices. The tools developed for assessing dogs and their breeding merit need to be used in light of an appreciation that handlers and husbandry techniques can compromise the potential of working dogs.

Introduction

This project was designed to provide information of direct and immediate benefit to the Australian rural livestock working dog community, including dog breeders, handlers and trainers, to improve efficiency and reduce dog wastage rates. The ultimate objectives of this study were to identify objective measures of desirable behavioural phenotypes in Australian livestock working dogs and explore genetic parameters of these 'quality of working life' traits.

The working material that the dog breeder has available to manipulate through breeding programs is the total genetic potential available. All dog behaviour, whether desirable or undesirable to owners, has a genetic component. Some behaviours, such as livestock guarding by Maremmas and flank- and blanket-sucking in Dobermans, are breed-specific. While rapid advances are being seen in identification of genes responsible for common canine diseases, the identification of the genes underlying behaviour remain elusive. This is because canine behaviours are complex traits and as such are influenced by a large number of genes as well as environmental factors. The identification of genes that underlie such traits in other species typically relies upon the availability of large cohorts of objectively scored as well as genotyped individuals. Such resources require large scale participation by stakeholders.

Breeding program manipulation takes place by careful selection of breeding animals in an attempt to increase or ‘fix’ desirable traits whilst also decreasing or removing undesirable traits. To select the best animals for breeding purposes, we must be able to assess the traits that influence working 'success' and thus minimise wastage rates. This means the provision of genotyping of dogs to show the genetic regions underlying the traits that breeders truly care about. Development of a set of markers that help us to understand the biological basis of the traits of interest to breeders allows us to understand the scientific basis of behaviour and how traits are passed from one generation to the next.

There are two ways that dogs’ genetic value can be assessed. The first is through the provision of 'estimated breeding values’ for different traits that enable the strengths of dogs from different breeding programs to be compared. The second might be through the identification of genes of major effect that influence working success. To select the best dogs for the job, there needs to be a clear pathway of communication, as well as agreed understanding, between handlers and trainers on the one hand, and breeders on the other, of what the industry favours and values in livestock working dogs. What is valued will likely differ between end-users. Understanding the value of dogs to farm labour and efficiency is also vital for improving efficiency and increasing welfare.

Conservative estimates place the number of livestock working dogs in Australia at 95 000, with a more realistic number probably being between 270 000 and 300 000. Given that a good dog is commonly recognised as doing the work of at least one person, the contribution of the Australian working dog to agricultural production is enormous. Regardless of exact number, history readily acknowledges the significant contribution of the Australian working dog to agricultural endeavour. The working dog folklore honours dogs’ workload, companionship and loyalty. Yet, despite widespread acknowledgement of the valuable role played by livestock working dogs in agricultural businesses, little is known about the factors associated with success rates in livestock working dogs. Similarly, despite the acknowledged value of the work of livestock working dogs, research has not yet applied scientific rigor to the estimation of the economic value of farm dogs.

To select the best breeding candidates for breeding programs, owners need to know how phenotype (the outward appearance and behaviour of the animal) relates to genotype (the genetic make-up of the individual). Empirical evidence is urgently required to determine a number of factors including which particular working behaviours are of most value to the stock dog community. Currently, it is not even clear whether handlers actually use the same terms to describe working behaviours, and whether these terms have widespread industry concordance in materials such as working dog manuals.

Research is needed to better understand the athletic performance of livestock working dogs during typical farm tasks. Australian livestock working dogs are known for both their mental aptitude to move and contain livestock and also their physical endurance whilst performing livestock herding and mustering tasks. A better understanding of the speed and distances required of dogs at work will assist owners and handlers when devising training and conditioning programs.

Livestock working dog handlers and breeders have strong opinions on the characteristics that are desirable in the breeds that they use to handle stock. Dogs have been bred specifically for farm work for centuries with the focus on stock working ability and hardiness. The ultimate success of a working dog is determined not only by its environmental influences such as housing, care and training, but also by its genetic make-up. Heritability is a critical property of traits of interest to dog breeders as potential targets for selection. To select the best dogs for the required job, breeders need information about genetic and environmental factors that lead to dog success.

Dogs that are not successful are culled from work and breeding programs and represent costly wastage. It is estimated that approximately 20 per cent of livestock working dogs recruited for training in Australia fail to graduate successfully. Behavioural issues are widely acknowledged to be the leading cause of performance failure of dogs across a number of working sectors. One recent study of dogs in various working contexts, including livestock production, suggests that behavioural wastage can exceed 50 per cent of dogs in training. Clearly, this is of concern from an economic and welfare perspective. There is a growing body of evidence that husbandry practices and training methods significantly influence dog learning and welfare. It appears that the relationship between dogs and handlers may be an important determinant of dog success.

Dogs that do not graduate successfully are not highly valued and may be rehomed, euthanased or face other fates. In the sustainable farming paradigm, farming practices must be socially responsible as well as economically viable to sustain productivity over time. A number of agricultural industries in Australia recently have experienced consequences related to the economics of public opinion. In addition, recent proposed changes to codes of practice that impact Australian livestock working dogs have caused controversy and disagreement among producers. Therefore, it is essential to the sustainability of the livestock working dog industry that best practice be scientifically validated.

Finally, given the large numbers of livestock working dogs in Australia and their importance to agriculture, it is surprising that that no quantification of the value of the stock handling component of their workload has yet been made. Livestock working dog ownership represents an investment in farm labour efficiency. The Australian agricultural industries function in a climate of increasing input costs, competition with subsidised international markets and variable commodity prices. To maintain profitability, producers have to invest in various methods that improve productivity. Expenditure decisions relating to the care and upkeep of livestock working dogs should be informed by an appreciation of the value of these animals. An exploration of working dog value may also have implications for farm dog welfare. As a potentially valuable resource, dogs may merit a level of care that reflects not only the level of emotional attachment of their owner, but also their economic value to the farm enterprise.

To address all these knowledge gaps, our producer-focused collaborative research project collected data on over 4000 dogs via The Farm Dog Survey, which gathered information from over 800 livestock working dog owners around Australia. The target audience for the survey was all livestock working dog users. The questionnaire was designed to explore the current canine management and training practices on Australian farms and the characteristics of the farmers who handle and breed livestock working dogs. The entire questionnaire had a maximum of 143 items divided into ten sections. Participants were asked to answer questions relating to the size and location of their main property, the numbers and types of livestock and the number of livestock working dogs used. Details were requested up to three dogs that the respondents currently most often worked. Other questions were designed to gather information relating to training methods, breeding information (if relevant) and details regarding reason for, destination of, and age at dismissal of up to three dogs that the respondent had stopped working with due to failure and due to retirement. Information was also

gathered to allow the estimation of the economic value of livestock working dogs. This required an assessment of the costs required with owning livestock working dogs and also an estimate of the work they typically perform. Respondents were also asked questions designed to reflect their general attitude towards, and perception of, their livestock working dogs.

Our study also looked at the attributes of livestock working dogs and how these terms are described. Working behaviours of most value to the livestock working dog community were identified by examining a range of livestock working dog manuals. An analysis was performed to identify whether there was agreement on the use of these terms across manuals, and, presumably, the wider working dog community. To make judgments about dog athletic ability, recordings were made of a group of dogs working during a peak period. Another group of dogs were recorded during a standardised livestock working situation and their data were combined to create a score sheet of traits. Owner assessments of their dogs (using the score sheet) were compared to expert assessment scores to determine whether owners could be reliably used to score their own dogs to gather phenotypic data. Insights were gained into not only the dog-human relationship, but also aspects of the dog-sheep relationship.

The breeding and training of successful farm dogs is a complex enterprise, not least because they are selected for at least two different contexts, namely station work and trials. Our study also looked at the breed split of Australian Kelpies into the two very different cohorts of dogs – the Australian Kelpie and the Australian Working Kelpie – to learn more about the external characteristics regarded as desirable in these two types of kelpie. Our study also collected data and examined a range of factors relating to the heritability of genetic components of dog success, with the ultimate aim of developing estimated breeding values and assessing gene behaviour associations for livestock working traits.

A particularly exciting aspect of our work is the opportunity to apply rigor and expertise at the start of a new project. Taking the correct formative steps ensures that enormous ground can be covered. Our study provides the groundwork required before we can go onto extension work.

This final report documents and discusses the hugely significant and innovative results and findings that our team has discovered in these areas. The work has already resulted in five published papers, with a further four in progress at this time. The work has already contributed much new understanding to this field, but has also put in place frameworks for ongoing research and development that will continue to deliver ever more detailed and refined information of direct benefit to livestock working dog owners, handlers, trainers and breeders, and also to the wider rural and agricultural communities.

This project report will present our research findings in producer friendly format. For ease of reading, some sections of this report have been combined within the relevant chapters section, thus individual section methodology, results, implications and recommendations will be combined in the relevant section. On advice from the RIRDC, no in-text citations appear in the current report. A suggested reading list is supplied in the References section. Our studies have already resulted in a number of published peer-reviewed articles and conference proceedings and a list of these is presented in Appendix A. A number of journal articles and other communications are also in production, and these are also listed in Appendix B.

Objectives

The first broad objective of this ambitious project was, in consultation with the producers, to identify objective measures of desirable behaviour and health phenotypes in Australian livestock working dogs and to ensure that measures ultimately chosen are practically applicable in the farm setting. The second objective was to explore genetic parameters of these 'quality of working life' traits and provide an indication of the extent of the genetic contribution to the expression of the traits such that they can be integrated into an effective breeding program.

To address these objectives, a number of specific tasks were undertaken, including:

- Producer consultation
- Exploration of current practices in dog acquisition, breeding, management and training
- Quantification of canine work-load and athletic performance
- Quantification of canine contribution to labour efficiency
- Characterisation of issues of suboptimal canine performance/longevity
- Identification of traits of value
- Establishment of a method of collection of phenotypic data that are reliable and practical
- Genotyping of Working Kelpies
- Analysis of genetic characteristics of valuable behavioural traits, and
- Estimates of heritability of valuable behavioural traits.

Methodology

The Farm Dog Survey was designed to investigate many areas of farm dog usage and management and the characteristics and views of their owners. The methodology for the farm dog survey is detailed in section 4.1.1 below. For other sections of the work presented in this report, methodology will be presented in context, in the relevant sections.

Chapters

The first segment (4.1) of the current report begins with a brief description of the Australian Farm Dog Survey (4.1.1) and then describes and discusses the background and process involved in estimating the net economic worth of the Australian livestock working dog (4.1.2). This producer consultation process generated valuable insights to the ways that farmers currently perceive the contribution, value and worth of their stock dogs.

The second segment (4.2) of the report describes and discusses environmental factors associated with success rates of Australian livestock working dogs. Current management practices associated with livestock working dogs on Australian farms and their relationship with dog success rates will be discussed (4.2.1). Also discussed are findings relating to handler attributes that relate to success rates. This section of the report also presents findings on the athletic performance of working sheepdogs in Australia (4.2.2), along with a brief evaluation of GPS units used for measuring dog performance. Our findings and observations relating to dog-livestock interactions in yard trials will then be presented (4.2.3).

The third segment (4.3) of the report deals with studies of behavioural phenotypes in large numbers of Working Kelpies, to inform breeding and genetics research. The behaviour of livestock working dogs can be evaluated in two broad contexts, namely personality (or temperament) traits and livestock working (herding) behaviours. The first part of this segment reports on a pilot study of the terminology that characterises Australian working dog manuals (4.3.1) and is followed by a review of the limitations of research into canine behavioural genetics (4.3.2). Results relating to the measurement of these traits of importance (4.3.3) then precede discussion of the formation of the Livestock Working (Herding) Dog Assessment Form (LWHDAF) (4.3.4). Responses to this form were used to identify patterns of personality (4.3.5), patterns in working manoeuvres and livestock working attributes (4.3.6) and, importantly, correlations between important traits in Working Kelpies (4.3.7). Validation of the LWHDAF for both personality traits (4.3.8) and working traits (4.3.9) is then presented and discussed.

The final segment (4.4) of the report presents findings relating to working dog breeding and genetics. Heritability of working dog traits of interest to dog breeders as potential targets for selection are discussed first (4.4.1) and then an examination of the genetic basis for selection of working ability is presented and discussed (4.4.2). This segment concludes with a discussion relating to gene mapping of specific working traits (4.4.3).

4.1. The Producer consultation process

4.1.1 The Australian Farm Dog Survey

Why was the study carried out?

The contribution of livestock working dogs to the rural economy is significant but poorly understood. Aspects relating to such commonplace statistics as the number of livestock working dogs, where they are sourced from, the work they perform, their associated training, health and maintenance issues and costs, as well as reasons and methods of dismissal are largely unknown. The Farm Dog Survey was designed to provide answers to these questions.

What was done?

The target population for the survey was all livestock working dog users in Australia. Participation was encouraged with an incentive in the form of the opportunity to win commercial working dog food in a prize draw at the end of the survey period. An introductory message gave participants the option to respond anonymously and the assurance of confidentiality if they chose to leave their details to enter the prize draw.

The Questionnaire

The online version of the Farm Dog Survey was administered for a three-month period from 10 March 2013 to 10 June 2013. All promotional materials indicated that a hard copy of the survey could be provided to participants with a reply-paid envelope if they requested one by telephone. Approval for this study was granted from the University of Sydney Human Research Ethics Committee (Approval number 15474).

A link to the online questionnaire was posted on the websites of the University of Sydney, Meat and Livestock Australia and the Working Kelpie Council of Australia (WKCA). It was advertised through stories in multiple rural newspapers, on two television programs and in two agricultural magazines with Australia-wide distributions. The committee of the 2013 Casterton Kelpie Auction (CKA, one of Australia's leading working dog auction events) promoted the survey in a mail-out to past and present vendors and purchasers. The researchers also recruited survey participants, in person, at livestock herding dog trials during the study period.

Prior to publication of the questionnaire, advice was sought from members of the Working Kelpie Council of Australia (WKCA) to ensure that the question terminology was appropriate for the target audience. A pilot distribution of the survey to 125 solicited participants led to some minor modifications prior to widespread distribution.

The online version of the Farm Dog Survey was constructed using the survey system, Qsmart (Torque Management Systems Limited, Auckland, New Zealand). The entire questionnaire had a maximum of 143 items divided into 10 sections. However, participants had fewer questions to answer if they responded in the negative to questions about certain activities, such as breeding or trialling of dogs. Furthermore, the participants had the option in three sections of the questionnaire to give details on *up to* three of their dogs. Choosing to answer these questions for one or two dogs reduced the number of questions to be answered by 28 or 56, respectively. The logic system of the online survey allowed for the routing of participants to questions of relevance. Eighteen questions were relevant to the economic value of the dogs. These are described below. For the complete questionnaire see: http://sydney.edu.au/vetscience/research/animal_behaviour/farmdog/surveys.shtml.

Respondents were asked to indicate the number of each type of livestock on their property. The answer options included six continuous categories for cattle from 'nil' to 'more than 8000' and seven categories for sheep from 'nil' to 'more than 25 000'. There was the option to describe 'other' livestock using free text.

The questionnaire required participants to report the number of dogs they currently had in work. Respondents were then asked to give details on one to three of the dogs they currently worked with most often. They were asked what type of work they mostly used each dog for. The options were 'yard (forcing)', 'mustering', 'both (all-rounder)' and 'trial only'. When asked where each dog was acquired, respondents could select from the options 'own breeding program', 'external breeder' or 'other'. In addition, if they had not bred a given dog, they were asked to state how much they paid for that dog. The options were six categories from $0 to over $5000. Respondents were requested to report, for each dog discussed, what level of training it had when acquired; from 'unstarted', 'started' or 'fully trained'. They were asked to declare the 'approximate non-routine veterinary costs for each dog in the past five years'. The four option categories ranged from $0 to more than $2000. The respondents were also asked if their dogs were insured.

The workload of the dogs was investigated by asking their owners, 'at peak times, how much time does your top dog spend working on average, each day and each week?' They could select 'less than two hours', 'two to four hours', 'four to six hours' or 'more than six hours' per day and from one to seven days per week.

Respondents were asked to report the percentage of the dogs they acquired or retained for work that become successful livestock working dogs. The options were 'less than 50%', '50-64%', '65-79%', '80-99%' and '100%'. For these 'dishonourable' discharges (dogs dismissed before old age or injury), survey respondents were asked to focus on the last dog they had had in training that they did not retain as a working dog. They were then able to choose one of four options to indicate the age at which the dog had been dismissed from 'less than 3 months' to 'more than twelve months'. Respondents were also asked to report the retirement age for the last successful working dog(s) (honourable discharges) they had to retire or that ceased work prematurely.

To investigate the training of livestock working dogs, respondents were asked how long, in general, it takes them to train both started and unstarted dogs to a competent working standard. In addition, they were asked 'how much time is spent with the dog during an average training session?' The options were; 'I don't have formal training sessions', 'less than 15 minutes', '15-30 minutes', '30-60 minutes' and 'greater than 1 hour'. They were also asked to select how many training sessions they have per month from the options: 'I don't have formal training sessions', 'less than eight', 'eight to 15', '16-30' and 'more than 30'.

Respondents were asked to 'estimate the average yearly cost per dog of feeding and routine health care'. The options were 'less than $400', '$40–800', '$801–1500' and 'more than $1500'. In addition, they were asked to state the maximum amount they would consider spending on their best working dog to treat it for a serious illness or injury to allow it to return to work. They could choose a response from one of six categories ranging from '$200 or less' to 'more than $5000'.

Calculations and Analysis

All data were exported into Microsoft Excel (Microsoft Corporation, 1 Epping Road, North Ryde, NSW) and descriptive statistics were generated using this software program. To estimate the typical economic contribution of the dogs, the median values for the major costs associated with dog ownership were added and compared to the median number of hours worked over a lifetime by the sample of dogs reported in the Farm Dog Survey. Where median values were ranges, the midpoint of the range was used for calculations. A limitation of the survey data was that response options were ranges e.g., less than $500, $500 -$2,000. Accurate means could be calculated as thus would require assumptions of the exact value the respondent intended within the range. Therefore, cumulative frequencies were used to indicate the median response range.

The major costs were considered to be the dog's purchase price, the time invested in training the dog to competency, feed, routine health care and veterinary costs over the typical working lifetime. Additionally, these same costs were included for the resources lost on dogs culled during the process of recruiting a successful dog.

Some assumptions were required for the purposes of the calculations. To create a financial representation of time investments and returns, an hourly rate of $20 was used. This represents the median Australian farm-hand wage. In addition, because specific details of each respondent's stock management calendar were not requested in the Farm Dog Survey, the typical annual frequency and duration of stock handling periods had to be estimated from a secondary source. The estimated frequency of these work periods was calculated using a sheep husbandry calendar template tool, which lists eight major husbandry tasks, required on sheep producing properties throughout the year. The duration of the tasks was estimated using the typical flock size reported by the respondents and, as an indicative figure, the number of sheep able to be crutched in a single day employing a crutching cradle. Crutching was chosen as a representative husbandry task as the time taken to perform this activity would be expected to be longer than drenching, jetting and vaccinating but shorter than the major task of shearing.

What was found?

The survey provided a considerable amount of important and useful information related to livestock working dogs in Australia. This information is presented in some detail in section 4.1.2. In brief, survey respondents submitted details for 1806 of the dogs currently working, 864 dogs they had most recently dismissed and 1357 dogs they had most recently retired. Table 1 shows the respondent's demographic information compared with that of the Australian livestock producing population. Whilst the method of recruiting survey participants could not guarantee a random sample of the stock dog owning population, our survey sample is similar to the Australian farming population when considering several demographic characteristics such as gender, age and geographic location.

Table 1. Demographic information for the respondents of the Farm Dog Survey (n=812) and corresponding information (where available) for the Australian farming population

Demographic characteristic	Farm Dog Survey sample relative frequency, %	Australian farming population relative frequency, %
Gender		
male	69	72[1]
female	31	28[1]
Age (years)		
18 – 29	11	
30 – 39	15	
40 – 49	20	
50 – 59	26	
60 – 70	22	
over 70	5	
median	50 – 59 years	53 years[1]
Location		
NSW	42	32[2]
VIC	17	25[2]
QLD	19	31[2]
SA	9	10[2]
WA	6	9[2]
TAS	5	3[2]
NT	0.6	0.4[2]
ACT	0.3	0.04[2]
Property Size (ha)		
less than 500	32	
500 – 1,000	17	
1,001 – 3,000	23	
3,001 – 7,000	11	
7,001 – 15,000	8	
15,001 – 30,000	5	
more than 30,000	5	
Production		87[1,3]
cattle	76	48[1,3]
sheep	75	
cattle & sheep	51	0.2[1,3]
goats	6	
Cattle herd size		
nil	24	
less than 100	20	
100 – 500	31	
501 – 1,500	15	
1,501 – 3,000	7	
3,001 – 8,000	3	
more than 8,000	1	
median herd size	100 – 500 head	

Sheep flock size		
nil	25	
less than 500	21	
501 – 2,000	17	
2,001 – 5,000	18	
5,001 – 10,000	11	
10,001 – 25,000	7	
more than 25,000	1	
median flock size	2,001 – 5,000 head	

1. Australian Bureau of Statistics (2012b)
2. Australian Bureau of Statistics (2012c)
3. Australian Bureau of Statistics (2012a)

In basic terms, the vast majority of dogs were purchased rather than home-bred, and cost less than $500. Costs relating to maintenance and training were also reported to be modest, with 77 per cent of survey participants estimating spending less than $800 annually on feeding and routine healthcare. Australian farm dogs appear to be a robust and generally healthy group, with respondents reporting that 80 per cent of the dogs described cost their owners less than $500 veterinary costs in the last five years. In addition, 89 per cent of dogs were reported to have been retired for issues other than health. Table 2 summarises the characteristics of the dogs currently used by the survey participants.

Table 2. Characteristics of the 1,806 dogs currently engaged in stock work as reported by the Farm Dog Survey respondents

Canine characteristic	Dogs in work, %
Gender	
female	41
female neutered	10
male	44
male neutered	5
Age	
Mean	5 years
Breed	
Kelpie	60
Kelpie cross	8
Border collie	16
Border collie cross	7
Australian cattle dog	1
Australian cattle dog cross	1
Koolie	1
Koolie cross	1
Other	4
Main work	
all-rounder (utility)	63
mustering	27
yard (forcing)	8
trialling only	2
Trial participation	
no	84
yes	16
Insurance status	
Insured	9
Not insured	91

The next section of the report (4.1.2) describes the background and process involved in estimating the economic value of farm dogs.

4.1.2 Estimation of the economic value of livestock working dogs

Why was the study carried out?

Despite widespread acknowledgement of the valuable role that the livestock working dog plays in livestock production, and the undisputed affection and esteem that they command in the iconic place that they hold in the Australian psyche, their contribution to the Australian economy has never been quantified.

To maximise profitability, producers have to make decisions based on costs and expected financial returns. Better quality information available to farm decision makers enables them to be more accurate in predictions and decision-making. The ownership of livestock working dogs represents an

investment in farm labour efficiency. Financial decisions related to dog ownership, training and breeding must be informed by knowledge of the value of these animals. Although many dog owners have great affection and respect for their livestock working dogs, these emotions alone may not be sufficient to justify expenditure on these animals. Many production industries already have extensive information relating to the value and production costs of their livestock. In the dairy industry, for instance, we know that many farmers recognise their cows as having an intrinsic value beyond production alone, but the factor most likely to influence the farmer's intention to take action on the health of their herd remains the cost effectiveness of treatment intervention. Similarly, a survey of livestock producers showed that the cost of veterinary care relative to the value of the animal requiring treatment was an obstacle to using these services.

Thus, quantifying the economic value of the typical Australian livestock working dog in terms of predicted return upon investment is likely to have implications for farm dog welfare. As a potentially valuable resource, dogs may merit a level of care that reflects their economic value to the farm enterprise, rather than simply their owner's emotional attachment.

What was done?

The Farm Dog Survey was designed to investigate many areas of farm dog usage and management and the characteristics and views of their owners. For the purposes of estimating the economic value of livestock working dogs, respondents were asked approximately 20 questions associated with the cost of acquiring and maintaining their dogs, the time invested in training them and the dog's workload and longevity. The online version of the Farm Dog Survey was administered for a three-month period from March to June 2013. The target population for the survey was all working dog owners in Australia.

What was found?

Eight hundred and twelve responses were received of which nearly 99 per cent were online submissions. The respondent's demographic information is shown in Table 1 with that of the Australian livestock producing population for comparison (where available).

The mean number of dogs currently in work was four per respondent (median of three, mode of two, minimum of one, maximum of 30). The median retirement age for the last one to three dogs retired by the respondents was ten years. Thirty-one per cent of these dogs finished their working lives due to death, 21 per cent were euthanased on retirement, 5 per cent were rehomed and the remaining 43 per cent of retired dogs were retained as companion or breeding animals.

Only 27 per cent of dogs currently working were bred by their current owner. For the dogs that were not home-bred, the median purchase price range was 'less than $500' with 69 per cent of dogs purchased for this amount. With respect to maintenance costs, the median annual cost per dog of feeding and routine health care was estimated by survey participants to be $400–$800, with 77 per cent reporting these maintenance costs to be $800 or less. The median estimate of the veterinary expense per dog (those still working) in the last five years was ' $500'. This category applied to 80 per cent of the 1806 dogs described.

As only 7 per cent of dogs were purchased fully trained, training costs applied to 93 per cent of the 1806 dogs currently in work. The median time for the respondents' livestock working dogs to become considered 'competent' was 12 months. During this period of training, the duration and frequency of training sessions ranged from less than 15 minutes, less than twice a week to over one hour, more than once a day. However, approximately 35 per cent of respondents reported that they did not set aside specific training sessions. Accounting for this 'on-the-job-training', the median training session duration and frequency was 15 minutes, less than eight times per month.

Respondents to the survey reported a cull rate of one dog in five. For 95 per cent of the dismissed dogs described in the survey, the decision to cull the dog was made when the dog was 6 months or older. However, the median age category for dismissal was 'over 12 months' of age.

An estimation of the typical life-time investment into a livestock working dog was made by summating the median per dog expenditure reported by survey respondents for the purchase price, the training costs, the maintenance costs and veterinary expenditure over the median working lifespan of ten years and the costs related to failed dogs occurring at a ratio to success of 1:4.

With respect to how much farm work dogs performed, respondents reported a peak workload for their dogs from less than 2 hours, one day a week to more than six hours, seven days a week. The median number of days respondents' dogs worked per week during peak periods of stock work was five. The median number of hours worked during these periods was four to six hours per day.

The typical livestock working dog's value can be estimated by calculating the return the owner receives on their investment. The efficiency of the investment is derived by dividing the output of the resource by the input or costs: $40 000/$7763 = 5.2

The Farm Dog Survey respondents were asked to predict how much they would spend to treat their best working dog for an illness or injury to allow it to return to work. The median response range was $1001 - $2000. Forty per cent of respondents would spend over $2000 to save their best dog, while twelve per cent nominated that they would spend over $5000 to ensure their best dog returns to work (Figure 1).

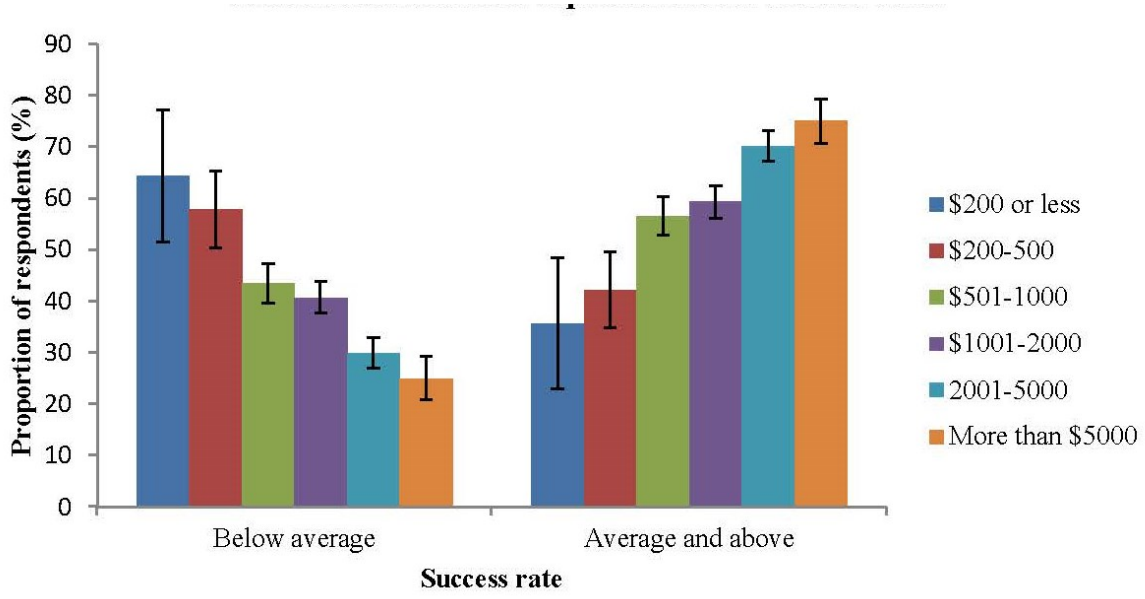

Figure 1. Estimates by respondents of maximum expenditure to save best dog from illness and their reported canine success rates.

What does this mean?

Our study is the first to estimate the value of the typical Australian working dog in terms of economic efficiency and revealed that the estimated total median costs involved in owning a livestock working dog were $7763 over the period of its working life. The work performed by the dog throughout this time was estimated to have a median value of $40 000. So, livestock dogs typically provided their owners with a 5.2 fold return on investment. When respondents were asked to nominate the maximum one-off veterinary expenditure they would consider spending on particularly valued dog, the median response was $1001–2000, which is not in line with the dogs' calculated median lifetime value. This disparity may reflect the lack of insurance.

This study has revealed a tremendous amount of valuable information on what Australian livestock dog owners spend to acquire and maintain livestock working dogs, as well as the work performed by

these dogs. There are, of course, some limitations to the study and among these we include the possible non-random nature of our sample of the livestock dog owning population. The method of participant recruitment could not ensure a random sample of the dog-owning population. There was potential for survey involvement to be greatest among people with a particular interest in livestock working dogs and a particular interest in the research. Our recruitment method also enlisted the help of two Kelpie affiliated societies (the CKA committee and the WKCA) and so it is possible that Kelpies are over represented in the data. The survey was also promoted at yard trials and again, dogs and handlers participating in these events may be over-represented. That said, the finding that dogs not competing in dog trials represented 84 per cent of the sample is reassuring.

As previously discussed, despite these potential issues, our survey sample reflects data on the Australian farming population in a range of demographic characteristics, such as gender, age and geographic location.

To calculate the financial contribution of a typical dog over its lifetime, some assumptions had to be made. The amount of work performed annually was derived from the survey data detailing the days and hours worked during peak periods. Estimates of the number of peak periods each year were required. For information relating to the type and amount of work performed by dogs during these peak periods, our team carried out studies on the athletic performance of working sheepdogs in Australia (see Section 4.2.2). To represent the time worked by dogs as a financial contribution, the work was valued at $20 per hour as this is the median rate paid to farmhands in Australia. It is interesting to note that the assumption that the dog could be replaced by a human worker does not take into account the ability of the dog to negotiate farmland inaccessible by vehicle, move over and through stock in yards, and the stock sense thought to be at least partially genetically determined in these dogs. If anything, it appears that our calculations are more to under-estimate, rather than over-estimate, the net economic worth of Australian livestock working dogs.

Where to now?

Australian producers operate in an environment of rising production costs as well as competition in markets under the influence of highly subsidised overseas products. Variable input and operating costs must be minimised to maximise profitability. Our study has revealed that the livestock working dog represents extremely valuable labour efficiency and that the expenditure decisions of their owners do not always reflect recognition of the value of these dogs. The findings of these study help to equip livestock working dog owners with useful information to make financially appropriate decisions about their livestock working dogs. This will lead to increased profitability for farmers and improved welfare for dogs. Further studies can capitalise on this work to focus on optimising breeding and training outcomes of the Australian livestock working dog. Decreasing the number of young dogs that do not become workers would save approximately $1,000 per failed dog. The following chapter suggests management methods that may help to achieve this. Additionally, optimization of the breeding work has the aim of contributing to this goal.

4.2 Optimising working dog performance - environmental factors

4.2.1 Environmental factors associated with success rates of Australian livestock working dogs

Why was the study carried out?

Our studies have revealed that the net economic value of the Australian livestock working dog represents a 5.2 fold return on owner investment. They also showed, as a mid-point estimation, that over $1000 worth of time and resources are wasted on each culled dog. Whilst this is a significant amount of money, economics are not the only incentive to increase success rates of livestock working dogs. Welfare is another important concern. Unsuccessful dogs are culled – which may mean euthanasia or rehoming or some other, non-quantified, fate. Wastage rates are estimated to be in the area of 20 per cent of livestock working dogs recruited for service in Australia. To ensure the sustainability of the livestock working dog industry, it must be perceived as socially responsible as well as economically viable. A growing public awareness of the welfare issues associated with food production has caused significant pressures to industries such as dairy, chicken meat and egg and pork production. Behavioural issues are the leading cause of performance failure of dogs across several working sectors. Identifying factors associated with livestock working dog success and failure will enable producers to adapt their practices to gain maximum financial return from their dogs.

What was done?

The online version of the Farm Dog Survey was administered for a three-month period from March to June 2013 with the target population being all livestock working dog users in Australia. As previously mentioned, the questionnaire was designed to explore the current dog management and training practices on Australian farms and the characteristics of the famers who handle and breed the livestock working dogs. These variables were analysed to explore potential risk factors for livestock working dog failure. Section 5 of the survey asked for information relating to the dismissal of dogs due to failure and retirement. Section 6 asked for information relating to the method and equipment used to train livestock working dogs and the dog-training education of the respondent. Section 7 asked respondents questions relating to the costs of dog ownership and what they would be willing to spend on their best dog to allow it to return to work from illness or injury. Section 10 requested basic demographic information from the respondents but also asked them to describe their general attitude towards and perception of their livestock working dogs. Finally, the survey contained the ten-item Big Five Inventory (BFI-10) human personality test that has been validated to measure personality in terms of the five personality dimensions of 'neuroticism' 'extraversion' 'openness' 'agreeableness' and 'consciousness'. Participants were scored from one (low expression) to five (high expression) for each of the five personality traits according to their average ratings.

The outcome we were interested in was 'success rate'. This was defined as the percentage of dogs acquired by respondents for training or for immediate use as a livestock working dog that ultimately became successful livestock working dogs. The converse of this was the 'cull' rate. Statistical analysis was performed on the 812 responses relating to over 4000 dogs.

What was found?

The mean success rate reported by survey respondents was 80 per cent. For the 864 dogs most recently failed by respondents, 89 per cent were for non-health related problems. Our study revealed a total of seven factors as significantly associated with dog success rates. These were dog breed, housing style, trial participation, age at acquisition, use of electric collars, hypothetical maximum treatment expenditure and owner conscientiousness score.

With respect to breed, the owners of a cattle dog crossbreed reported below average success significantly more than any other dog bred owners and had the lowest mean probability of reporting average or above average success rates.

Housing method was also associated with reported cull rates, with the highest probability of having average or greater success rates applying to respondents who housed their dogs in a group yard or pen rather than in a group cage or on a chain. It is hoped that further research will shed light on the decisions producers make about housing their dogs and the role that group yard or pen accommodation has on working outcomes.

Owners competing in working dog trials had a significantly greater chance of being in the group reporting average or above average success rates. Of the 267 dogs (out of a sample of 1,806 dogs) competing in working dog trials, only 16% (43 dogs) were used exclusively for trialling. The majority of dogs participating in trials were also used for on-farm work.

Below average success rates were reported by respondents who had acquired a dog when it was older than 6 months of age compared to those who purchased their pups at a younger age or bred their own dogs.

The remaining three factors (use of electric shock collar, hypothetical maximum expenditure and owner personality) were all owner factors. The vast majority of owners (93 per cent) do not use electric shock collars in their training but, the small percentage that do reported significantly below average rates of success more often.

With respect to the hypothetical maximum amount of money that owners would spend to treat their best dog to ensure its return to work, a positive association was found. This means that those owners that report average or above average success rates are those prepared to spend more money on their dogs' treatment.

Five owner personality traits were tested but only 'conscientiousness' was significantly associated with dog success rates. A trend was observed of increasing success rate with increasing consciousness score. Conscientiousness, in the human psychology literature, is a personality trait frequently associated with positive outcomes for workers. This trait encompasses characteristics of perseverance, organisational ability, ambitiousness and self-discipline. It is worth noting that consistent behaviour has been associated with the conscientiousness trait, and consistency in training plays an important role in effective communication with animals. It is logical to expect that the typical behaviour of a livestock working dog trainer/handler with a conscientious personality is likely to lead to good training outcomes in their dogs.

Other variables significantly associated with success rate included dog training level at acquisition, insurance status, training with positive reinforcement, the frequency with which the dog was exercised and the handler's view of their dog. Most dogs reported in this survey were acquired unstarted, but a trend was seen of increasing success rate as the extent of training at acquisition decreased. Whilst relatively few respondents reported that they insured their dogs, those who did were more likely to report average or greater success rates.

With respect to owner factors, success was associated with the use of positive reinforcement in training, as well as with increased dog exercise frequency. Interestingly, a significant association was found between the view handlers took of their dogs and reported success rates. Respondents who viewed their dogs as 'companions' or 'work mates' had a higher probability of average or greater success than those respondents who reported their dogs to be 'a workplace resource only'.

What does this mean?

A number of organisations that raise and train dogs for working purposes can definitively measure working dog success rates because they keep detailed records and adhere to testing protocols. These organisations include those that train guide dogs, detection dogs and military dogs. Our previous work with several of these organisations confirms that merit of best practice in selecting and training dogs. Our current results provide the greatest insight to date into the success rates of Australian livestock working dogs and the reasons for success or failure.

Many previous studies have found that the major reasons for culling livestock working dogs relate to behaviour and our study reinforces those findings. Other researchers have previously examined aspects relating to the heritability of behavioural traits valued in livestock working dogs. Heritability estimates of behavioural traits are often low to moderate at best. Low heritability estimates may result from imprecise behavioural evaluations but also emphasises the significant role that environment plays in shaping dog behaviours. Our study identifies a series of non-genetic factors that can affect livestock working dog success rates.

Where to now?

Our study reveals a number of husbandry practices, and handler attributes, associated with dog outcomes in terms of becoming a successful livestock working dog. The importance of addressing dog welfare aspects such as housing, exercise frequency and training technique is shown by the significant influence these parameters have on success. The importance of the human-dog bond is clearly shown by our study. Factors such as handler personality, view of their dogs, involvement in dog trials and the training level of the dog when acquired highlight the importance of fostering this bond to facilitate success. It is clear that the animal is not solely responsible for success or failure. Human interactions with the dog—and not simply the dog's actions in isolation—have a pivotal influence on results. Our study provides the groundwork for further studies investigating the optimisation of care and management of Australian livestock working dogs and highlights the need to communicate these best practices to livestock working dog-owners. The insights revealed by our research also have potential relevance to the mental health of companion dogs and other working dog sectors. Future research will be crucial in providing robust evidence for working dog codes of practice and owner training resources, rather than relying on recommendations not based on rigorous enquiry.

4.2.2 Athletic performance of working sheepdogs in Australia

Why was the study carried out?

Our studies have shown that livestock working dogs can contribute greatly to the productivity of farms. Livestock working dogs are valued not only for their speed and stamina on farms but also for their cognitive skills in manoeuvring livestock. Livestock working dogs have to be smart, skilled and fit. Previous research has shown that dogs develop expertise in both agility and livestock working contexts as a result of specific skill training and continued practice. The need for sustained work is emphasised by our recent finding that dogs often work for ten years. Emerging evidence from our group suggests that we have selected livestock working dogs to be resilient but the physical demands of work, particularly during peak periods of sheep stock work, such as shearing, weaning and marking, have not been quantified.

What was done?

Our study sought to measure the distance, speed and heart rate of a group of sheep dogs working during an eleven-day period of peak activity (shearing) to quantify distance travelled and average and maximum speeds. To do this, GPS units were attached to six dogs during the peak work period of shearing. Recordings were taken for each day a dog was worked. Work involved mustering and yarding rams, ewes and lambs, and filling pens in the shearing shed (shed dog only). Heart rate monitors were placed on the shed dog and one of the paddock dogs.

What was found?

Recording periods over the ten days of study ranged from 37 minutes up to 9 hours 50 minutes. The furthest distance covered by an individual dog in a single day was 68.3 km in less than 8 hours. However, dogs mustering in paddocks were transported by motor vehicle while wearing the GPS unit so some of the distances logged would also have included short vehicle trips. The furthest distance covered by an individual dog during the study period was 279 km whilst its mean average speed (over the five days of recording) was 3.63 km/h. The maximum speeds reached by individual yard dogs

ranged between 2.51 and 37.01 km/h. The lower maximal speeds most likely reflect the movement of dogs assigned to work passively in particularly small areas within a yard. Average working speeds in the yard ranged between 2.26 and 9.13 km/h, with a mean of 5.91 km/h.

What does this mean?

Our results reveal that livestock dogs in Australia working during peak periods are capable of covering large distances over successive days while moving livestock to various locations as required by handlers. We have shown that each dog involved in mustering and yard work was capable of running in excess of 40 km in a day. In the yard context, we saw no clear difference in average or maximum speeds between the dogs. We found that the dogs involved in this study regularly exceeded 40 kilometres while mustering, with one dog exceeding this distance on three consecutive days and five out of the six days it worked. Unfortunately, we were unable to record heart rate during a series of mustering sessions because the dogs worked so hard and were so athletic in their work that the high viscosity gel dissipated, leading to contact loss, and the heart rate transmitters were dislodged. Recent developments in smart textiles for measuring physiological parameters offer a more promising future for studies in the working dog domain but, for the time being, the technology is a limiting factor. This study did find that the manufacturer's claim of up to five hours battery life was conservative in estimate. We found that recordings over seven hours can be expected. We also found that, with rest periods, the dogs in this study were capable of working in excess of ten hours over a single day. Discussions with handlers revealed that the dogs regularly worked beyond the times recorded with the GPS units. This finding represents further evidence of the hugely significant workload of Australian farm dogs. If current trends in the development of technology continue, we may one day see heart rate monitors and GPS fitted to all dogs to monitor workload and possibly to ensure welfare.

Where to now?

The use of GPS and battery technology, if used on farm, will assist farm dog handlers in measuring and assessing the physical performance of their dogs during work. Over time, this has the potential to assist farm dog handlers in planning the workload of their dogs during peak periods to reduce injuries and exhaustion from overworking. It also has the potential to ensure that dogs are regularly exercised and trained to ensure they maintain a high level of fitness prior to beginning work during peak periods. We anticipate the development of technologies that remind producers to exercise their livestock working dogs. As GPS and battery technology improves, along with improvements in how we interpret the recorded data, further applications to benefit both handler and their dogs may be identified.

4.2.3 Dog livestock interaction: Canine and competition factors associated with sheep behaviour in yard trials.

Why was the study carried out?

This study investigated dog-livestock interaction and the canine and competition factors associated with sheep behaviour in yard trials. This work is important not only within the trial context but also by providing information that may help select the best kelpies for farm work, and the best dogs for improving the breed. The primary objective of the study was to investigate links between the herding activity of livestock working dogs and the frequency of undesirable responses (such as foot-stamping, splitting, stopping/starting and escaping) in the herded sheep. Identifying the specific dog behaviours that elicit sheep defense behaviours will help breeders to select dogs based on their ability to work in a way that optimises efficiency and welfare in livestock work.

What was done?

Our researchers attended the NSW West Wyalong Yard championships and recorded video of 50 dogs competing in the 2013 trials. Sixteen of these dogs were from the 'Improver' level (14 sheep used in trial) and the remaining 34 from the 'Open' level (16 sheep used in trial). Information about the dogs

(breed, sex, competition level, the number of sheep used in the trial and dogs trial score) was collected before the video was analysed. Ethical approval was granted before the research began (University of Sydney Animal Ethics committee approval number N00/1-2013/3/5902).

This study's primary objective was to investigate links between the herding activity of working dogs and the frequency of undesirable responses (such as foot-stamping, splitting, stopping/starting and escaping) in the herded sheep. Video recordings were analysed using behavioural coding software to determine the frequency of sheep and dog behaviours. Trial score, competition level ('Improver' or 'Open'), trial run duration and dog sex were selected as factors that may influence sheep responses during yard trials.

Some dogs ran multiple trials, and in some instances dogs competed in both 'Improver' and 'Open' classes. Coding criteria were developed to classify the primary sheep and dog behaviours of interest. Analysis concentrated on the time spent performing each behaviour, its frequency, and the total duration of the trial run.

What was found?

The only significant factors associated with the frequency of undesirable sheep behaviours were trial score, and total trial run duration. No difference was found across competition levels. A significant interaction was found between trial score and the frequency of sheep behaviours (escaping, foot stamping, splitting and starting/stopping). In general, the number of escape attempts per minute was greater in lower scoring dogs than in high-scoring dogs. There was also a relationship between sheep escape behaviour and dog trial score and total trial duration and sheep escape frequency. Predictably, a decrease in trial duration corresponded with a reduced frequency of escape attempts.

Moderate to strong associations were found between sheep and dog behaviours. Sheep foot stamping was correlated with stalling in dogs. Single sheep escape attempts were strongly associated with chasing activity by dogs. Trial score and duration were strongly correlated. This means that high scoring dogs were more likely to complete the trial faster than dogs with low trial scores. This reflects the better dogs' ability to avoid the flock stalling and splitting.

What does this mean?

These results provide evidence of significant relationships between dog and sheep behaviours, and contribute to our understanding of the interactions that take place between sheep and livestock working dogs in a yard environment. Based on the results, yard trial scores offer a useful means of verifying a dog's efficiency in yard work. High-scoring dogs tend to trigger low levels of escape and splitting behaviour in the sheep they manoeuvre and may serve to minimise sheep stress. Keeping livestock together and moving to the desired destination is likely to result in fewer undesirable displays and thus reduce total working time.

Where to now?

In this study, all videos were scored by a single investigator. There is scope for future research to determine the reliability and the degree of agreement of results among multiple raters. This could facilitate the development of a tool that allows behavioural observations to be used as a subjective measurement of animal welfare. An exciting next step could also include the validation of behavioural responses against physiological parameters that indicate reduced welfare, such as cortisol concentrations.

4.3 Behavioural phenotypes of the Working Kelpie

The previous section of this report discussed our findings relating to the influence of environmental factors upon livestock working dog success rates. In the following section, we report on studies that aim to directly assist dog breeders and canine genetics researchers by facilitating the collection of behavioural phenotypes of large numbers of Working Kelpies. To do this, we must first identify the working behaviours of most value to the livestock working dog community and also identify the terminology, and how that terminology is used to describe these valued behaviours. The first study described below provides critical analysis on the use of common terms in livestock working dog manuals. It is followed by a review of some of the limitations of research in canine behavioural genetics, and then studies describing the measurement of traits of importance and the formation of the Livestock Working (Herding) Dog Assessment Form.

4.3.1 The Manual muster: A critical analysis of the use of common terms in Australian livestock working dog manuals.

Why was the study carried out?

Livestock working dog training manuals represent an important educational resource for handlers and trainers. Previous studies by our team have shown that most Australian farm dog handlers have received no training in dog behaviour and its modification. This is perhaps not surprising, given the isolation of many rural areas and the lack of targeted and relevant education opportunities.

We currently cannot tell what proportion of the failure of livestock working dogs to perform adequately is due to a lack of natural ability (poor breeding) and how much is due to a lack of, or inadequate training. However, we do know that effective training of dogs has the potential to improve the quality of their work. Suboptimal working dog performance can not only compromise animal welfare, but also to decrease the efficiency of work. It has previously been demonstrated that animal handling techniques can influence the behaviour and physiology of herded animals. We know that physiological changes associated with the stress of various handling procedures, when chronic, are associated with unfavourable outcomes such as decreased wool production and poor meat quality.

One of the approaches to reduce behavioural wastage in livestock working dogs is education of trainers and handlers. We know that training manuals are an important source of information for many dog handlers. Interestingly, our results show that handlers with high openness scores (people with intellectual curiosity and preference for variety) were more likely than those with average openness to have sourced some of their training knowledge from books. Training manuals tend to be written by experienced handlers, who are often established as experts in the field. Arguably, they represent the best recorded wisdom on Australian dog handling, and so it would seem important to find out how much agreement there is in terminology both between, and possibly even within, these manuals. On an even more fundamental level, it seems critical that dog handlers and trainers agree upon the group of core traits that describe the Australian livestock working farm dog. This would greatly assist breeders, trainers and handlers in selecting dogs with desired characteristics. As previously discussed, consistency plays a vital role in effectively communicating with animals. If animals are unable to predict whether their actions lead to rewards or punishment, they become confused and distressed. Other researchers have previously shown correlations between owner inconsistency and dog disobedience, fear and anxiety. Agreement and consistency of use of terms are important because inconsistency leads to confusion and poor training outcomes.

What was done?

A pilot study of the terminology that characterises Australian livestock working dog training manuals was carried out by analysis of eight key texts that used a wide range of common terms. The texts were selected from a variety of sources including the University of Sydney library, books received from authors, and some were purchased online. Common terms used to describe general behavioural attributes, working manoeuvres and skills in each text were manually counted and ranked according to

their frequency of use. Seventy-three common terms were counted from the raw data to form the final list. Statistical analysis was carried out to map common term usage.

What was found?

Of the 73 terms counted, all authors used 13 terms. These 13 terms were 'cast', 'head', 'bark', 'eye', 'confidence', 'force', 'hold', 'keen', 'instinct', 'bite', 'temperament' and 'fear'. Figure 2 shows the top ten terms for working manoeuvres and skills, when all authors are included.

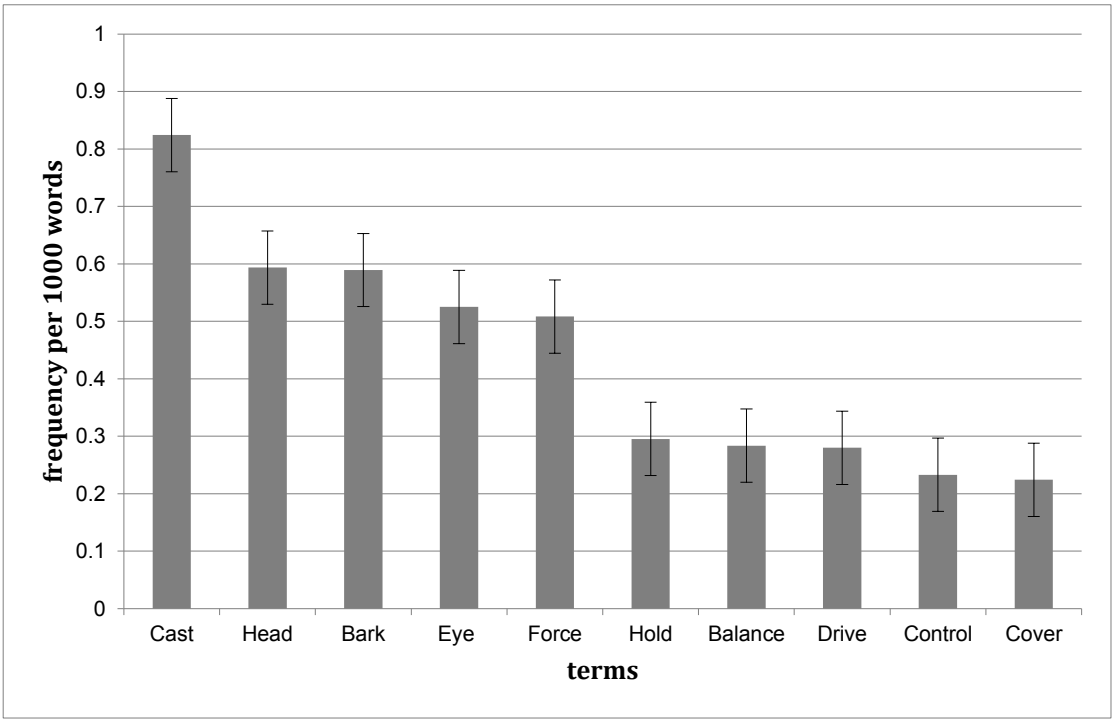

Figure 2: Top ten terms for working manoeuvres and skills (all authors). Error bars show +/- 1 standard error of mean.

The most common term used was 'cast', which describes the searching or outrun behaviour of the livestock working dog. The only terms with a mean frequency greater than 0.5 per 1000 words were 'cast' 'head' 'bark' 'eye' 'confidence' and 'force'. Our study showed that the final list of 73 words was used very broadly among authors, with the mean frequency being only 0.13 per 1000 words. We also showed that most of the high frequency terms described working manoeuvres or skills rather than temperament terms. Only two of the eight authors provided glossary sections in their manuals.

Terms describing general dog personality (not specific to the livestock working dog) such as 'confidence', 'keen', 'temperament', 'obedient' and 'intelligent' were used less frequently but were still found in the group of highest-ranking terms. Figure 3 shows the top ten terms for general behavioural attributes, when all authors are included. Statistical analysis revealed that only two authors showed similar frequencies of use of terms.

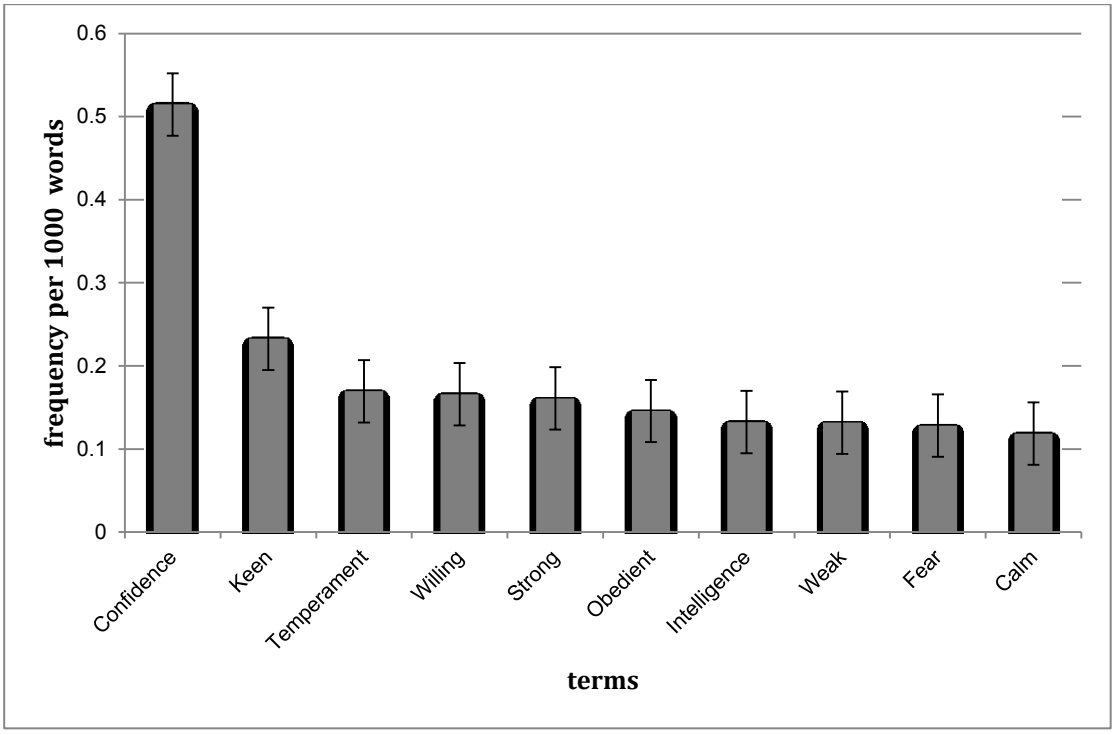

Figure 3. Top ten terms for general attributes (all authors). Error bars show +/- 1 standard error of mean.

What does this mean?

This study examined authors' use of dog working behaviour and personality terms in eight Australian livestock working dog manuals. It revealed significant disagreement in the frequency of use of key terms by authors. Indeed, it identified only two of eight authors who used terms with the same frequency in their writing. In addition, glossary sections were provided in only two of the training manuals. A glossary is a list of words relating to a specific subject, which includes brief explanations of the terms (please see Glossary in the current report). These findings raise some questions about the use of terms in working dog training manuals. First, are the general terms used by authors based on agreed definitions, colloquial understandings, or both? Second, are the terms sufficiently specific to describe each separate working manoeuvre unambiguously? The lack of alignment between authors on the frequency of use of terms suggests that the authors may be using more than one term to describe the same behaviour, or possibly even describing two separate behaviours with one term. Or, that they place a different emphasis on the importance of the traits. We cannot be sure from this study that each individual author using the same term has the same meaning in mind. This raises the possibility of some significant confusion, not only between authors, but also for the readers of the manuals and, of course, the dogs being trained with use of the manuals. Having clear and unambiguous communication between authors and their readers is essential for effective transfer of information and will greatly assist in the assessment, selection and training of dogs. Some very interesting observations relating to dog handler and trainer personality attributes and their uptake of training opportunities have come to light as a result of other studies from our research team. These may allow us to comment on the potential for experts in training dogs possibly to collaborate with others that have different skill sets, to optimise the transfer of knowledge to the majority of novices.

This pilot study also identified a group of core traits (cast, head, bark, eye, force, hold, confidence and keenness) that exemplify the successful Australian working dog. Such working manoeuvres and skills represent the core requirements in the working farm dog and, along with health traits that are already strongly selected for, should be the focus when selecting breeding stock.

Where to now?

This pilot study has not only provided a significant amount of new knowledge but has also raised some interesting and exciting questions that point to new avenues of research. Firstly, it would seem logical that a priority for research and extension work is industry clarification of the language used by the 'on the ground' experts and those creating the educational and training materials. The possibility of creating educational and training resources in the form of online materials would seem to be ideal here – allowing clear and transparent trainer and user agreement on skills and manoeuvers – as well as greatly facilitating reach and access of material into the working dog community. The results of our studies have shown that the working dog community appears to be enthusiastic users of online resources, with over 98 per cent of respondents to The Farm Dog Survey being online submissions. Additionally, this research outlines the traits of relevance in the breeding of successful dogs and thus informs the focus of research into phenotyping and genetic selection of dogs.

4.3.2 Holding back the genes: a review of limitations of research into canine behavioural genetics.

Genetics is a major influence on both desirable and undesirable behavioural phenotypes. If the genetic basis of dog behaviours followed simple Mendelian inheritance then progress into identification of genes responsible for dog behaviours could be expected to advance as rapidly as the identification of genes responsible for canine diseases caused by one gene. In reality, the genes underlying behaviours are elusive. This is because canine behaviours are influenced by both environmental and multiple genetic effects.

One of the major obstacles in behavioural studies is the challenge of accurately defining and measuring behaviours. Unfortunately, it is not possible to combine data from multiple behavioural studies, as researchers tend to use a variety of different ways to measure behaviour. International standardised testing protocols and standard terminology definitions in dog behavioural evaluations will greatly assist progress in this field. Our reports on assessing and scoring individual dog working traits will contribute to this process The genome of the dog is extremely well suited to genetic research as there is large genetic variation between breeds, accompanied by small variation within breeds. Considerable progress has been made in canine inherited disease research, and somewhat less in terms of the genetics of canine behaviours. Improved understanding of canine behavioural genetics has the potential to benefit the dogs themselves and also provide useful models for several human psychiatric disorders. There are a number of limitations and hurdles faced by researchers in the field of canine behavioural genetics. As we have stated, these include factors related to complexity of dog behaviour, challenges relating to phenotyping as well as issues relating to inconsistency in terminology use and to the challenges of international collaboration. In the future, with the use of standardised phenotyping, standardised terminology and encouraging collaboration among research groups, it is anticipated that many of the current limitations to behavioural genetics research will be overcome.

Despite these limitations, our research has managed to shed new light on a number of aspects of canine genetics. In the following section, measurement of traits of importance is discussed and then the formation of the Livestock Working (Herding) Dog Assessment Form is described and discussed.

4.3.3 Measuring traits of importance

Animal behaviour is influenced by a range of factors apart from inheritance, including interactions between behaviours, the environment, learning and epigenetics (functionally relevant changes to the genome that do not involve a change in the nucleotide sequence). Behavioural interactions with the environment, with humans and with stock add greatly to the complexity of defining behavioural phenotypes in livestock working dogs. To be useful for genetic analysis, phenotyping must be valid, reliable, sensitive and as objective as possible. Unlike most disease testing methodology, there are no specific physical characteristics or blood tests for behavioural conditions. There are a variety of

methods of phenotyping used in behavioural studies including subjective owner ratings, owner questionnaires and observational study.

Numerous behavioural tests are applied to dogs. Some measure a single trait and others measure different aspects of temperament or aptitude for a particular function. Empirical behavioural assessments are rigorous only if they are standardised so that the same scenario and observation technique is used for every dog tested. It can also use objective measures to assess responses, for example, the time spent performing a behaviour or the time taken to approach an object can be measured. The major disadvantage of behavioural testing is that the rating is often based on a single observation or test. Observational studies also suffer from the significant disadvantages of financial and time costs.

Subjective owner ratings have several advantages over behavioural assessments. Measurement error is reduced as the owner is intimately familiar with the subject and can assess behaviour over numerous events compared to third party assessment based on a single trial. Such ratings are arguably more authentic records of the dogs' behaviour if carried out in the familiar home environment of the dog rather than the artificial environment of a testing area. Another significant advantage is that this form of rating is relatively quick and simple and therefore economical, as well as encouraging of increased participation. A potential disadvantage is the possibility of susceptibility to observer bias but this can be outweighed by the advantages gained by recruiting large numbers of participants.

Because questionnaires are economical they are commonly used for owner ratings. There are a number of validated questionnaires that have been used in other studies, largely on companion animals. Our researchers conducted a pilot study to assess the suitability of such questionnaires for Australian livestock working dogs. Producer feedback indicated that these questionnaires were not suitable for use due to lack of applicability to livestock working dogs as well as the time taken to complete. This consultation process also raised the very important point that dog behaviour traits may differ depending on whether the dogs were assessed in the presence of stock or without stock. Taking these needs into account, researchers developed an assessment form that addresses the requirements for relevance, brevity and accessibility to working dog owners and handlers.

4.3.4 Formation of the Livestock Working (Herding) Dog Assessment Form

Why was the study carried out?

The previous section of this report discussed our findings relating to environmental factors with a possible effect on livestock working dog success rates. This section of the report deals with the development of an assessment form for livestock working dogs to facilitate data collection about the behavioural phenotypes of large numbers of livestock working dogs.

This is the first critical step in any behavioural genetics research process. We evaluated the behaviour of livestock working dogs within two broad domains, namely personality (or temperament) traits and, livestock working-specific behaviours.

What was done?

Personality section of LWDAF

Our Livestock Working (Herding) Dog Assessment Form (LWHDAF) asks owners to rate their dogs in both 'stock' and 'no stock' situations. Whilst it is expected that dog behaviour will be similar in both contexts, there are anecdotal reports of dogs showing different behaviours in the two situations.

As discussed previously, the purpose of this questionnaire was to phenotype livestock working dogs. A large sample size is required for heritability calculations. To encourage high levels of owner

participation, the questionnaire must be quick and simple to complete. This requires both brevity and accessibility. To ensure brevity, a maximum of four adjectives (and minimum of two) was set to assess each behavioural trait. In terms of accessibility, it is essential that terminology aligns with that used by livestock working dog handlers to ensure clarity and to maximise ease of participation. Our previous study of working dog manuals and texts provided a reference for common livestock working dog terminology. Traits considered extremely valuable by most Farm Dog Survey participants when rating utility dogs included bold/shy, calmness/excitability, trainability, intelligence, sociability, stamina, persistence and impulsivity.

Of the validated canine personality assessment techniques, the Canine Behavioural Assessment and Research Questionnaire (C-BARQ), has a measuring tool for the trait 'obedience and trainability' which largely met the criteria for brevity, accessibility and relevance. For this reason, it was included as a final section of the LWHDAF. However, in terms of relevance, we were mindful that livestock working dogs are generally managed and cared for very differently to companion dogs. Therefore, we excluded questions and statements developed in companion animal behavioural questionnaires that could not be assessed by the working dog owners.

What was done?

Herding behaviour section of LWHDAF

A copy of the Livestock (Herding) Dog Assessment Form is presented below.

University of Sydney

Farm Dog Project

Dog's name:

Age (or DOB):

Coat colour:

Sex (please circle):

Male entire	Male desexed	Female entire	Female desexed

WKC registration number (if relevant):

Sire (if known):

Dam (if known):

Dog's main type of work (please circle):

Paddock	Yard	Utility	Droving	Trucks

Dog works the following stock (circle all that apply):

Sheep	Cattle	Goats	Other:

This dog participates in trials (please circle):

Yes	No

Housing (please mark the top row and one in second row):

Pen/yard	Cage	Chain
Individual	Pair	Group

Owner/handler name:…….

For each of the traits in the table, please tick one of the five boxes (from 'Very low' to 'Very high') to best describe this dog.

In the first table please rate how the dog is when working with stock. In the second table, rate how the dog is in situations without stock. The ratings may be the same, or different, in each table.

1. WITH STOCK	Very low	Low	Average	High	Very high	I don't know
Confidence						
Calmness						
Intelligence						
Trainability (easiness to train)						
Boldness						
Patience						
Timidness						
Persistence						
Hyperactivity						
Initiative taking						
Excitability						
Obedience						
Nervousness						
Impulsiveness (has sudden, strong urges to act; acts without forethought; acts without considering effects of actions)						
Stamina						

2. WITHOUT STOCK	Very low	Low	Average	High	Very high	I don't know
Confidence						
Calmness						
Intelligence						

Trainability (easiness to train)						
Boldness						
Patience						
Timidness						
Persistence						
Hyperactivity						
Initiative taking						
Excitability						
Obedience						
Nervousness						
Impulsiveness (has sudden, strong urges to act; acts without forethought; acts without considering effects of actions)						
Sociability						
Friendliness						

	Extremely poor	Poor	Average	Good	Excellent
Cast					
Gather					
Force					
Cover					
Head					
Hold					
Balance					
Break					
Back					
Initiative					

Anticipation					
Trainability					
Natural ability					

	None	Weak	Light	Medium	Strong	Over
Eye						

	Very low	Low	Average	High	Very high
Confidence					
Calmness					

	Extremely shy	Shy	Moderate	Bold	Extremely bold
Boldness					

	Inadequate	Appropriate	Excessive
Bark			
Bite			
Cast			
Force			

	Never	Very rarely	Rarely	Occasionally	Frequently	Very frequently
Bark						
Bite						

	One of the worst dogs I have ever seen/trained	Below average	About average	Above average	One of the best dogs I have ever seen/trained
Overall ability					

Training and obedience

Some dogs are more obedient and trainable than others. By marking the appropriate choices, please indicate how trainable or obedient your dog has been in each of the following situations in the recent past.

	NEVER	**SELDOM**	**SOMETIMES**	**USUALLY**	**ALWAYS**	Not observed/ Not applicable
1. When off the leash, returns immediately when called.						
2. Obeys the "sit" command immediately.						
3. Obeys the "stay" command immediately.						
4. Seems to attend/listen closely to everything you say or do.						
5. Slow to respond to correction or punishment; "thick-skinned".						
6. Slow to learn new tricks or tasks.						
7. Easily distracted by interesting sights, sounds, or smells.						
8. Will "fetch" or attempt to fetch sticks, balls or objects.						

Additional comments about this dog:

4.3.5 Identifying patterns of personality

Why was the study carried out?

Seventeen adjectives (terms) were included in the LWHDAF to assess the personality of Working Kelpies. These adjectives were selected from terms frequently used in working dog manuals as well as terms that feature in the emerging scientific literature on canine personality. However, there is a lack of consensus on the definitions of these terms and many of them are used interchangeably.

To identify which terms relate to one another, we looked for patterns in our survey respondents' use of the terms. These patterns reveal how the terms cluster together and are used to describe particular dogs. We identified terms that cluster together significantly using a statistical method called principal component analysis. The patterns that emerge from this sort of analysis are expressed as so-called components.

Principal component analysis has previously been employed in companion dog personality studies that have identified 5 major components of canine personality. These components are described by the sub-scale labels: Extraversion, Motivation, Training Focus, Amicability and Neuroticism. We hypothesised that some of these personality sub-scales would emerge in the descriptions of working dog data but that others would not, e.g., because they do not align with the experience of dog handlers and breeders and the terms they favour when describing canine personality.

What was done?

The descriptions of 233 dogs reported via the LWHDAF were analysed. The ordinal scores (from one to five) for the 17 terms were converted to continuous scores with a normal distribution. These continuous scores were then used in the principal component analysis. The scores of the terms timidness, nervousness, hyperactivity, excitability and impulsiveness were reversed so that a score of 5 represented the more desirable of the two limits for all traits.

What was found?

The first four components explain 64% of the variance. Component 1 represents the best linear summary for all the data. The most traits that have the strongest influence on Component 1 are intelligence, calmness, patience, trainability and initiative. Having accounted for Component 1, Component 2 identified a contrast between high scores for boldness (and related terms such as confidence, persistence and a lack of timidness) and high scores for terms such as calmness, patience and a lack of hyperactivity, excitability and impulsiveness. This component accounted for 19% of the variance. After adjustment for this pattern, Component 3 identified a contrast between obedience (and the highly related trait of trainability) and a lack of excitability, nervousness, hyperactivity and timidness. Component 4, adjusted for the three preceding patterns, grouped the highly correlated friendliness and sociability, and contrasted these terms with persistence, initiative, and stamina. Table 3 below shows the loadings of the terms on these four components.

Table 3: Loadings of personality LWHDAF terms on largest four components

Terms	Component 1	Terms	Component 2
Intelligence	-0.336	Lack of Hyperactivity	-0.368
Calmness	-0.324	Lack of Excitability	-0.349
Patience	-0.316	Lack of Impulsiveness	-0.267
Trainability	-0.296	Patience	-0.262
Initiative	-0.272	Calmness	-0.225
Obedience	-0.251	Obedience	-0.135
Lack of Nervousness	-0.251	Trainability	-0.046
Lack of Impulsiveness	-0.248	Intelligence	0.036
Persistence	-0.239	Lack of Nervousness	0.097
Confidence	-0.234	Friendliness	0.123
Lack of Hyperactivity	-0.224	Sociability	0.141
Boldness	-0.205	Initiative	0.15
Lack of Excitability	-0.19	Stamina	0.205
Lack of Timidness	-0.169	Lack of Timidness	0.276
Friendliness	-0.157	Persistence	0.293
Sociability	-0.141	Confidence	0.325
Stamina	-0.138	Boldness	0.391
PROPORTION OF VARIANCE	0.27	PROPORTION OF VARIANCE	0.19
CUMULATIVE VARIANCE	0.27	CUMULATIVE VARIANCE	0.46

Terms	Component 3	Terms	Component 4
Obedience	-0.414	Sociability	-0.659
Trainability	-0.377	Friendliness	-0.58
Intelligence	-0.189	Lack of Nervousness	-0.097
Patience	-0.113	Obedience	-0.035
Initiative	-0.111	Boldness	-0.026
Friendliness	-0.088	Lack of Hyperactivity	-0.023
Stamina	-0.05	Lack of Excitability	-0.019
Sociability	-0.043	Lack of Impulsiveness	0.007
Calmness	-0.025	Confidence	0.007
Persistence	0.044	Trainability	0.011
Lack of Impulsiveness	0.054	Calmness	0.012
Boldness	0.074	Patience	0.046
Confidence	0.104	Lack of Timidness	0.053
Lack of Hyperactivity	0.347	Intelligence	0.089
Lack of Nervousness	0.369	Persistence	0.21
Lack of Excitability	0.404	Stamina	0.269
Lack of Timidness	0.415	Initiative	0.296
PROPORTION OF VARIANCE	0.10	PROPORTION OF VARIANCE	0.09
CUMULATIVE VARIANCE	0.56	CUMULATIVE VARIANCE	0.64

What does this mean?

Principal component analysis mathematically condenses a large number of terms into a smaller number of terms while retaining much of the important information. In this case, the 17 behavioural terms can be simplified into 4 component terms which capture nearly two thirds (64%) of the information. In doing so, the analysis indicates traits that are different from each other and those that are more similar, or related, in some way.

Asking owners to score their dogs on several similar terms has the potential to act as a repeated measure and, thus, reduce measurement error associated with disparate or inconsistent interpretation of terms. The PCA analysis supports our assumptions about which terms have similar (and contrasting) meanings and which terms can be used to represent underlying personality traits.

Component 1 represents the most informative possible combination of terms for the data from these 233 dogs. It alone is able to account for over a quarter of the information in the full dataset. It tells us that scores for intelligence, calmness, patience and trainability are particularly informative of this single term summary in the dataset. However, unsurprisingly, the aspects of canine personality surveyed by the LWHDAF are too complex, to be fully summarized by a single number. The PCA analysis therefore surveys the yet unexplained variation in its additional three components.

Component 2 supports the notion that, among the dogs surveyed, there is a personality continuum described by excitable/hyperactive behaviour at one end of the spectrum and patient/calm behaviour at the other. This component accounts for nearly another 20% of the variation. Component 3, the next most prominent signal, groups the strongly correlated trainability and obedience and is associated with high activity levels (hyperactivity and excitability). Unexpectedly, these terms also appear to share some relationship with shyness (nervousness and timidity). On reflection, it is quite plausible that dogs that are more timid will be more sensitive to human instruction especially if a degree of intimidation or coercion is relied on in training. Component 4 groups the strongly correlated terms friendliness and sociability in contrast to a grouping of initiative with stamina and persistence.

Thus, over 60% of the variation in these 233 dogs scored for 17 behavioural terms can be expressed which just 4 component terms. These component terms may represent underlying patterns and continuums in the personality of Working Kelpies. Exploration of the economic value of these underlying patterns for different Working Kelpie roles and types of work could potentially inform future selection programs.

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4.3.6 Identifying patterns in working manoeuvres and livestock working attributes

Why was the study carried out?

Twenty-three terms were included in the LWHDAF to assess the working manoeuvres and livestock working attributes of Working Kelpies.

To identify which terms relate to one another, we looked for patterns in our survey respondents' use of the terms. These patterns reveal how the terms cluster together and are used to describe particular dogs. As outlined above (4.3.4.2), we identified terms that cluster together significantly using a statistical method called principal component analysis. Principal component analysis mathematically summarises a large number of terms into component terms. A far smaller number of component terms can thus contain most of the information contained in the larger set. These component terms correlate with the original terms in patterns which can reveal how the original traits relate to each other. Related terms will have similar correlation patterns with the large components. Traits that tend to occur separately will be described by terms with opposite correlation patterns with the large components.

What was done?

The descriptions of 218 dogs reported via the LWHDAF were analysed. The ordinal scores for the 23 terms were converted to continuous scores with a normal distribution. These continuous scores were then used in principal component analysis

What was found?

As with the pattern analysis in personality traits, we found that much of the information from the ordinal scores for the 23 traits could be expressed in a relatively small number of component traits with the first four components explaining 60% of the variance. Component 1 represents the best linear summary for all the data and accounts for 35% of the variance. In this analysis, the most important terms for this component were cover, gather, hold and head. After accounting for this averaging effect, Component 2 identified a grouping between boldness/confidence and a series of assertive manoeuvres, force, bite, bark, and back. This grouping of terms contrasts with calmness and a series of more equilibrated manoeuvres, such as cast, balance, gather, and hold. This second component accounts for about 14% of the variance. Having accounted for the effect of Component 2, Component 3 identified the next most prominent pattern in the terms, contrasting back/bark with eye/bite. Component 4 contrasts eye /boldness with a grouping of terms including bark, bite, cast and calmness.

Table 4 below shows the loadings of the terms on these four components.

Table 4: Loadings of LWHDAF livestock working manoeuvres and attributes on first four components.

Terms	Component 1	Terms	Component 2
Cover	-0.288	Calmness	-0.207
Gather	-0.282	Cast	-0.193
Hold	-0.281	Balance	-0.156
Head	-0.28	Cast_2	-0.148
Break	-0.269	Gather	-0.141
Initiative	-0.263	Hold	-0.115
Overall_ability	-0.262	Head	-0.11
Balance	-0.26	Cover	-0.109
Anticipation	-0.26	Eye	-0.093
Natural_ability	-0.255	Break	-0.049
Confidence	-0.233	Natural_ability	0.023
Cast	-0.226	Overall_ability	0.049
Boldness	-0.205	Anticipation	0.071
Calmness	-0.197	Initiative	0.145
Eye	-0.165	Bite_2	0.181
Force	-0.157	Bite	0.209
Cast_2	-0.12	Force_2	0.255
Back	-0.103	Confidence	0.266
Force_2	-0.067	Bark_2	0.268
Bark_2	-0.029	Boldness	0.294
Bite_2	-0.027	Back	0.296
Bite	-0.007	Bark	0.398
Bark	0.041	Force	0.401
PROPORTION OF VARIANCE	0.35	PROPORTION OF VARIANCE	0.14
CUMULATIVE VARIANCE	0.35	CUMULATIVE VARIANCE	0.48

Terms	Component 3	Terms	Component 4
Back	-0.292	Bark	-0.48
Bark	-0.211	Bark_2	-0.399
Bark_2	-0.171	Cast	-0.337
Cast	-0.103	Calmness	-0.281
Calmness	-0.08	Bite	-0.28
Initiative	-0.076	Bite_2	-0.234
Cast_2	-0.072	Cast_2	-0.173
Confidence	-0.063	Gather	-0.107
Overall_ability	-0.06	Overall_ability	-0.103
Gather	-0.047	Balance	-0.039
Force_2	-0.044	Initiative	-0.035
Force	-0.038	Break	-0.028
Hold	-0.022	Hold	-0.025
Balance	-0.009	Cover	-0.007
Head	0.01	Natural_ability	0.054
Natural_ability	0.028	Head	0.091
Cover	0.056	Anticipation	0.112
Break	0.056	Force_2	0.113
Anticipation	0.08	Force	0.13
Boldness	0.096	Back	0.148
Eye	0.343	Confidence	0.191
Bite_2	0.461	Eye	0.209
Bite	0.668	Boldness	0.267
PROPORTION OF VARIANCE	0.07	PROPORTION OF VARIANCE	0.05
CUMULATIVE VARIANCE	0.55	CUMULATIVE VARIANCE	0.60

What does this mean?

The analysis shows that it is possible to condense the 23 terms of the LWHDAF, which assess working manoeuvres and livestock working attributes, into a manageable number of composite traits.

In the Component 1, which represents the most informative possible loading of the scores, the most important terms are cover, gather, hold and head. This component accounts for about 35% of the variance detected by the 23 LWHDAF terms. While this is not insubstantial, the 65% of the variance as yet unexplained by this best combination of scores demonstrates the complexity of Working Kelpie activities surveyed. Following the averaging effect of Component 1, the most important pattern grouped high scores for boldness and assertive working manoeuvres was and contrasted them with a grouping of high scores for calmness and equilibrated working manoeuvres in Component 2. This may represent a continuum of Working Kelpie ability or owner preference for different styles of working with stock. Further investigation of this contrast may reveal the ideal styles for different types of work both for individual dogs and also for the assembly of effective teams of dog. Components 3 and 4 accounted for somewhat less variance but did detect distinctive patterns in the association between scores for different terms.

Identifying important patterns in the scores for working manoeuvres and attributes terms, particularly the pattern described by Component 2 might identify potential targets for selective breeding, candidate attributes for gene-behaviour investigation and characterise optimal attributes for different kinds of work.

4.3.7 Correlation between important traits in Working Kelpies

Why was the study carried out?

The LWHDAF surveyed personality (using 17 terms) and working manoeuvres and livestock working attributes (using 23 terms). While principal component analysis was the primary methodology for examining patterns in the scores of these attributes, phenotypic correlation between the scores for the terms is an alternative method for evaluating relationships between terms.

Phenotypic correlation measures the association of scores between the terms; the tendency for dogs to score high or low on *both* terms within a pair of terms. Similar terms would be expected to have a strong positive correlation (close to 1), contradictory terms would be expected to have a strong negative correlation (close to -1) and independent, unrelated terms would be expected to have no or weak correlation (close to 0).

Genetic correlations measure the association of genetic merit for the terms; the tendency for the terms to be affected by the same genes. The genetic correlation between a pair of traits may vary in both strength and direction from the phenotypic correlation and is, in most cases, independent of heritability. Estimation of genetic correlation is very complex, ideally taken from a large, balanced dataset collected in ways that minimise potential confounders. Nonetheless, as a preliminary investigation into the potential of such analyses in Working Kelpies, we used the current early data to estimate the genetic correlation between some pairs of traits

What was done?

The phenotypic correlations between the LWHDAF 17 personality terms, and 23 working attributes and livestock working manoeuvres were estimated for 233 and 218 dogs, respectively. Kendall's rank correlation coefficient (also known as Kendall's Tau) was used in place of the more familiar Pearson's product moment correlation coefficient due to the ordinal nature of the LWHDAF scores.

The potential for genetic correlations were surveyed using bivariate linear mixed models on ordinal scores converted to a normal distribution. A wide-ranging fixed effect model was employed to correct data for known environmental and husbandry factors. The random effect models were as complex as possible to minimise the impact of potential confounders.

What was found?

The phenotypic correlations are presented in Table 5a, 5b and 5c. Associations ranged from moderately strong (both negative and positive) to low or no association. The strongest associations among the personality terms were between hyperactivity and excitability, calmness and patience and between obedience and trainability. Among the working attributes and working manoeuvre terms, the strongest associations were between hold and cover, and between hold and balance.

When examining associations between personality and working attribute and manoeuvre traits apart from similarly named personality descriptors, the strongest associations were between initiative and anticipation and between confidence and force.

Where genetic correlation models reached convergence, values varied across the range of potential values between nearly zero (e.g., persistence and intelligence) and nearly 1 (e.g., boldness and persistence).

Table 5a: Kendall's rank correlation coefficient for LWHDAR term scores - Personality

	Confidence	Calmness	Intelligence	Trainability	Boldness	Patience	Timidness	Persistence	Hyperactivity	Initiative	Excitability	Obedience	Nervousness	Impulsiveness	Sociability	Friendliness
Confidence																
Calmness	0.13															
Intelligence	0.34	0.41														
Trainability	0.13	0.34	0.45													
Boldness	0.61	0.03	0.28	0.16												
Patience	0.02	0.64	0.40	0.34	-0.04											
Timidness	-0.41	0.00	-0.14	-0.06	-0.43	0.05										
Persistence	0.43	0.16	0.31	0.17	0.49	0.17	-0.36									
Hyperactivity	0.06	-0.48	-0.17	-0.13	0.14	-0.40	-0.01	0.07								
Initiative	0.37	0.24	0.50	0.25	0.27	0.26	-0.23	0.40	-0.09							
Excitability	0.04	-0.40	-0.09	-0.06	0.13	-0.38	0.04	0.05	0.69	0.04						
Obedience	0.07	0.32	0.32	0.63	0.04	0.40	0.07	0.10	-0.15	0.18	-0.10					
Nervousness	-0.33	-0.22	-0.22	-0.19	-0.27	-0.17	0.50	-0.25	0.19	-0.21	0.16	-0.08				
Impulsiveness	0.01	-0.33	-0.27	-0.27	0.04	-0.39	0.04	-0.04	0.43	-0.18	0.36	-0.33	0.20			
Sociability	0.21	0.09	0.18	0.12	0.21	0.04	-0.14	0.11	0.03	0.06	0.04	0.08	-0.18	-0.01		
Friendliness	0.23	0.13	0.23	0.15	0.24	0.11	-0.11	0.14	0.01	0.09	0.05	0.16	-0.20	-0.05	0.62	
Stamina	0.22	0.11	0.20	0.18	0.23	0.09	-0.20	0.38	0.06	0.24	0.06	0.06	-0.13	0.08	0.07	0.06

Table 5b: Kendall's rank correlation coefficient for LWHDAR term scores –Working Manoeuvres and Livestock Working Attributes

	Cast	Gather	Force	Cover	Head	Hold	Balance	Break	Back	Initiative	Anticipation	Natural ability	Eye	Confidence	Calmness	Boldness	Bark 2	Bite 2	Cast 2	Force 2	Bark	Bite
Gather	0.60																					
Force	0.02	0.20																				
Cover	0.41	0.60	0.22																			
Head	0.40	0.56	0.17	0.61																		
Hold	0.37	0.52	0.18	0.67	0.60																	
Balance	0.39	0.50	0.10	0.58	0.58	0.63																
Break	0.36	0.45	0.24	0.59	0.50	0.50	0.54															
Back	0.08	0.09	0.38	0.09	0.13	0.16	0.15	0.08														
Initiative	0.29	0.44	0.36	0.41	0.44	0.36	0.40	0.37	0.31													
Anticipation	0.24	0.40	0.27	0.49	0.48	0.38	0.41	0.44	0.15	0.61												
Natural ability	0.36	0.39	0.24	0.44	0.46	0.44	0.44	0.38	0.14	0.49	0.53											
Eye	0.20	0.29	0.04	0.27	0.26	0.20	0.23	0.22	-0.03	0.21	0.28	0.31										
Confidence	0.10	0.27	0.49	0.31	0.37	0.34	0.24	0.37	0.27	0.49	0.42	0.39	0.12									
Calmness	0.42	0.40	0.03	0.34	0.33	0.42	0.35	0.32	0.03	0.31	0.22	0.35	0.13	0.25								
Boldness	0.13	0.24	0.50	0.28	0.28	0.27	0.21	0.31	0.33	0.38	0.36	0.33	0.17	0.58	0.08							
Bark 2	0.01	0.02	0.27	0.01	-0.02	0.06	0.00	0.07	0.14	0.21	0.16	0.07	-0.15	0.22	-0.03	0.13						
Bite 2	-0.01	-0.06	0.18	0.03	0.04	0.03	0.04	0.08	0.03	0.11	0.13	0.02	0.05	0.09	0.01	0.20	0.11					
Cast 2	0.48	0.38	-0.06	0.24	0.34	0.22	0.29	0.24	-0.02	0.24	0.14	0.22	0.17	0.08	0.31	0.06	-0.05	-0.07				
Force 2	0.00	0.10	0.47	0.11	0.12	0.09	0.04	0.08	0.23	0.14	0.11	0.12	-0.01	0.31	-0.15	0.33	0.25	0.09	0.02			
Bark	-0.10	-0.14	0.27	-0.10	-0.22	-0.14	-0.16	-0.08	0.20	0.11	-0.02	-0.03	-0.18	0.10	-0.15	0.07	0.46	0.09	-0.14	0.18		
Bite	-0.06	-0.05	0.13	0.01	-0.06	-0.03	-0.05	0.00	-0.02	0.01	0.00	0.02	0.12	0.02	-0.06	0.15	0.05	0.47	-0.10	0.09	0.12	
Overall ability	0.38	0.47	0.27	0.43	0.38	0.41	0.32	0.34	0.18	0.47	0.44	0.49	0.26	0.46	0.41	0.32	0.13	0.06	0.22	0.10	0.05	0.00

Table 5c: Kendall's rank correlation coefficient for LWHDAR term scores – Personality vs Working Manoeuvres and Livestock Working Attributes

	Cast	Gather	Force	Cover	Head	Hold	Balance	Break	Back	Initiative	Anticipation	Natural ability	Eye	Confidence	Calmness	Boldness	Bark 2	Bite 2	Cast 2	Force 2	Bark	Bite	Overall ability
Confidence	0.12	0.20	0.51	0.25	0.30	0.21	0.18	0.28	0.21	0.37	0.38	0.32	0.16	0.64	0.12	0.52	0.12	0.12	0.07	0.31	0.10	0.01	0.36
Calmness	0.45	0.40	-0.04	0.26	0.32	0.31	0.34	0.21	-0.03	0.25	0.21	0.33	0.15	0.09	0.70	0.00	-0.03	-0.01	0.34	-0.17	-0.19	-0.12	0.31
Intelligence	0.35	0.32	0.16	0.29	0.33	0.28	0.31	0.26	0.02	0.45	0.41	0.48	0.30	0.30	0.35	0.27	0.09	-0.03	0.22	0.04	-0.04	-0.08	0.35
Trainability	0.23	0.17	0.10	0.14	0.16	0.15	0.22	0.12	0.14	0.29	0.25	0.30	0.19	0.21	0.31	0.16	0.03	0.03	0.05	0.01	0.02	0.02	0.24
Boldness	0.04	0.19	0.50	0.17	0.23	0.16	0.10	0.22	0.24	0.31	0.35	0.28	0.16	0.58	0.04	0.62	0.22	0.19	-0.03	0.31	0.08	0.16	0.30
Patience	0.44	0.38	-0.07	0.28	0.30	0.29	0.34	0.26	-0.04	0.25	0.26	0.30	0.20	0.04	0.59	-0.03	-0.02	0.04	0.33	-0.19	-0.20	-0.05	0.28
Timidness	-0.08	-0.19	-0.36	-0.21	-0.22	-0.22	-0.20	-0.29	-0.18	-0.31	-0.33	-0.25	0.07	-0.47	-0.08	-0.44	-0.23	-0.12	0.00	-0.20	-0.12	-0.03	-0.32
Persistence	0.19	0.30	0.29	0.28	0.30	0.27	0.26	0.31	0.12	0.41	0.45	0.36	0.15	0.45	0.18	0.46	0.17	0.13	0.07	0.22	0.01	0.05	0.40
Hyperactivity	-0.26	-0.22	0.13	-0.15	-0.16	-0.21	-0.18	-0.11	0.14	-0.07	-0.04	-0.12	-0.02	0.04	-0.49	0.16	0.15	0.09	-0.24	0.22	0.22	0.15	-0.17
Inititaive	0.25	0.39	0.25	0.39	0.40	0.37	0.36	0.35	0.15	0.61	0.54	0.44	0.26	0.42	0.27	0.32	0.20	0.06	0.22	0.16	0.09	0.07	0.41
Excitability	-0.19	-0.19	0.11	-0.14	-0.16	-0.22	-0.18	-0.12	0.18	0.00	-0.05	-0.08	0.04	0.02	-0.42	0.13	0.11	0.09	-0.20	0.23	0.20	0.17	-0.18
Obedience	0.16	0.14	0.06	0.13	0.10	0.12	0.14	0.09	0.11	0.16	0.13	0.26	0.08	0.09	0.27	0.03	0.06	0.01	-0.04	-0.05	0.00	-0.02	0.15
Nervousness	-0.15	-0.20	-0.15	-0.18	-0.27	-0.15	-0.17	-0.24	-0.02	-0.27	-0.22	-0.22	-0.04	-0.41	-0.32	-0.29	-0.05	0.01	-0.13	-0.05	0.01	0.01	-0.32
Impulsiveness	-0.18	-0.18	0.04	-0.25	-0.22	-0.27	-0.26	-0.18	0.09	-0.14	-0.19	-0.26	0.02	-0.05	-0.36	0.03	-0.02	0.12	-0.16	0.12	0.14	0.11	-0.17
Sociability	0.12	0.09	0.17	0.07	0.11	0.14	0.13	0.16	0.16	0.19	0.15	0.16	0.03	0.29	0.19	0.24	0.06	0.01	0.02	-0.03	-0.08	-0.14	0.12
Friendliness	0.13	0.12	0.14	0.03	0.11	0.09	0.06	0.11	0.11	0.15	0.18	0.22	0.07	0.19	0.14	0.18	0.05	0.01	0.04	-0.07	-0.08	-0.05	0.11
Stamina	0.10	0.14	0.18	0.04	0.13	0.07	0.11	0.09	0.16	0.24	0.23	0.20	0.00	0.33	0.12	0.22	0.22	0.00	0.03	0.18	0.08	-0.05	0.14

What does this mean?

Phenotypic correlations between traits varied from no association to strong association, but in no case reached 1, indicating that no traits were completely synonymous for all survey respondents. The strength of the correlations was generally intuitive. For example, one would expect obedience and trainability to correlate. This suggests that owners had engaged thoughtfully with the LWHDAR.

There appear to be patterns between personality traits and working manoeuvres. So, attributes suggestive of different working styles or strengths are exhibited by different personalities or preferred by some owners or for some types of work. Owners' perceptions of a dog's personality, particularly regarding a contrast between boldness/confidence and calmness were accompanied by perceptions of ability with different working manoeuvres. Similar findings were noted in the principal component analyses. Further exploration of owner preferences, the most useful skills for different modes of work and the ability of dogs with different personalities to work cooperatively in teams to accomplish tasks could be fruitful.

When convergence was reached, the range observed in the genetic correlation estimates were promising. However, these early results must be interpreted with caution. Clearly, on the basis of the available data, confounding due to owner knowledge of pedigree, owner biases, maternal genetic effects, litter effects and maternal environmental effects cannot be excluded as explanations for the estimates. That said, the results certainly suggest that further investigation in this area using a customised design and a larger dataset to minimise confounders and deploy a more complex random effect structure could be fruitful.

4.3.8 Validating LWHDAF – personality traits

Before employing the LWHDAF for large-scale phenotyping, it was assessed for its accuracy in measuring the personality traits of interest.

Several studies have shown that subjective ratings can be accurate in assessing canine behaviour. We attempted to establish if this was the case with the assessment of behaviour in Working Kelpies by measuring the agreement of owner assessments of some of their dogs' temperament traits with behaviour tests. Sixty-one Kelpies were tested at 5 separate breeders.

What was done?

A number of behavioural tests were carried out to validate the LWHDAF with respect to personality traits. These included detour testing, sudden appearance testing and the passive test, all of which are briefly explained in the following section.

Behavioural tests

Detour testing

Detour testing was carried out in to assess the spatial problem-solving abilities of Working Kelpies and to use the results to validate the LWHDAF intelligence trait. A standard assessment method was used as a template for the test. This involved placing food inside a V-shaped wire (transparent) fence, without the dog watching. The dog was then walked on a lead from a point 2 metres from the outside angle to identify the food at the fence, returned to the 2 metre starting point and released. The time that the dogs took to reach the food inside the fence was measured. Dogs that showed fearfulness of new objects were excluded from the study results. We adapted this standard test to better cater for livestock working dogs.

First, livestock working dogs are trained from an early age not to move from the handler's side unless given a command. The command is usually a directional one (to travel clockwise or anticlockwise) or to act in reference to the presence of stock. This means that, when attempting to release the dogs to

obtain the food, it is largely meaningless for the dogs to be sent from the starting point without interfering with the cognition test by telling them to go around the fence.

Second, food motivation is not strong in many livestock working dogs. Their strongest motivator is to work stock; they also appear to be strongly motivated to explore the environment (possibly as a result of being released from confinement) and to follow their handlers' directions (either because this is associated with working stock or because they are trained to do so). Due to ethical considerations, livestock could not be used as the target in the detour test, so a combination of both food and the owner were chosen.

The livestock working dogs also displayed some reluctance to eat food out of the context of the kennel without permission. This is possibly a learned behaviour, that is, that eating food that is not theirs is not allowed. It was observed that the keenness to eat the food target was not related to food motivation alone. Some dogs that would complete the detour of the fence successfully would not eat the food offered during the test but would eagerly eat it when encouraged by the owner or experimenter after the test.

Modifications were made to the behaviour test to account for these working dog factors. First, the owner positioned themselves behind the plate of food without the dogs watching, and stood passively (ie without vocalising or gesturing to the dog). Then, at the start of the test, the owner called the dog's name a maximum of two times with encouragement to go to them. The completion of the test was the point at which the dog reached the owner's side, as measured by the position of the tip of their nose. Measurements were made from video recordings using a behavioural coding software program.

Sudden Appearance Testing

Sudden appearance testing was carried out to validate the LWHDAF's relevance to the so-called boldness trait by assessing the reaction of the dogs to a suddenly appearing novel object. In this test, markings were made on the ground at 10 cm, 50 cm and 100 cm distances from the novel object. The novel object in this case was a remote control car with a mesh frame, covered with sheep wool, in the general shape of an animal. It provided salient stimuli in the form of sight, sound and smell. The use of sheep's wool was chosen to motivate exploration of the object, providing that the startle and novelty aspects could be overcome by the dog when undertaking the test. The novel object was driven out from an obscured position behind a wall, with its trajectory being parallel to the dog, rather than directly towards it. The dog was held by a handler at the 2 metre mark from the object's final position and released as the object became visible from behind the wall.

After 15 seconds, the experimenter walked to the stationary object, and encouraged the dog to approach it by vocalising and gesturing. The test ended after 90 seconds or when the dog touched the object. A numbers of measurements were made from video recordings using the behavioural coding software. These measurements included the dog's initial reaction, the time it took to reach 100 cm, 50 cm and 10 cm and to touch the object.

Passive Test

Passive tests are used to assess the dogs' behavioural reactions to the presence of a stranger, and their reaction to confinement and potential frustration, as well as their response to a non-stimulating environment. The passive test was used in this case to validate the LWHDAF's relevance to sociability, calmness/excitability and impulsivity traits. A standard methodology was used as a guide, in which an observer sits in the corner of a 5 m x 6 m room, reading. The dog undertaking the test was leashed and observed for 6 minutes and measurements were made of the time the dog took to sit, drop and lie down.

The standard passive test used a single indoor facility. In our study, behavioural tests needed to be carried out on a large population of Working Kelpies, on farm, and across a large geographical area and so we needed to make some modifications. To accommodate this, a 3 m^2 enclosure with solid

timber sides of height 1.5 m was erected on each farm in a location that was as quiet as possible, and also distant from stock. The observer sat passively (reading) in the corner opposite the entrance gate, and holding one end of a long lead. The experimenter brought the dog to the entrance of the test room and, after clipping the dog lead to the observer's lead, left the room and shut the gate. The test was then video-taped for 6 minutes. Another deviation from the standard passive test was that the outdoor testing environment was inevitably more stimulating than an indoor room, and thus the measurements of the time the dog took to sit, lie down and rest gave an incomplete picture of the dog's arousal during the test. To help compensate for this, a number of other measurements were also made. These included the time the dog took to approach the observer, the number of vocalisations made, the time spent with the observer, the time engaged in walking, running, jumping, sniffing and exploring and play. The time spent standing, sitting, laying down and resting was also assessed.

What was found?

Intelligence, boldness, sociability, calmness/excitability and impulsivity traits were examined for purposes of validation of the LWHDAF.

With respect to the detour tests, in broad terms there was no strong evidence that the intelligence trait is associated with these detour tests, although there was some suggestion that time taken to approach food in young dogs is negatively associated with intelligence trait (as one goes up the other goes down). This suggests that, to achieve an accurate assessment of cognitive ability, rather than a reflection of a dog's age, dogs over one year old should be tested. The LWHDAF scores for intelligence, provided by owners, had a low range. Owners assigned scores from 3-5, (representing average to very high) for the intelligence of dogs, without the presence of stock. This could reflect a bias of the owners and an unwillingness to judge their dogs harshly. Or it could possibly mean that dogs believed to be less intelligent were simply not acquired or retained.

When the trait of 'boldness' was assessed using the 'Sudden Appearance' test, dogs that were scored highly bold by their owners approached the novel and startling object more significantly more rapidly than those dogs scored less bold by their owners.

This means that there was agreement between owners scoring their dogs as 'highly bold' and the dogs approaching a potentially threatening object quickly. Our statistical analysis showed strongest agreement between owner scores and behaviour testing in the dogs of less than one year of age.

With respect to the passive test results and owner ascribed LWHDAF calmness (no stock) scores, a moderate strength negative correlation was seen. Specifically, the calmness without stock score given by owners in the LWHDAF decreased with the total time the dog spent in rapid walking and running during the testing. The impulsivity trait may have a positive association with the sum of rapid walk and jump in dogs one year or older and with vocalisation in younger dogs. There appeared to be a mild positive association between the sociability trait and time interacting with observer but this just missed statistical significance. Finally, there was a mild but significant positive association between time interacting with observer and the bold trait in younger dogs (Table 6). During the 'Passive Test', dogs that owners considered calm spent less time in rapid movement than those considered to have less calm and more impulsive personalities. Dogs less than one year of age described as more impulsive tended to vocalise more. These younger dogs rated as 'bold' by their owner also tended to spend more time interacting with the stranger. Dogs that owners considered to be highly sociable also spent more time interacting with the stranger during the behaviour test.

Table 6: Kendall's Tau rank correlation coefficients and p-values indicating associations between subjective owner trait scores collected using the Livestock working (herding) dog assessment form (LW-HDAF) and behaviour test results.

	Behaviour test results (objective)					
LW-HDAF owner trait score (subjective)	Detour test: Latency to complete	Sudden appearance test: Latency to touch object	Passive test: Time spent running and jumping	Passive test: Number of vocalisations	Passive test: Time interacting with observer	Passive test: Latency to approach observer
Intelligence	-0.02 NS					
Boldness (all dogs)		-0.3*				
Boldness (< 1 year)		-0.6**				
Calmness (all dogs)			-0.3***			
Calmness (> 1 year of age)			-0.5***			
Impulsivity (> 1 year of age)			0.4***	0.2NS		
Impulsivity (< 1 year of age)			-0.07NS	0.5*		
Sociability					0.2NS	0.2 NS

*p<0.05
**p< 0.01
***p< 0.001
NS – not significant

4.3.9 Validating LWHDAF – working traits

Why was the study carried out?

A group of traits (23 in total) that encompassed working manoeuvres and livestock working attributes, identified from the Farm Dog Survey results, were used to develop a simple and practical score sheet

for this part of the project. This score sheet was needed to build a working behaviour profile of each farm dog assessed to determine heritability and estimated breeding value calculations as well as to assist in identifying genetic markers for the traits measured. To provide confidence in owner assessments of their dogs using this score sheet, a study was conducted to compare owner versus expert scores.

What was done?

Twenty dogs were video-recorded during a standardised working context (a yard trial). The subsequent recording was edited to conceal the handlers and their verbal and physical commands. Each owner (13 in total) was then asked to score the dogs based on their overall knowledge of working with that particular dog in the farm situation. A separate group of experts (total of 15) was then recruited and asked to use the same score sheet to assess each dog from the edited video-recordings.

What was found?

Analysis of owner versus expert and expert-only scores was undertaken to assess agreement between these cohorts. This revealed fair to moderate agreement across most traits scored (Table 7). The experts having had only a short audio-visual representation of a dog's working ability in a single context may have limited the higher agreements between the owners and experts. However, the level of agreement was sufficient to justify the use of owners' data to collect trait score data for heritability calculations. We are confident that dog owners/handlers are reliable when it comes to assessing the working behaviours of their dogs.

Table 7. Agreement between owners' scores of dogs versus experts' scores

Traits	All scorers	Experts only
Cast	0.46 (0.31-0.66)	0.49 (0.34-0.68)
Gather	0.42 (0.27-0.63)	0.45 (0.29-0.65)
Force	0.52 (0.28-0.74)	0.58 (0.35-0.78)
Cover	0.42 (0.27-0.63)	0.45 (0.29-0.65)
Head	0.38 (0.24-0.58)	0.38 (0.24-0.59)
Hold	0.39 (0.24-0.60)	0.43 (0.28-0.64)
Balance	0.42 (0.27-0.63)	0.46 (0.31-0.66)
Break	0.27 (0.16-0.47)	0.30 (0.17-0.49)
Back	0.46 (0.29-0.67)	0.47 (0.30-0.67)
Initiative	0.38 (0.22-0.59)	0.42 (0.26-0.63)
Anticipation	0.36 (0.22-0.57)	0.40 (0.25-0.60)
Natural ability	0.40 (0.23-0.62)	0.44 (0.26-0.65)
Eye	0.25 (0.14-0.44)	0.26 (0.15-0.46)
Confidence	0.39 (0.25-0.60)	0.42 (0.27-0.63)
Calmness	0.28 (0.16-0.48)	0.30 (0.18-0.50)
Boldness	0.39 (0.22-0.61)	0.40 (0.22-0.62)
Bark2	0.44 (0.24-0.66)	0.44 (0.23-0.67)
Bite2	0.35 (0.20-0.67)	0.41 (0.25-0.72)
Cast2	0.37 (0.23-0.57)	0.43 (0.28-0.64)
Force2	0.38 (0.23-0.59)	0.42 (0.26-0.63)
Bark	0.58 (0.43-0.76)	0.60 (0.45-0.77)
Bite	0.10 (0.04-0.22)	0.09 (0.03-0.20)
Overall ability	0.47 (0.30-0.68)	0.53 (0.36-0.72)

NB Traits 'cast' and 'force' were measured on the quality with which they were performed whereas 'bite' and 'bark' by the frequency with which the dog performed them when working. Meanwhile, 'cast2', 'force2', 'bark2' and 'bite2' were measured on whether the dogs performed these inadequately, adequately or excessively for the environment and livestock they were working. (See Section 4.3.4 for each trait scale used in the LWHDAF) (Range is the 95% confidence interval).

Where to now?

Notwithstanding the limitations of subjective scores, these results give us some assurance that, by choosing a method that will optimise ease of participation, we are not compromising reliability. This approach aligns with previously published evidence on the accuracy of subjective behavioural ratings. Interestingly, the dairy industry has long been using a very subjective trait of 'likeability' that is essentially asking the question: *would you like to have another cow like this one*? Using this measure, dairy scientists have established that this desirable trait is indeed an inherited one.

This brings us to the topic of the heritability of the livestock working dog personality traits, which will be presented and discussed in detail in the following section, 4.4. The reason that heritability is important is because it can indicate the expected effectiveness of a selective breeding program.

4.4 Livestock Working Dog Breeding and Genetics

As previously mentioned, breeding program manipulation takes place by careful selection of breeding animals in an attempt to increase or ‘fix’ desirable traits whilst also decreasing or removing undesirable traits. To select the best animals for breeding purposes, traits that influence livestock working 'success' and thus minimise wastage rates must be objectively assessed. This means the provision of genotyping of dogs to show the genetic regions underlying the things that breeders truly value. Development of a set of markers that reveal the biological basis of the traits of interest to breeders allows us to understand the scientific basis of behaviour and how this is passed from one generation to the next. The provision of sets of 'estimated breeding values' that enable the comparison of different dogs based on different breeding programs will provide an invaluable resource for livestock working dog breeders to meet their breeding goals more efficiently.

4.4.1 Heritability of livestock working dog traits

Heritability is a very important property of traits of interest to dog breeders as potential targets for selection. Heritability describes the proportion of the differences in performance due to differences in genetic merit and so expresses the extent to which relatives will resemble each other. This is important because it is the key to the expected effectiveness of a selective breeding program. As heritability is such an important determinant of which traits will respond best to selective breeding, knowledge of heritability is highly desirable when planning a breeding program. For example, a trait of moderate importance with a high heritability (approaching a value of 1) will be a more sensible choice for selection than a trait of the same importance with low heritability (approaching a value of 0), as a better response to selection can be expected based on the same selection pressure.

What was done?

Processing of the Working Kelpie pedigree

A multigenerational pedigree is an essential component of quantitative genetic analysis. The pedigree is used to build the numerator relationship matrix (NRM), which details the genetic relationship between every dog in the pedigree. This matrix is a crucial component of the animal model which produces heritability and breeding value estimates.

For this report, we processed a pedigree of over 84 000 dogs, up to 21 generations deep. Using computer algorithms, we identified several loops and instances of dogs listed both as sires and dams, and removed a series of errors to create a three-column pedigree compatible with many genetic analysis packages (Figure 4).

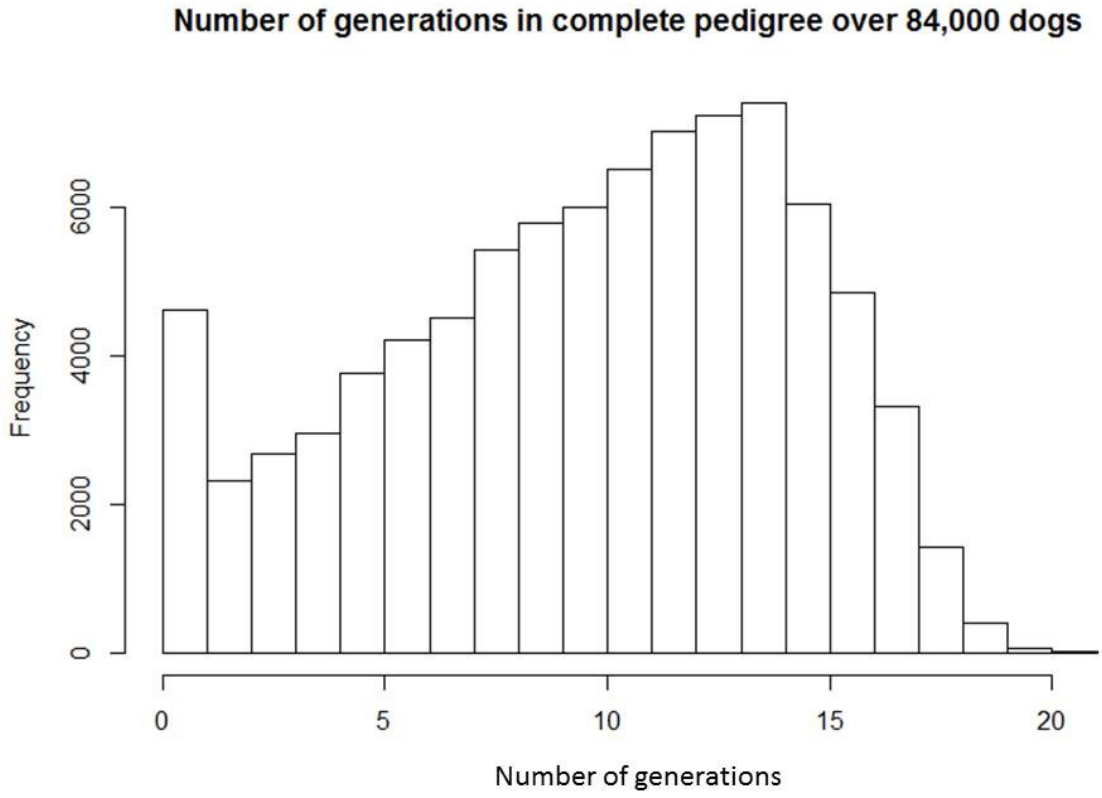

Figure 4. The number of generations in the complete pedigree of over 84 000 kelpies, up to 21 generations deep.

Using a different algorithm, we identified the key individuals that provided useful information about the modern day kelpies in our studies and created a working pedigree up to 20 generations deep and involving close to 2000 dogs to create the numerator relationship matrix required for our analyses (Figure 5).

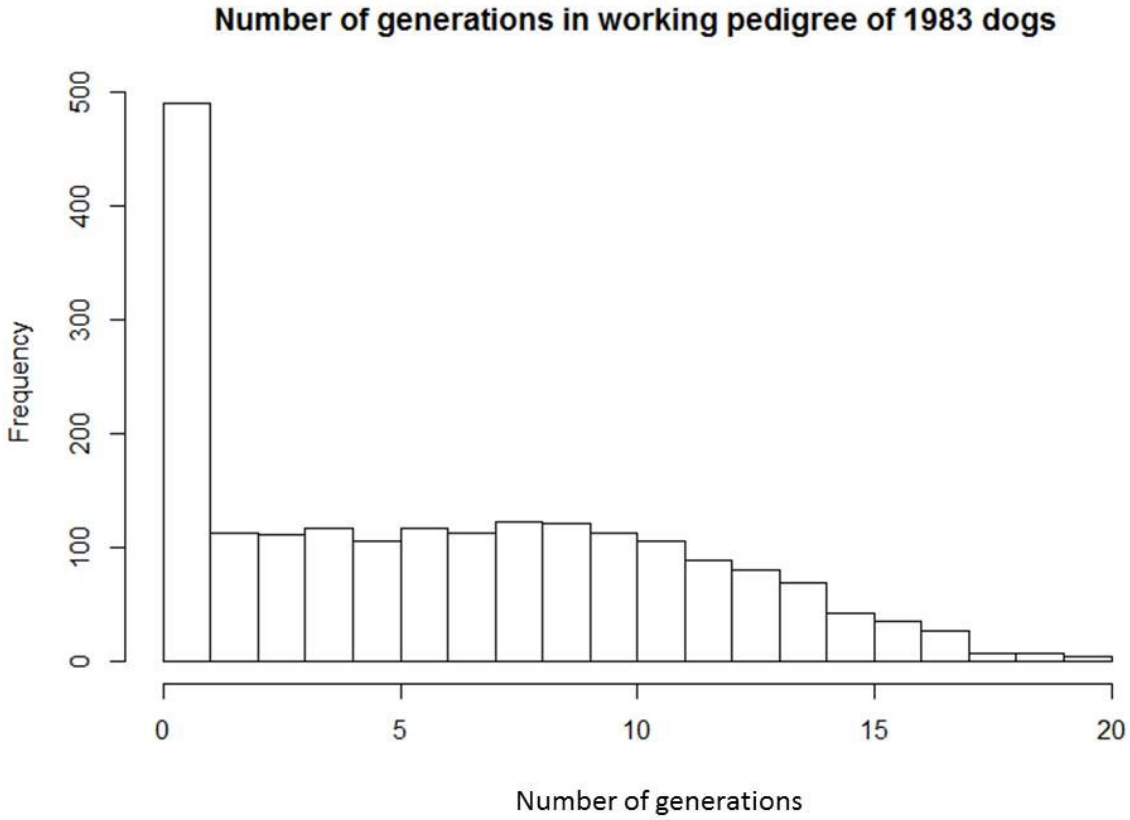

Figure 5. The number of generations in the working pedigree of 1983 kelpies that have made critical contributions to the current population.

Personality and working behaviour

A series of behavioural traits was measured in a cohort of 180 Australian Working Kelpies using the Livestock Working (Herding) Dog Assessment Form. The traits were then assembled into a series of indices, many of which were constructed from both dogs in the presence of stock and without stock observations. To estimate heritability, estimates of the additive genetic variance were obtained through statistical means.

What was found?

The report is a preliminary investigation into the heritability of behavioural traits in a cohort of Australian Working Kelpies (see Table 8). It aims to make preliminary estimates of the heritability of these potentially valuable selection objectives, which are needed for the calculation of estimated breeding values. Heritability calculations for the traits 'break', 'back', 'head', 'bite2' and 'overall ability' could not to be calculated with confidence at this stage due to sample size. The coefficient of inbreeding for Australian Working Kelpies was found to peak at between 0.7 and 0.91, depending on the depth of the pedigree analysed. These figures are comparable to those for most other breeds.

Table 8. The preliminary heritability estimates (between 0 and 1) and associated standard errors for behaviour traits in a cohort of Australian Working Kelpies.

Trait	Heritability	SE (Heritability)
Bold		
Stock	0.33	0.29
No stock	0.25	0.27
Calm		
Stock	0.29	0.25
No stock	0.24	0.23
Trainable		
Stock	0.60	0.24
No stock	0.05	0.20
Intelligent		
Stock	0.19	0.27
No stock	0.35	0.27
Impulsivity		
Stock	0.33	0.22
No stock	0.02	0.20
Sociability	0.23	0.29
Stamina	0.46	0.19
Cast	0.42	0.35
Force	0.66	0.65
Gather	0.01	0.24
Hold	0.05	0.30
Balance	0.09	0.33
Cover	0.21	0.48
Eye	0.49	0.35
Bark	0.26	0.23
Bite	0.32	0.26
Bark2	0.03	0.22
Cast2	0.04	0.33
Force2	0.37	0.33
Natural ability	0.28	0.30
Initiative	0.08	0.31
Anticipation	0.34	0.35

What does this mean?

Dog breeders must consider a large number of traits and breeding objectives when making selection decisions. Due to both practical limitations and also the need to maintain genetic diversity, the extent to which breeders can be selective with their breeding stock is limited. As increasingly higher benchmarks—and increasingly more benchmarks—for breeding suitability are added, fewer of the available animals can meet the required standard. This can reduce genetic diversity and potentially increase inbreeding, putting animals at risk of genetic disease. We have to consider selection pressure (the 'choosiness' with which animals are selected as parents) as a limited resource, and use it accordingly.

This report contains preliminary heritability estimates for indices based on ordinal adjectival descriptors of valuable behavioural traits in a population of Australian Working Kelpies (Table 6). Some values are near zero and may not have a genetic basis. However, it is very encouraging to note that many of these preliminary estimates are greater than 0.15, suggesting that these traits may be suitable to form part of a selective breeding program for behaviour in Working Kelpies.

Estimated Breeding Values

Estimated Breeding Values (EBVs) may be calculated by the same sort of analyses with which we may estimate heritability. EBVs represent the best estimate of a dog's genetic merit according to the statistical model to which the data best fit. For moderately heritable traits, EBVs represent a more accurate indication of a dog's genetic merit than its own test result, because it can be corrected for fixed effects and includes information provided by the test results of relatives. EBVs can also be calculated for dogs for which we do not have test results by inferring information from the test results of their relatives.

Using the standard errors of the estimated breeding value, the additive genetic variance and the inbreeding coefficient of the dog, it is possible to calculate the accuracy of a breeding value estimate. Some anonymised examples of estimated breeding values produced by the models and their standard error are reported in Table 9. These dogs had exceptional EBVs for boldness with stock. Clearly, the scores for the trait of the herding trait of anticipation are lower.

Table 9. Some anonymised examples of estimated breeding values and their standard errors as produced by the statistical models.

	BOLD stock		Anticipation	
	EBV	Accuracy(EBV)	EBV	Accuracy(EBV)
Dog 1	0.4988	0.579255	0.1747	0.579560
Dog 2	0.4477	0.652601	-0.3709	0.513377
Dog 3	0.4293	0.620064	-0.3388	0.444141
Dog 4	0.3869	0.574358	0.445	0.596112
Dog 5	0.3782	0.600312	-0.3438	0.425522
Dog 6	0.3719	0.568945	-0.3433	0.60076
Dog 7	0.3598	0.627838	-0.2608	0.471747

Where to now?

This report provides preliminary evidence that important economic behaviours in Australian Working Kelpies can be described by heritable indices. The most important limitations of these preliminary heritability estimates are the relatively large standard errors. It is expected that these limitations can be addressed by the analysis of a larger and more complete data set as industry uptake continues to grow and traits are reported for subsequent generations of dogs. This process is on-going with the online portal we have developed that makes the Livestock Working (Herding) Dog Assessment Form available for livestock working dog owners to contribute to. With a larger dataset, there is also the potential for exploring genetic correlation between indices and preliminary development of estimated breeding values for these traits. Confirming the heritability of these indices through an expanded analysis and further quantitative genetic analysis has the potential to meaningfully inform breeders of Working Kelpies interested in selecting for these behaviours.

Estimated breeding values are an important technology for improving accuracy of selection by pooling phenotypes from relatives together to get a more accurate understanding of each breeding candidate's

genetic merit. Estimated breeding values are especially useful for traits with low-to-moderate, to moderate heritability estimates

4.4.2 Examining the genetic basis for selection for working ability

Why was the study carried out?

Handlers and breeders of livestock working dogs have strong opinions on desirable characteristics in the breeds that they use to handle and work stock. Most of these characteristics are related to conformation or behaviour. This study employed a technique called 'selective sweep analysis' to reveal more about the external characteristics (often called the 'phenotype') that are regarded as desirable in two very different cohorts of dogs that share a common breed origin. One group of dogs is intensively selected for its ability to work with livestock (the Australian Working Kelpie) whilst the other group is selected for conformation and companionship (the Australian Kelpie). The Australian Working Kelpie breed represents dogs registered with the Working Kelpie Council and is the product of more than a century of breeding by Australian sheep and cattle farmers who have selected dogs based on livestock working ability. The Australian Kelpie represents dogs registered with the Australian National Kennel Council and breeding is focused on companion animals that are more likely to be involved in activities such as showing and obedience and agility work. Both breeds can be traced back to the same original breeding stock. The Australian Kelpie (Figure 7) is frequently self-coloured brown or black (sometimes reported as 'red' or 'chocolate') whilst the Australian Working Kelpie (Figure 6) usually also has tan markings (commonly referred to as 'black and tan' or 'red and tan'). This study was designed to identify regions that underpin the observable behaviours and physical differences between the two types of kelpie. This sort of information can help us define effective selection and breeding programs.

Figure 6. Australian Working Kelpie (Photo credit: Jonathan Early)

Figure 7. Australian Kelpie (photo credit: Jenny Bayliss Photography)

What was done?

Twelve Australian Working Kelpie (AWK) dogs and twelve Australian Kelpie (AK) dogs were used in the primary analysis. In the secondary analysis (carried out to validate aspects of the primary study) a further ten AK and 28 AWK dogs were used. Blood and saliva samples were collected, processed and analysed using standard methodology under University of Sydney ethics clearance.

What was found?

A selective sweep spanning 3 megabases on chromosome 3 was identified in the AWK. This region is the location of genes relating to fear-memory formation and pain perception. Selective sweep loci of similar magnitude were seen in the AK. On chromosome 8 is a locus, which may be related to behavioural excitability, and on chromosome 30 is a smaller locus, which is most likely related to body shape and structure.

What does this mean?

We know that the HOMER1 gene (positional candidate gene on chromosome 3) is associated with fear memory formation and pain perception in the mouse. Australian livestock working dogs deal with hostile working environments on a regular basis. A large number of common ground covers including species such as cathead burr (*Tribulus terrestris*), Bathurst burr (*Xanthium spp*) and Scotch thistle (*Onopordum acanthium*) are spiked in nature and traumatic injuries caused by livestock, fences and vehicles are well documented. Dogs that can overcome pain and continue working in such environments are strong assets to the handler. Interestingly, an important founder sire for the AWK, a blue dog named 'Coil' is renowned for his endurance and exceptional pain tolerance. Coil won the 1898 Sydney trial achieving a perfect score despite competing with a broken foreleg. Thus, it seems as if AWK have been selected for their resilience and ability to tolerate working in a harsh and often painful environment.

With respect to the AK, the major identified sweep locus on chromosome 8 contains genes that relate to both behaviour and body shape and structure. Interestingly, a gene that is linked with hyperactivity in the mouse was identified close to the region of interest in the AK. Given the activity of genes in this region that driver for the chromosome 30 sweep locus in the AK likely has a body shape and function, rather than behavioural, basis.

This element of the current project has revealed that while livestock working dog breeders may be selecting primarily for traits such as stock sense and boldness, they are actually favouring breeding from dogs that can continue to focus and work despite a hostile working environment and the presence of often significant discomfort levels. The Australian Kelpie is not usually employed in stock work but is valued as a companion dog and is usually kept in an urban environment. This group of kelpies appears to be selected predominantly for body shape and structure rather than behaviour.

Where to now?

Domestic dogs have been extensively selected for various attributes such as size, shape and behaviours. The behavioural and morphological characteristics of the dog are referred to as its phenotype. When selection is based upon a common breeding goal, progress in breed improvement is enhanced. Current selection practices in the breeding of livestock working dogs rely on rigorous training and testing of breeding candidates prior to selection. This results in considerable time and expense. To successfully manage a livestock working dog breeding program requires that genetic information for individual dogs should be integrated optimally with the broader information resource available for each dog. This might be done through a combination of phenotypic analyses, assessment of genetic diversity and the integration of genetic marker information through the use of genotyping arrays. There may be merit in assessing how morphological traits, such as pad conformation, relate to these genetic findings.

4.4.3 Gene mapping for specific working traits

Why was the study done?

In our ambitious project we were, and continue to be, interested in a number of questions. One of these questions relates to how much influence genetics has upon the various working behaviours and livestock working dogs types? Another question asks whether we can produce a platform through which livestock working dog breeders can improve selection of livestock working dogs?

To investigate each question required a different approach. First, in order to assess the influence of genetics on livestock working dog success, we examined the problem from two angles: both from the bottom up (from the DNA to the behaviour) and from the top down (from the behaviour to the underlying breeding value).

Bottom-up approach

To try to discover the individual genes that have the most impact on working behaviour, geneticists typically use panels of genetic markers to locate the influential genes. For this project, we employed a combination of genotyping arrays (which comprise vast samplings of single letter differences in the dog DNA at over 170 000 locations in the genome) and also next-generation sequencing that enables us to read nearly every letter of the dog's 2.5 billion letter DNA genome.

The value of using genotyping arrays is that they have relatively low cost and are relatively easy to analyse. This allows us to examine trends in many dogs. However, this ease comes at the cost of being able to get only a quite low-resolution picture of what is happening in the DNA. To overcome this, we try to use as many dogs as possible and to sensibly group dogs for comparison, so that in the broader DNA landscape the dogs have very little difference between them, but if they then have quite different working behaviour, this will enable the signals that come from the relevant genes to 'stand-out' from the genetic background. We can also use families to assess the differences, and this tends to give a lower intensity but broader signal in our data.

Another method that we employed was to use the arrays to compare the DNA profiles of Australian Working Kelpies (Working Kelpie Council registered) with Australian Kelpies (Australian National

Kennel Council registered). By examining just a modest number of dogs from each cohort, we were able to detect regions of DNA that were relatively stable (fixed) in each group and where the groups were quite different from one another in the segments of DNA beneath the signals. The results of this analysis are presented in section 4.4.2 of this report and reveal that the major selected factor in working success for WKC centred on genes that enable dogs to feel pain and to form fear-based memories. Whilst the work in this project focused on dog behaviour—personality and livestock working traits—it has also questioned some of the current thinking on health problems, most noticeably the disease of cerebellar abiotrophy (CA). Our studies identified an area on interest on chromosome 3 with respect to working success for the AWK. It is not the first time that the locus on chromosome 3 has been identified in research on this breed. This area has previously been identified by other researchers as possibly of interest in the disease of CA. We predict that this disease association study had included a mixture of AK and AWK in the control group of dogs and so the results had been unwittingly muddied.

When we look at the full DNA sequences we are able to look between the markers and determine what is happening at the individual DNA letter level. The DNA differences that underlie subtle differences between dog behaviours are unlikely to be as stark as those that completely disable the production of proteins. Instead, we expect to find subtle differences in the switches and dials that promote the fine control of gene expression. Proving causation for these observed differences is often difficult. Nonetheless, it is well worth doing because it allows us to better understand the biology of behaviour. We expect work in this portion of the project to continue for some time.

Top-down approach

Another way to understand the genetics of behavioural differences is to apply a top-down approach. For this portion of the project, we have applied statistical genetics techniques based on the actual observed differences between behaviours within families of dogs to calculate heritabilities for the various behavioural traits. These analyses tell us that many of the traits that livestock working dog breeders and handlers care about have strong inherited components. This analysis justifies our use of the bottom-up approach to investigate the genetic differences further. This part of our research is detailed in section 4.4.1 of this report.

We also asked the question: can we create a platform through which livestock working dog breeders can improve selection of livestock working dogs? A significant outcome from the top-down approach is that it provides the framework for a practical solution that will help livestock working dog breeders to better select breeding dogs and to identify other kennels that have similar breeding goals to their own. Those in the livestock industries may be familiar with the concept of estimated breeding values. Estimated breeding values look at the traits that are similar for dogs within families and different for dogs between families. The breeding value of a dog is its predicted capacity to pass on good genes (which need not be individually identified) to its progeny. This is the method that is scientifically preferred to enable breeders to achieve genetic improvement in traits that are considered to be complex. Estimated breeding values account for environmental differences between dogs. Environmental differences include things such as access to high quality training and exercise.

The major part of this project was to devise a method by which dogs could be assessed to identify these differences. We needed to compromise between evaluation methods that might be highly accurate (such as behavioural assessments) with those that are accessible to a broader range of participants (subjective owner ratings). In the end, we elected to base our ultimate breeding value calculations on owner-handler ratings of dog abilities. While we appreciate this may have lower accuracy than other methods, we still expect that by sampling a broad range of related dogs, we can determine the flow of good genes among the dogs that will enable us to give some overview of their relative talents. By sampling more dogs, we can use statistical averaging to arrive at higher accuracy evaluations for breeding dogs higher in the pedigree. This owner-based rating method also allows behavioural data collection into the future as it does not rely as heavily on financial and manpower input once the system is in place.

The provision of a resource that quantifies the performances across a range of traits will provide an unprecedented opportunity for breeders to identify other lines of dogs with qualities similar to those that they value in their breeding program. Breeders will be readily able to identify other kennels from outside of their local area that produce dogs like their own. This will enable them to make better use of outcrossing in their breeding programs. There will be reduced risk of purchasers obtaining dogs that are of a kind unsuited to their needs.

Valuable behavioural phenotypes in Australian Farm Dogs

THE ISSUE

The Australian working dog makes a profound contribution to Australia's livestock industries and to the rural economy. There are significant gaps in our knowledge relating to livestock working dogs.

QUESTIONS WE ASKED:

- What work do we ask them to do and how hard do they work?
- How do we breed and select the best dogs for the job?
- What is the economic value of the Australian livestock working dog?
- What are the environmental factors associated with success?

WHAT WE FOUND:

- Our study identified the working behaviours of most value to the livestock working dog community, and found that owners were generally good dog ability assessors.
  - Differences in signals of selection in the DNA of 'Working' and 'non-working' Kelpies were exposed.
- Our study revealed that livestock working dogs typically provided their owners with a five-fold return on investment.
  - Management factors and handler attributes that are related to the success of dogs in the workplace were identified.
- Our study showed heritability estimates for the traits of value that indicate that genetic progress is possible through selection for these traits'
- Preliminary results suggest that yard trial scores are useful in understanding dog's efficiency in yard work and that high scoring dogs may cause less stress to sheep

Our study has provided a rigorous scientific approach to reveal a number of important new findings and expose significant factors in the human-dog-stock working relationship. This study provides the groundwork needed for extension work of huge benefit to producers.

Producers can use these results to assist in decision-making that allows savings, and improvement of productivity, whilst demonstrating increased social responsibility and improved animal welfare practices.

Results

Our research has provided much valuable information and insight into identifying opportunities for optimising the breeding and management of Australian livestock working dogs. The work has already resulted in five published papers, with a further four in progress at this time. Not only has our research already contributed much new understanding to this field, it has also established robust frameworks for ongoing research, development and extension.

Producer consultation

The results are presented in detail within the body of this report, in the relevant chapter sections. The findings from the Australian Farm Dog Survey are presented in Section 4.1.1. In brief, our survey results give an overview of the Australian livestock working dog industry and show that an average of 3-4 dogs are owned per farm. Ninety per cent of these dogs are Kelpies, Border collies and their crosses. The majority of livestock working dogs are used as 'all-rounders', or utility dogs. Twenty seven per cent of the dogs reported in the survey were used for mustering, eight per cent for yard work, and only two per cent were used exclusively for trialling. Sixty two per cent of these dogs were acquired from a breeder and 70 per cent of dogs purchased cost less than $500. Seventy four per cent of dogs were acquired unstarted, with 17 per cent started and only nine per cent fully trained. Livestock working dog breeders reported that 86 per cent breed utility dogs, with 7 per cent breeding yard dogs or trialling dogs. Forty-six per cent of livestock working dog breeders who responded to the survey breed dogs only to unrelated dogs, with 34 per cent breeding dogs to a grandsire or an uncle and seven per cent breeding to a sire. With respect to husbandry factors, 83 per cent of dogs are exercised daily or more and approximately one-third of dogs are kept on chains, one-third in yards, and one-third in cages. Of our respondents, 39 per cent had attended a dog training school and 39 per cent had not consulted any training resources.

Economic worth

An estimate was then made of the economic worth of the livestock working dog and these results and discussion are detailed in Section 4.1.2. The typical livestock working dog's value was estimated by calculating the hours of work and expressed as a function of total lifetime expenditure to derive the return the owners receive on their investment. Our research showed that the typical livestock working dog represents a 5.2 fold return on investment.

Environmental factors

The second segment of the report (Section 4.2) describes and discusses environmental factors associated with success rates of Australian livestock working dogs. Management practices and handler attributes that contribute to dog success rates were identified. In brief, above average success rates were associated with a series of management factors including housing dogs in yards (especially with company), exercising dogs daily, positive reinforcement training, trial participation and aspects of owner personality. Below average success rates were associated with factors such as electric shock collar use, acquiring fully trained, older dogs, and lack of insurance for dogs. The athletic performance and workload during a representative peak work period (shearing) was also studied. This revealed that dogs typically worked for five hours a day, five days a week and travelled over 40 km per day with top speeds of 37 km per hour. Our studies also explored dog-livestock interactions in yard trials and found that yard trial scores offer a useful means of verifying a dog’s efficiency in yard work and that high-scoring dogs may minimise sheep stress.

Behavioural phenotypes

The third segment of the report (Section 4.3) deals with studies of behavioural phenotypes in large numbers of Working Kelpies, to inform breeding and genetics work. A pilot study was first carried out to obtain information relating to the terminology that characterises Australian working dog manuals. The results of this pilot study are reported in Section 4.3.1. In brief, little concordance was found in the use of terms by authors of eight livestock working dog training manuals. This may help to explain why the current manuals can sometimes confuse those seeking how to select and handle dogs optimally. This pilot study also identified a group of core traits (cast, head, bark, eye, force, hold, confidence and keenness) that exemplify the successful Australian working dog. Such working manoeuvres and skills represent the core requirements of the working farm dog that, along with health traits already strongly selected for, should be the focus when selecting breeding stock.

The next section of the report opens with a review of the constraints on research into canine behavioural genetics. The behaviour of livestock working dogs can be evaluated in two broad contexts, namely personality (or temperament) traits and livestock herding behaviours. Results relating to the measurement of these traits of importance are presented in Section 4.3.3 before discussion of the formation of the Livestock Working (Herding) Dog Assessment Form (LWHDAF) in Section 4.3.4 and then validation of this form for both personality and working traits. Intelligence, boldness, sociability, calmness/excitability and impulsivity traits were examined for purposes of validation of the LWHDAF. A number of behavioural tests of personality traits were carried out to validate the LWHDAF. As far as herding traits were concerned, a group of 23 that encompassed working manoeuvres and livestock working attributes, identified from the Farm Dog Survey results, were used to develop a simple and practical score sheet. To provide confidence in owner assessments of their dogs using this score sheet, a study was conducted to compare owner versus expert scores. Analysis of owner versus expert and expert-only scores was undertaken to assess agreement between these cohorts. This revealed fair-to-moderate agreement across most traits scored and provides confidence that dog owners/handlers are reliable when it comes to assessing the working behaviour of their dogs.

Working dog breeding and genetics

The final section of the report (Section 4.4) presents findings relating to livestock working dog breeding and genetics. It required us to format the pedigree of over 80 000 kelpies. Preliminary heritability estimates for behaviour traits in a cohort of Australian Working Kelpies are presented in Section 4.4.1. These results provide preliminary indications of the proportion of traits attributable to genetic merit. Heritability estimates for 22 traits are presented, with many of the estimates being of an order that suggests that these traits may be suitable to form part of a selective breeding program for behaviour in Working Kelpies. Estimated Breeding Values (EBVs) may be calculated by the same sort of analyses with which we may estimate heritability. EBVs are particularly useful for traits with low to moderate heritability estimates, and also for improving accuracy of selection by pooling phenotypes from relatives together to get a more accurate understanding of each breeding candidate's genetic merit. Some examples of EBVs for both personality and herding traits as produced by the statistical models are presented in Section 4.4.1. In terms of the genetic regions underpinning behaviour, a comparison was made, using selective sweep analysis, of the genomic architecture between two breeds that are derived from common foundation stock but with selection for different traits. The Australian Working Kelpie (AWK) breed represents dogs registered with the Working Kelpie Council and has been selected and bred for livestock working ability. The Australian Kelpie (AK) has been bred as a companion and sporting animal and is represented by the Australian National Kennel Council (ANKC). Our results reveal that active livestock working dogs of the AWK breed have been bred primarily for gene loci influencing pain perception and memory retention, and thus the ability to continue to work in hostile and potentially painful environments. Dogs of the AK breed, in contrast, have been subject to selection for body shape and coat colour.

Implications

The optimisation of livestock working dog performance involves understanding and addressing husbandry, training and management techniques. The importance of addressing dog welfare and the quality of the human-dog relationship is indicated by our findings. These findings provide the groundwork for further studies and extension programs.

The quantification of the hugely important contribution that livestock working dogs make to farm labour efficiency justifies focusing resources into optimising their efficiency. Producers are now able to make financial decisions related to dog ownership, training and breeding on an evidence-based basis.

Heritability estimates indicate that many of the traits that working dog breeders and handlers value have strongly inherited components. They give an indication of the expected effectiveness of a selective breeding program and can be used to generate estimated breeding values. These will help breeders to better select breeding dogs and to identify other kennels that have similar breeding goals to their own.

A specific area of the genome has been identified in the Australian Working Kelpie that appears to reflect breeders' emphasise on selecting dogs for the ability to continue working in hostile environments. To better understand the biology of behaviour, work continues to discover the individual genes that have the most impact on working behaviour.

Recommendations

This report and its recommendations align with the DAFF Working Dog Industry Action Plan (Branson et al 2012) that described the need for an umbrella research body to coordinate research and development; manage and fund priority research and facilitate translation of results into practical outcomes for industry

Our project has adopted a rigorous scientific approach to reveal a number of important new findings and provide the groundwork needed to provide extension work of huge benefit to industry producers. We recommend that the industry acknowledges the value of the traits we have reported here and uses the indicative heritability estimates for personality and herding traits in breeding plans. Producers can use this report to assist in decision-making that allows cost savings and productivity improvements, whilst also demonstrating increased social responsibility and improved animal welfare practices. Implementation of the results depends on on-going industry buy-in to grow the current data-set (over generations of dogs) and improve the accuracy of genetic parameters and the usefulness of genetic evaluation system. As such, promotion of working dog performance science in general is an important next step. Without it, the scientific advancements in behaviour, genetics and statistical analysis may fail to increase the number of 'fit for purpose' dogs on farms.

We have produced methods of scoring dog husbandry in a bid to optimise their output in the workplace. We recommend that information technology is used to help producers to manage their dogs as well as possible. The tools we have developed for assessing dogs and their breeding merit need to be used in light of an appreciation that handlers and husbandry techniques can compromise the potential of working dogs. Given that those who exercise their dogs out of work and those who trial their dogs as well as working them at home have a reduced failure rate, extension programs that help producers to optimise their dogmanship would appear to have merit.

Appendix A: Published papers arising from this project

Arnott ER, Early JB, Wade CM, McGreevy PD. 2014. Environmental Factors Associated with Success Rates of Australian Stock Herding Dog, *PLoS ONE* 9(8):e104457

Arnott, ER, Early, JB, Wade, CM and McGreevy PD. 2014. Estimating the economic value of Australian stock herding dogs *Animal Welfare* 23, 189-197

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Appendix B: Works in progress as a result of this project

Early, JB, Arnott, ER, Wade, C.M, McGreevy, P.D. 2015 Interval dogs: Results and evaluation of Global Positioning System (GPS) units in measuring athletic performance in stock herding dogs. J*ournal of Veterinary Behavior: Clinical Applications and Research*. *Submitted*

Early, JB, Aalders, J, Arnott, ER, Lomax, S, Wade, CM, McGreevy, P.D. 2015. Dog-livestock interaction: Canine and competition factors associated with sheep behaviour in yard trials.

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Glossary

Backing: action of a dog jumping up onto sheep's backs in order to assist in moving them in tight spaces such as in yards, sheds or trucks.

Balance: position a dog assumes in relation to the livestock and the handler that is best suited to move the livestock to the desired location efficiently.

Break: Type of movement a dog performs to move around and redirect livestock usually when some animals separate from the main group.

Cast: initial movement of a dog around to the far side, in relation to the handler, of the livestock in order to gather and deliver them back towards the handler.

Classical conditioning: A training procedure in which some initially neutral stimulus (conditioned stimulus or CS; e.g. a sound of low to moderate intensity) is paired with a response-eliciting event (unconditioned stimulus or US; e.g. food) with the frequent result that the CS comes to elicit the same or a related response.

Conformation: Features of the external morphology (viz relative musculoskeletal dimensions) of a dog that interest breeders and exhibitors, not least because they can affect its performance.

Conscientiousness: the personality trait of being, thorough, careful or vigilant. Conscientiousness implies the intention to do a job well.

Cover: type of movement a dog uses around livestock while keeping them together.

Cue: Stimulus (including command or context) that elicits an instrumental response (see Discriminative stimulus) or signals the arrival of a positive reinforcer (see Conditioned stimulus).

Epigenetics: the study of changes in organisms caused by modification of gene expression rather than alterations in the genetic code itself.

Ethology: Systematic observation and description of behaviour intended to improve understanding of its mechanism, function, development and evolution.

Eye: postural behaviour that involves staring at livestock from a stationary position or involve stalking-like movement. Considered to be a remnant of stalking behaviour that forms part of the predatory sequence in wild dogs and wolves.

Exploration: Any activity that offers the individual the potential to acquire new information about itself or its environment.

Force: pressure applied by the dog in order to move livestock.

Genome: A genome is an organism's complete set of DNA including all its genes.

GPS: Global Positioning System.

Heading: movement of a dog to the front of a group of livestock to stop or redirect their movement.

Hold: the action of a dog to keep livestock together.

Heritability: the proportion of the phenotypic variance attributable to differences in genetic merit. As it represents the extent to which relatives will resemble each other, it also expresses the expected effectiveness of a selective breeding program.

Latency: the time interval between stimulation and response.

Learning: The process underlying relatively permanent changes in behaviour or acquisition of knowledge.

Negative punishment: A procedure whereby a reinforcer is removed or made unavailable if an unwanted response is made. See also omission training (qv).

Neophobia: Fear of novel stimuli.

Neuroticism: Neuroticism is also sometimes called Emotional Stability. This dimension relates to one's emotional stability and degree of negative emotions. People that score high on neuroticism often experience emotional instability and negative emotions. Traits include being moody and tense.

Obedience trials: Competitions to compare the compliance of dogs to handler's commands in a number of traditional exercises on and off the lead.

Punishment: A decrease in the likelihood of a response due to the presentation of an aversive stimulus or, in the case of negative punishment, the removal of a reinforcing stimulus.

Reinforcement: In instrumental conditioning (qv) this refers to the process whereby some event, usually one of some significance to the animal, makes the preceding response more likely to occur in future.

Send away: An obedience exercise that involves a dog travelling away from its handler in a given direction governed by the handler.

Sit Stay: An obedience exercise that involves a dog remaining in a sitting position for a defined period with or, in the case of advanced dogs, without the owner present.

Standard error: a measure of the accuracy with which a sample represents a population. The smaller the standard error, the more representative the sample will be of the overall population.

Stress: Refers either to a set of events, usually aversive ones, that put pressure on an individual or to the state induced by such pressure

Trait: characteristics or attributes of an organism that are expressed by genes and/or influenced by the environment. Traits include physical attributes such as coat colour in horses, and behavioural characteristics, such as nesting in birds.

Working dog trials: Competitions designed to show the absolute and relative ability of dogs as they perform specific trained responses in challenges, categorized according to their complexity, which include companion dog (CD), trials dog (TD), working dog (WD) and police dog (PD) classes.

Recommended reading list

Note please: this is by no means a comprehensive or exhaustive list of recommended readings. It represents a cross section of important works in the field and useful background information.

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Valuable behavioural phenotypes in Australian farm dogs

By PD McGreevy, CM Wade, ER Arnott, JB Early

October 2015

Pub. No. 15/081

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