# final report

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# National Wild Dog Metrics Project

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NATIONAL
WILD DOG
ACTION PLAN

# National Wild Dog Metrics Project

## B.AWW.0244 Final Report

September 2016

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miracle dog
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## Acknowledgements

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## Disclaimer

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## Abbreviations used in this document

| | |
|---|---|
| ABARES | Australian Bureau of Agricultural and Resource Economics and Sciences |
| AWI | Australian Wool Innovation |
| CI | Confidence interval |
| IACRC | Invasive Animals Cooperative Research centre |
| IGAB | Intergovernmental Agreement on Biosecurity |
| LCL | Lower confidence limit |
| MER | Monitoring, evaluation and reporting |
| MLA | Meat & Livestock Australia |
| NLWRA | National Land & Water Resources Audit |
| NWDAP (ISC) | National Wild Dog Action Plan (Implementation Steering Committee) |
| SOP | Standard operating procedure |
| UCL | Upper confidence limit |
| WDAG | Wild dog action group |

## Purpose of this report

The control, management and assessment of the impact of wild dogs in Australia are limited by the lack of an agreed set of metrics for measuring the effectiveness of management activities and the program as a whole. Additionally, significant resources are invested by Commonwealth and state/territory jurisdictions, and by industry, in wild dog management every year. If an appropriate return on investment on these resources cannot be demonstrated, these resources will progressively decline as they are shifted into areas of more demonstrable need. This requires credible metrics.

This report presents the findings of a project, commissioned by the National Wild Dog Action Plan (NWDAP) Implementation Steering Committee (ISC) through Invasive Animals Ltd, to:

- Develop and gain in-principle adoption of minimal metrics standards for assessing the impacts and efficacy of wild dog management for local, state and national scales;
- Seek endorsement of the developed metrics as the standard by the NWDAPISC;
- Integrate agreed minimum metrics into Wild Dog Management Plan template and distribute through regional and local networks; and
- Gain adoption of minimum metrics at jurisdictional level and identify/establish methods for collection and integration into a national database.

Much of the content of this report is contained in Appendix 3, which reproduces the main elements of a discussion paper prepared as a key milestone in the project. The discussion paper explores what outcomes might be required from a set of national metrics and how candidate metrics might be assessed for inclusion in a national system; describes current jurisdictional monitoring, evaluation and reporting with respect to wild dogs; discusses the considerable challenges of developing metrics for wild dog populations and their impacts; proposes a range of candidate metrics for discussion; and explains the statistical methodologies that will be required to draw meaningful inferences from some of the nominated metrics.

## Approach to the project

The project involved:

1. A desktop review of relevant published and grey literature, and interviews with a range of stakeholders from the various jurisdictions and affected industries. A listing of the key documents reviewed is provided in Appendix 1. Interviewees for the project, including those who attended the stakeholder workshop (see below) are listed in Appendix 2.
2. Preparation of a discussion paper which:
   - Described the findings of the desktop review and consultation phases of the project with respect to:
     - The range of dog control activities currently undertaken by jurisdictions and industry in wild dog control;
     - Data collection formats and methods, metrics and reporting systems currently in use;
     - The legislative, political and other requirements of the various stakeholders in respect to metrics; and
     - Metrics that might be considered for future adoption, and their strengths and weaknesses;
   - Posed questions for discussion at a stakeholder workshop, particularly where there were significant areas of disagreement or uncertainty;
   - Made preliminary recommendations in respect to a set of national metrics and its implementation; and
   - Proposed draft Communications and Implementation Plans for a national set of metrics.

   The discussion paper was circulated to a group of stakeholders identified in conjunction with a project steering group. The paper has been included in this report as Appendix 3.
3. Conduct of a stakeholder workshop, to review and explore the findings of the discussion paper and to agree a set of minimum national metrics, key performance indicators and a communication strategy for them. This workshop was held in Sydney on 2 December 2015.
4. Finalisation of this report, incorporating the main elements of the discussion paper and the outcomes of the workshop.

## Main conclusions from the discussion paper

The following points summarise the main conclusions of the discussion paper (Appendix 3), which were subsequently discussed at the industry workshop.

- No jurisdiction is currently using metrics for wild dog management that could be simply scaled up for national application.

- Most metrics currently in use are based on voluntary reporting and as such are very prone to reporting bias.
- Meaningful data could be collected and used to demonstrate efficacy of wild dog control measures. A promising metric at an impact level is the time interval between attacks (median and quartile values) for properties that undertake 'complete' reporting. This is a rate metric that is resistant to differences in absolute numbers of (voluntary) participants who are reporting. This innate robustness provides stability and greater validity for comparison between and within regions across time. Several other options were examined and dismissed including abattoir data and changes in lambing or calving rates.
- A range of lower-level metrics such as the weighted proportion of properties (by number, area or livestock numbers) in a district participating in collective wild dog control activities should also be collected and reported.
- For the time between attacks data to be useful, some structured activity will be required to supplement the current emphasis on voluntarily-reported data. Consideration should be given to the idea of a series of 'super observers' – individuals who can be relied upon to collect and report information reliably and consistently such that the 'completeness' of reporting is constant across time. These engaged, active, relevant and resourced individuals could be commissioned to undertake longitudinal and sample-based surveys of the background dog population and/or dog encounter events.
- There is a need for additional coordination of wild dog action groups (WDAGs) by people with expertise in both the practical control of wild dogs and understanding of data collection, analysis and reporting processes. These coordinators would direct, focus and encourage the collection of data in a consistent and complete a manner as possible, and would also liaise with the central database (at state level) to assist in the aggregation of data and to provide an indication of the completeness of data capture.
- Useful data on lower-level metrics (inputs, activities, participation, human responses, practices) are important and can be relatively easily captured, provided clear process is relayed to jurisdictions in relation to the necessary background meta-data required that is essential for aggregation of data. These activity and input measures can be compared to the (robust) impact measurements to allow inference be drawn about the relative effectiveness of controls. Most importantly, the effectiveness of a change in the level of control can be assessed from examining the change in impact – such as the change in the average interval between dog attacks – that has occurred pre- and post-change.

## Recommended national metrics and approach to monitoring, evaluation and reporting

### Key messages

The stakeholder workshop agreed on a series of key messages arising from the discussion paper. These messages summarise the principles to be considered in developing a set of national metrics, as well as the agreed metrics themselves:

- Monitoring, evaluation and reporting is a key component of the NWDAP.

- Wild dog control is an industry / government partnership with co-investment by both.
- National consistency is important.
- 'Metrics' are not the same as 'data' – metrics are created by combining, standardising and correcting data to enable meaningful inferences to be drawn from them.
- Metrics must be reliably associated with control measures, and should preferably be accurate.
- Four levels of metrics are proposed (described in greater detail below):
  - Social (satisfaction)
  - Impacts
  - Activities
  - Inputs.
- Metrics should be aggregated from the base (local) level up through regional, state and national levels, and fed back down through this cascade as well.
- There are significant resourcing implications:
  - To collect, collate and 'clean' data (and combine with metadata – such as proportion of properties reporting) to create usable metrics, especially in the 'impact' level; and
  - To report the metrics and provide governance of the overall system.
- A national system of metrics will demonstrate benefits, gaps and opportunities of wild dog control and will provide justification for funding from governments and industry bodies.
- A national system of metrics would also improve the control measures taken – which makes it vital that the metrics are standardised and therefore as reliable and repeatable as possible allowing valid comparisons; making sure the 'story' is right.
- The data collection system needs to be simple and flexible to obtain the maximum value for the lowest possible cost.
- Any data collected must be de-identified, aggregated, secured and only accessible at appropriate levels to protect privacy and guard against misuse.

## Recommended national metrics

The national metrics recommended by the workshop are listed in Table 1 along with the resources needed to gather the required data.

**Table 1: Recommended national metrics for wild dog control**

| Metric 'level' | Data | Collection / resourcing |
|---|---|---|
| Social, economic, environmental outcomes | Measurement of stakeholder satisfaction (including levels of producer stress, community satisfaction with control approach) | Link with ABARES survey – every 2 years (do in 2016 to establish baseline)<br>Will require extra funding for questions |
| Impacts | Measure the impact of activities at a WDAG level:<br>⌖ Specific data: User / species and class / event (kill/maim etc) / place / location / time / person / number involved<br>⌖ Metadata: User type / production system / location / size of enterprise | Establish standard data definitions and fields, and a data collection / reporting standard operating procedure (SOP)[1]<br>All groups with plans to capture this data using the SOP described above and report upwards to state coordinator<br>WDAG coordinators to promote, capture and analyse/manage the data according to a further SOP (describing aggregation, standardisation etc) so that data can be aggregated with those of other groups and reported downwards with minimal bias<br>Undertake periodic surveys (such as that in Qld) to further control for non-reporting bias and to look for emerging trends that may not be identified through data wholly generated by WDAGs |
| Activities and inputs | Capture activities of WDAGs:<br>⌖ WDAG numbers<br>⌖ Member numbers<br>⌖ Approved plans<br>⌖ Activities/actions within those plans<br>⌖ Area covered<br>⌖ Financial contributions<br>⌖ In kind contributions | Establish standard data definitions and fields, and a data collection / reporting standard operating procedure (SOP)<br>All groups with plans to capture this data using the SOP described above and report upwards to state coordinator<br>WDAG coordinators to promote, capture and analyse/manage the data according to a further SOP (describing aggregation, standardisation etc) so that data can be aggregated with those of other groups and reported downwards with minimal bias |

## Underpinning principles

Raw counts only of some impacts – such as the number of dog attacks observed on sheep – do not carry precise information on the rate of attacks for a group or region. This is due to variability in the number of sheep at risk, the observer reporting rate, differences in duration of the reporting period as well as differences in the (true) background dog attack rate. Raw impact counts are not suitable metrics to use for monitoring change within a group or district. Nor are they suitable for aggregating with other groups' or districts' data for calculating a regional estimate of impact. This is because the raw counts do not 'carry'

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[1] A detailed discussion of the importance of appropriate data collection and analysis, and what it requires, is provided in Appendix 3. Additional comments are provided in the 'Underpinning principles' section

the reference denominator with them to allow conversion of the count to a more suitable attack proportion or rate.

Reference denominators carry essential information about the number of animals at risk across the time period in question. Within a set (limited) period the (period) attack rate is the number of animals attacked divided by the number at risk of attack – this is simply the proportion of animals attacked in the period. Across a longer interval of time the incidence rate is the number of animals attacked divided by the number of animal-days at risk. In simple terms the animal-days at risk is calculated as the number of animals at risk multiplied by the length of the study period. This is a true rate as it captures attacks per animal per unit of time at risk. The average interval between attacks represents one way of expressing this rate of attack (when the majority of properties experience regular attack).

Effective control requires metrics that are capable of detecting change in the frequency of impacts. In order to do this the recording system must capture both counts of the occurrence of the event (e.g. sheep kills) and counts of the non-occurrence of the event (i.e. no sheep killed) and usually a measure of the time of observation across the study period. A sheep that was *killed* or *attacked* by a dog (and survived) and a sheep that was *not* attacked by a dog must both have an equal probability of being observed and reported. This is essential to prevent observational biases from distorting rate estimates.

The estimate of the rate for the impact can be calculated as:

*Attack rate = Attacked / (Attacked + Unattacked),* where *Attacked = Killed + Wounded*

This attack rate is expressed as the proportion of animals attacked (e.g. 10 attacks per 1000 sheep), typically over a short period of time (say a few days). This period attack rate is now a transportable metric – it can be recalculated at a later date (e.g. post a dog control activity) and compared with a preceding estimate to determine if dog control activities for the group have been effective[2]. The calculated rate may also be sent forward (with appropriate metadata) for aggregating with other group or district estimates to provide for an unbiased regional estimate of impact.

The period attack rate assumes that all compared observation periods are of equal (typically short) duration. More robust rates include a time component; these are true rates because they combine the number of attacks with the number of animal-days at risk of attack over a recorded time period. These are calculated as:

*Incidence rate = Attacked / (Total days at risk in both Attacked + Unattacked)*

*As an example assume that a mob of 1,000 sheep were observed for 10 days. During this time 50 sheep were attacked (either killed or wounded). 50 is therefore the numerator. There were 950 sheep that remained unaffected across the ten-day period. These sheep contribute 950*10 = 9,500 sheep-days-at-risk to the denominator. Unless exact times of attack are known it is assumed that the attacked sheep were assaulted midway through the observation period which in this case is 5 days. These sheep each contribute 5 sheep-days-at-risk to the denominator which in this case is 50*5 = 250 sheep-days-at-risk. The incidence rate is therefore 50/ (9,500 + 250) = 50/9,750 = 0.0051 sheep attacked per day. This can be expressed as 5.1 sheep attacked per thousand sheep per day.*

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[2] The confidence interval for the difference between two rates (pre and post) is generally wider than individual confidence intervals for each rate. This is because the difference must control for variation in both estimates

This incidence rate is expressed as the proportion of animals attacked per unit of time (e.g. 1 attack per 1000 sheep per day). These true rates are more robust measures of impact as they can be compared between and across observation periods that were of different duration. This may be an important consideration when aggregating rates across groups that have different capacities and abilities to observe stock across a pre-defined period.

The average interval between attacks represents a variant of the attack rate and for regions under wide-scale and regular attack the metric provides a robust and comparable measure of dog activity.

The key implication for impact metrics is that the raw data must be collected using the principles of random sampling. All units of interest – for example sheep – must have an equivalent probability of being observed and the occurrence or lack of the occurrence of the event recorded. Recording must be irrespective of whether the event occurred or not. Some sheep will experience dog attacks and others will not but there must be an equal probability between all sheep that they will be observed and reported. It is essential to ensure that participating observers record with this principle in mind. Recording an unaffected mob of sheep is just as important as recording an affected mob.

Users of metrics (e.g. industry, government) must decide how confident they wish to be in the reported metrics. The required level of confidence combined with the desired level of precision determines the width of the confidence interval (CI) for the impact estimate[3]. This in turn sets the minimal sample size (number of observations – both positive and negative) required to generate the impact metric. The number of observations required is presented in Table 2 and graphically in Figure 1. A fuller version of Table 2 is found in Appendix 4.

In Table 2, parameters in the first three columns – required confidence level, required precision estimate and estimated attack rate – are determined by the user. The fourth column, sample size required, is a calculated using a binomial approximation to the underlying Poisson distribution under these conditions. The final three columns provide an example of the observed number of attacks, the estimated true attack rate based on the actual observations and the confidence interval around the estimate.

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[3] Simply put, 'confidence' is the probability that the calculated confidence interval will contain the true estimate whereas 'precision' can be considered as the accuracy of the estimate. Both confidence and precision influence the width of the confidence interval. A more precise estimate (as obtained from a larger sample) will provide a smaller confidence interval – the true population value has been more closely estimated. An increase in the desired confidence level will expand the confidence interval (to ensure that the real estimate has been captured)

**Table 2: Accuracy, precision and sample size matrix for varying attack rates**

| Required confidence level | Required precision estimate | Attack rate | Sample size required (no. animal-days at risk) | *Example number impacted* | *Example incidence rate estimate (attacks per animal per day)* | *Example confidence interval* |
|---|---|---|---|---|---|---|
| 90% | 5% | 10% | 98 | *10* | *0.102* | *0.062-0.163* |
| | | 50% | 271 | *136* | *0.502* | *0.452-0.552* |
| | | 90% | 98 | *88* | *0.898* | *0.837-0.938* |
| | 10% | 10% | 25 | *2* | *0.08* | *0.027-0.215* |
| | | 50% | 68 | *34* | *0.500* | *0.402-0.598* |
| | | 90% | 25 | *22* | *0.880* | *0.735-0.951* |
| | 20% | 10% | 7 | *1* | *0.143* | *0.033-0.452* |
| | | 50% | 17 | *8* | *0.471* | *0.290-0.660* |
| | | 90% | 7 | *6* | *0.857* | *0.548-0.967* |
| 95% | 5% | 10% | 139 | *14* | *0.101* | *0.061-0.162* |
| | | 50% | 385 | *192* | *0.499* | *0.449-0.548* |
| | | 90% | 139 | *125* | *0.899* | *0.838-0.939* |
| | 10% | 10% | 35 | *4* | *0.114* | *0.045-0.260* |
| | | 50% | 97 | *48* | *0.495* | *0.397-0.593* |
| | | 90% | 35 | *32* | *0.914* | *0.776-0.970* |
| | 20% | 10% | 9 | *1* | *0.111* | *0.020-0.435* |
| | | 50% | 25 | *12* | *0.480* | *0.300-0.665* |
| | | 90% | 9 | *8* | *0.889* | *0.565-0.980* |

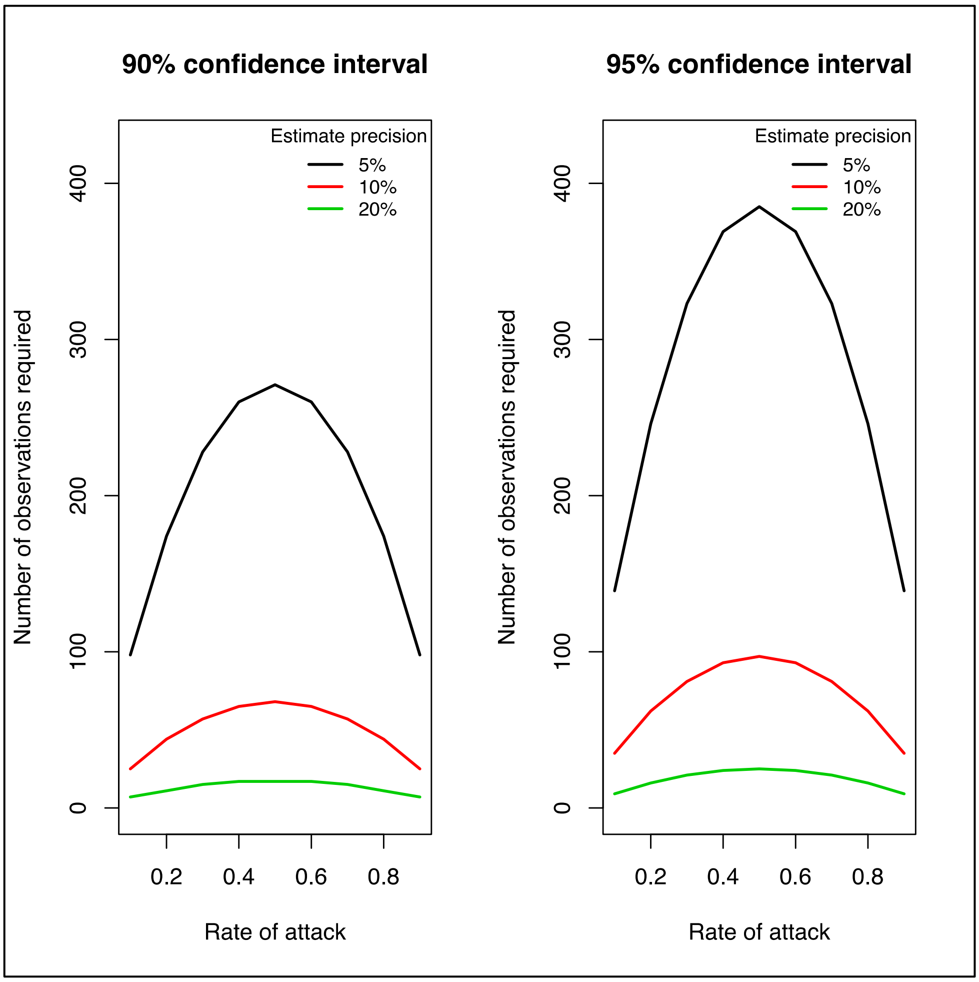


**Figure 1: Confidence, precision and attack rate sample size plot**

Incidence rates tend to have larger denominators (animal days at risk) and as a result are smaller values than attack rates. This often requires a greater precision in the estimate – an incidence rate of 0.001 sheep per day (1 in 1,000 sheep killed per day) usually requires greater precision in the estimate than ±10%. Typical sample sizes (number of animal days at risk) required for incidence rates with the desired level of confidence and precision are presented in Table 3. This is identical to Table 2 but in this case the required precision has been expressed as multiple of the estimate (0.25, 0.5 or 1 times the estimate).

**Table 3: Accuracy, precision and sample size matrix for varying incidence rates**

| Required confidence level | Required precision estimate (a fraction of the estimate) | Attack rate | Sample size required | *Example number impacted* | *Example rate estimate* | *Example confidence interval* |
|---|---|---|---|---|---|---|
| 90% | 0.25%<br>0.50%<br>1.00% | 1.00% | 4286 | 43 | 0.01 | 0.008-0.013 |
| | | 1.00% | 1072 | 11 | 0.01 | 0.006-0.017 |
| | | 1.00% | 268 | 3 | 0.011 | 0.004-0.028 |
| | 0.63%<br>1.25%<br>2.50% | 2.50% | 1689 | 42 | 0.025 | 0.019-0.032 |
| | | 2.50% | 423 | 11 | 0.026 | 0.016-0.042 |
| | | 2.50% | 106 | 3 | 0.028 | 0.011-0.069 |
| | 1.25%<br>2.50%<br>5.00% | 5.00% | 823 | 41 | 0.05 | 0.039-0.064 |
| | | 5.00% | 206 | 10 | 0.049 | 0.029-0.080 |
| | | 5.00% | 52 | 3 | 0.058 | 0.023-0.136 |
| 95% | 0.25%<br>0.50%<br>1.00% | 1.00% | 6085 | 61 | 0.01 | 0.008-0.013 |
| | | 1.00% | 1522 | 15 | 0.01 | 0.006-0.016 |
| | | 1.00% | 381 | 4 | 0.01 | 0.004-0.027 |
| | 0.63%<br>1.25%<br>2.50% | 2.50% | 2398 | 60 | 0.025 | 0.019-0.032 |
| | | 2.50% | 600 | 15 | 0.025 | 0.015-0.041 |
| | | 2.50% | 150 | 4 | 0.027 | 0.010-0.067 |
| | 1.25%<br>2.50%<br>5.00% | 5.00% | 1168 | 58 | 0.05 | 0.039-0.064 |
| | | 5.00% | 292 | 15 | 0.051 | 0.031-0.083 |
| | | 5.00% | 73 | 4 | 0.055 | 0.022-0.133 |

What these tables and figures indicate is that if regional, state or national wild dog management groups require or desire a specific level of reporting confidence and precision then the number of observations required is relatively easy to determine.

*For example:*

- *It has been suggested that approximately 50% of producers in a region are experiencing attacks and we wish to determine whether this is true. We can accept some imprecision in our estimate so choose a 10% precision and a 90% confidence level. This implies that our 90% confidence level will have a range of 20% (± 10%). At 90% confidence level and 10% precision and an estimated attack rate of 50% we require 68 observations. Note that the unit of analysis here is the property – so this means that 68 properties must participate. If we were to observe attacks on 34 of the 68 properties participating, our estimate of the true attack rate would be 50% and we would have 90% confidence that the value lies between 40.2% and 59.8%.*

- *We believe that 25 sheep per 1,000 are taken each day in the region. The farm management consultant would like an estimate of the rate of loss so she can calculate the annual financial loss due to dogs. Our baseline incidence rate is 25 killed / (1,000 sheep x 1 days) = 25/1,000 = 0.025 (2.5%). We need precise estimates so we set our precision to 0.25 times our estimate – this is 0.025*0.25 = 0.063 (0.63%) and set our confidence level to 95%. We need to observe 2,398 sheep days and can expect to find 60 dead sheep. Our estimate of the incidence rate is 2.5% (95%CI 1.9% to 3.2%).*
- *We wish to determine if a new baiting approach is more effective than the current approach. Our producers are experiencing an attack rate of 10% so we assign one of our two WDAGs to either use the regular baiting program or to use the new baiting program. We need to be able to see any change to the dog attack rate pre- and post-baiting so need an precise estimate of dog attacks pre- and post-baiting. With this is mind we choose 95% confidence level and 5% precision and with a 10% baseline attack rate we need 139 observations from each WDAG. If we observe 14 attacks in 139 observations our estimate is 10.1% (95%CI 6.1%–16.2%).*

These examples provide the desired level of precision and confidence in single estimate – for example the number of dog attacks in July. If the objective of sampling is to compare two rates (such as the rate of dog attacks pre- and post-baiting) then it is important to note that there are intrinsically larger errors in the difference estimate than exists in each single estimate alone. Because we are comparing two rates – each with their own (random) error – then the difference between the two rates will have a larger error than each individual estimate. A table demonstrating the impact on the width of the confidence interval for the difference between two rates (post – pre) is presented in Table 4 below.

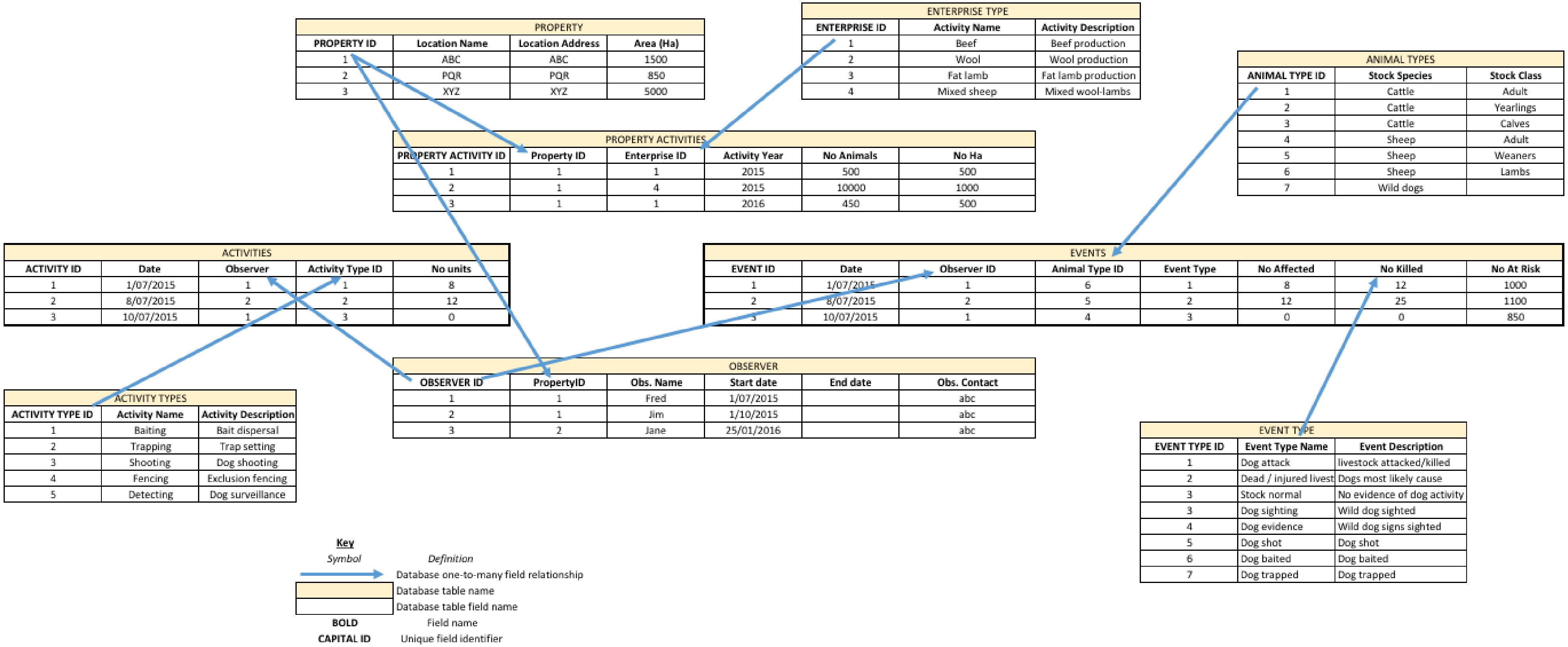
**Table 4: Examples demonstrating the widening effect on confidence interval (CI) of the difference between two rates from varying sample sizes**

| *Confidence* | *Rate pre* | *Rate post* | *Sample size* | *No. pre* | *No. post* | *Difference* | *CI* |
|---|---|---|---|---|---|---|---|
| *0.9* | *0.1* | *0.05* | *195* | *20* | *10* | *0.051* | *0.002-0.101* |
| | *0.5* | *0.05* | *542* | *271* | *27* | *0.450* | *0.410-0.491* |
| | *0.5* | *0.2* | *542* | *271* | *108* | *0.301* | *0.254-0.348* |
| | *0.5* | *0.05* | *136* | *68* | *7* | *0.449* | *0.364-0.533* |
| | *0.5* | *0.2* | *136* | *68* | *27* | *0.301* | *0.204-0.399* |
| | *0.5* | *0.05* | *34* | *17* | *2* | *0.441* | *0.256-0.626* |
| | *0.5* | *0.2* | *34* | *17* | *7* | *0.294* | *0.083-0.505* |
| *0.95* | *0.1* | *0.05* | *277* | *28* | *14* | *0.051* | *0.003-0.098* |
| | *0.5* | *0.05* | *769* | *384* | *38* | *0.450* | *0.410-0.490* |
| | *0.5* | *0.2* | *769* | *384* | *154* | *0.299* | *0.253-0.346* |
| | *0.5* | *0.05* | *193* | *96* | *10* | *0.446* | *0.363-0.528* |
| | *0.5* | *0.2* | *193* | *96* | *39* | *0.295* | *0.200-0.391* |
| | *0.5* | *0.05* | *49* | *24* | *2* | *0.449* | *0.278-0.620* |
| | *0.5* | *0.2* | *49* | *24* | *10* | *0.286* | *0.086-0.486* |

Sometimes it may be preferable to record attacks at the property level (the attack rate or proportion of properties experiencing wild dogs kills) or at the animal level (the incidence rate of sheep kills) – or both – depending on the objective of the study.

### Data capture and recording

Rate metrics are calculated from raw counts. A standardised system for capturing and recording raw data is therefore an essential component of the metric system. The recommended structure for recording data is presented in Figure 2. This data structure captures events and activity data and associated metadata. The one-to-many relationships links between the individual event and activity data link records to the metadata of time, person, enterprise and place. It is important that data collected at all levels – beginning with local wild dog management groups – be recorded consistently and completely according to this structure to allow aggregation and meaningful analysis. It must be emphasised that all dog event data must also be recorded using random sampling principles. The capture of 'negative' (no dog activity) data is equally as important as the capture of positive (dog attack) data for accurate estimation of rates.



PROPERTY

| PROPERTY ID | Location Name | Location Address | Area (Ha) |
|---|---|---|---|
| 1 | ABC | ABC | 1500 |
| 2 | PQR | PQR | 850 |
| 3 | XYZ | XYZ | 5000 |

ENTERPRISE TYPE

| ENTERPRISE ID | Activity Name | Activity Description |
|---|---|---|
| 1 | Beef | Beef production |
| 2 | Wool | Wool production |
| 3 | Fat lamb | Fat lamb production |
| 4 | Mixed sheep | Mixed wool-lambs |

ANIMAL TYPES

| ANIMAL TYPE ID | Stock Species | Stock Class |
|---|---|---|
| 1 | Cattle | Adult |
| 2 | Cattle | Yearlings |
| 3 | Cattle | Calves |
| 4 | Sheep | Adult |
| 5 | Sheep | Weaners |
| 6 | Sheep | Lambs |
| 7 | Wild dogs | |

PROPERTY ACTIVITIES

| PROPERTY ACTIVITY ID | Property ID | Enterprise ID | Activity Year | No Animals | No Ha |
|---|---|---|---|---|---|
| 1 | 1 | 1 | 2015 | 500 | 500 |
| 2 | 1 | 4 | 2015 | 10000 | 1000 |
| 3 | 1 | 1 | 2016 | 450 | 500 |

ACTIVITIES

| ACTIVITY ID | Date | Observer | Activity Type ID | No units |
|---|---|---|---|---|
| 1 | 1/07/2015 | 1 | 1 | 8 |
| 2 | 8/07/2015 | 2 | 2 | 12 |
| 3 | 10/07/2015 | 1 | 3 | 0 |

EVENTS

| EVENT ID | Date | Observer ID | Animal Type ID | Event Type | No Affected | No Killed | No At Risk |
|---|---|---|---|---|---|---|---|
| 1 | 1/07/2015 | 1 | 6 | 1 | 8 | 12 | 1000 |
| 2 | 8/07/2015 | 2 | 5 | 2 | 12 | 25 | 1100 |
| 3 | 10/07/2015 | 1 | 4 | 3 | 0 | 0 | 850 |

OBSERVER

| OBSERVER ID | PropertyID | Obs. Name | Start date | End date | Obs. Contact |
|---|---|---|---|---|---|
| 1 | 1 | Fred | 1/07/2015 | | abc |
| 2 | 1 | Jim | 1/10/2015 | | abc |
| 3 | 2 | Jane | 25/01/2016 | | abc |

ACTIVITY TYPES

| ACTIVITY TYPE ID | Activity Name | Activity Description |
|---|---|---|
| 1 | Baiting | Bait dispersal |
| 2 | Trapping | Trap setting |
| 3 | Shooting | Dog shooting |
| 4 | Fencing | Exclusion fencing |
| 5 | Detecting | Dog surveillance |

EVENT TYPE

| EVENT TYPE ID | Event Type Name | Event Description |
|---|---|---|
| 1 | Dog attack | livestock attacked/killed |
| 2 | Dead / injured livest | Dogs most likely cause |
| 3 | Stock normal | No evidence of dog activity |
| 3 | Dog sighting | Wild dog sighted |
| 4 | Dog evidence | Wild dog signs sighted |
| 5 | Dog shot | Dog shot |
| 6 | Dog baited | Dog baited |
| 7 | Dog trapped | Dog trapped |

**Key**

| *Symbol* | *Definition* |
|---|---|
| → | Database one-to-many field relationship |
| 🟨 | Database table name |
| ☐ | Database table field name |
| **BOLD** | Field name |
| **CAPITAL ID** | Unique field identifier |

**Figure 2: Wild dog activities and events recommended database schema**

The following are standard operating procedures (SOPs) for collecting data for calculating key metrics from Table 1.

### *Impacts*

For each impact measure:

1. Estimate the expected rate of events as a proportion (e.g. 30% of sheep flocks can expect to experience a dog attack across the period in question). This is required because the variance of a proportion (of attacks) is not constant (see Figure 1) – more observations will be required to estimate the proportion with the required precision when the proportion is close to 0.50 than closer to either 0 or 1.
2. Select the required confidence level for estimate. Typical confidence levels are 90% or 95% implying that 90% or 95% of similarly calculated confidence intervals will contain the true rate.
3. Select the required precision for the estimate. This sets the maximum width of the confidence interval. Choices can include ±5%, ±10% or ±20%.
4. These first three criteria determine how many observations (positive and negative) are required to generate a rate with the required precision. The number of observations can be read from Table 2. Note that the selection choices for options 1-3 will vary across the nation and between regions and animal production systems. This prevents a one-size-fits-all sample size for all observer groups. The selections used should be set at regional level following discussion and applied by all observer groups within the region.
5. The observation team (e.g. WDAG members) must regularly (annually) update their observer, enterprise and enterprise activity details. Observers should familiarise themselves with the impact event categories to be used for recording events in their stock. Observers are instructed to observe and record impacts in their stock during the study period and record the number affected, killed and at risk from within each class of animal where the number at risk is the total number of animals within each class in the observed group(s). The 'average interval between attacks' metric demands that animals at risk are observed daily for the study period. This is important because if dogs actually attack sheep on a daily basis but an observer only sees and reports every second day's attack (if the sheep killed on unobserved days are not detected as missing) the average interval between attacks will be calculated as 2 days. The average interval between attacks therefore depends upon a census period of observations. Not all voluntary observers will meet these demands so the average interval between attacks should be limited to observations from so-called 'super observers' which are identified as such in the database.
6. The observation and recording process should continue until the required total number of observations is obtained. If there are insufficient individual properties with observers to meet the total from a single observation and recording per property, then the number of observation periods should be increased to allow multiple observations per property and an adequate number of reports to be obtained. This may involve recording daily events over multiple days.

### *Activities and inputs*

For each metric to be calculated to the required level of confidence and precision it is important that all observers report in a consistent, predictable and reliable manner. This means that all participants:

1. Must regularly ensure their observer, property, enterprises and property activities details are up to date. This ensures the metadata that allows aggregation and calculation of regional statistics is up to date.
2. Regularly familiarise themselves with the activity type categories. They should also ensure they understand the requirements of their control group activities and conduct their controls in a consistent and timely manner according to their plan.
3. Record all their impact observations and control activities as they occur.

## Calculation of metrics

### *Individual metrics*

Only data obtained from random-sample based observation records is suitable for estimating impact metrics. This is because voluntary observational data is biased. Voluntary reporting systems will typically experience a positive reporting bias in which dog attacks are preferentially reported over non-attacks. Differences between observers who participate in voluntary reporting systems and those that do not provide another source of bias to the voluntary reported data. Metrics calculated using voluntary reporting data are unreliable and likely to lead to spurious and often counter-intuitive relationships between wild dog activity and their (true) impacts.

For each proportion-based impact measure such as the rate of dog attacks or the proportion of properties experiencing attacks, the formula for calculating the rate and the confidence interval for the rate is as follows:

1. Let A be the number of impact (positive) observations and let B be the number of no impact (negative) observations. Let N be the number of observations (N = A + B).
2. The proportion affected (p) is p = A/(A+B)
3. Calculate the standard deviation (s) for the estimate as: $s = \sqrt{\frac{P*(1-P\ )}{N}}$
4. Select the appropriate confidence interval for the estimate (90% or 95%). This determines the appropriate Z term. For a 90% confidence interval Z = 1.64 and for a 95% confidence interval Z = 1.96.
5. Estimate the lower confidence limit[4] (LCL) as LCL = max(0,p–Z*s)
6. Estimate the upper confidence limit (UCL) as UCL = min(1,p+Z*s)

*For example – using attack rate:*

- *100 observations show 20 attacks and 80 non-attacks*
- *P=0.2/(0.2+0.8)=0.2*

---

[4] Note that statistics programs can calculate exact confidence intervals

- *s=SQRT((0.2*(1-0.2))/0.8)=0.04*
- *For 95% confidence interval, Z=1.96*
- *Lower confidence limit = max(0,0.2-1.96*0.04)=0.122*
- *Upper confidence limit = min(1,0.2+1.96*0.04)=0.278*
- *P = 20% (95% confidence interval 12.2% – 27.8%)*

*For example – using incidence rate:*

- *4,578 sheep are observed across a week and 13 sheep are killed during the period (all are detected)*
- *This equates to (4,578-13)*7 + 13*3.5=32,000 sheep days at risk and 13 kills*
- *P=13/32,000=0.0004*
- *s=SQRT(0.0004*0.9996/32,000)*
- *For 95% confidence interval, Z=1.96*
- *Lower confidence limit = max(0,0.0004-1.96*0.00011)=0.00018*
- *Upper confidence limit = min(1,0.0004+1.96*0.00011)=0.00062*
- *P = 0.0004 (95%CI 0.00018—0.00062)*
- *This may be expressed as 1 sheep killed per 2,500 days at risk (95% confidence interval 1,613 – 5,555)*

For time-to-event impact measures (such as the median time between attacks):

1. Identify property observations with more than one observation per period. Exclude from these all properties providing data with 1 or fewer dog attacks (that is, the analysed data is from properties with at least two dog attacks within the study period) – this is because an interval between attacks can only be calculated if there are at least two separate attacks per property. This exclusion is a source of bias and therefore this index is only relevant to properties experiencing regular attacks. The average interval between attacks is meaningless for properties that are not impacted by wild dogs.
2. Calculate the number of days between consecutive dog attacks for each property as follows:

| Property | Dog attack date | Interval between attacks |
|---|---|---|
| 1 | 1/07/2015 | - |
| 1 | 5/07/2015 | 4 |
| 1 | 8/07/2015 | 3 |
| | | |
| 2 | 3/07/2015 | - |
| 2 | 5/7/2015 | 2 |
| 2 | 6/7/2015 | 1 |
| 2 | 9/7/15 | 3 |

3. Order the intervals between dog attacks in ascending order (excluding the first dog attack), as follows: 1,2,3,3,4…
4. Calculate the median interval between dog attacks. First, count the number of observations (N) in the sequence of ordered intervals. If N is an odd number, identify the value by calculating (N/2), rounding up to the nearest number and selecting that value. In our example N=5, N/2=2.5, so the third value is chosen[5]. If N is an even number take the average of the two values located at N/2 and N/2 + 1. For the sequence of 1,2,3,3,4 the median value is 3 days. For the sequence 1,2,3,4 the median value is 2.5 days[6].

### *Aggregating individual metrics*

Only metrics calculated from data obtained from random-sample based observation records with accompanying metadata are suitable for aggregation into regional or higher-level estimates. This is for the same voluntary reporting bias reasons as above but extends to include metrics that also provide sufficient metadata to support weighting in the calculation of regional estimates. Group (or regional) metrics with evidence of under-reporting bias should be excluded from regional calculations.

The approach for rate-based estimates is as follows:

1. Collect rate data and associated metadata (such as land area, number of livestock, number of participants for the group)
2. Identify and exclude any group rate data where the estimated rate is of questionable completeness. This will generally be as a result of under-reporting (whether intentional or unintentional). It is important that known under-reporters are excluded from the estimate as they will artificially lower the estimate.
3. Determine the weighting unit(s) for aggregation of rates (commonly livestock numbers – but can be land area). Exclude any group without required metadata as this prevents appropriate weighting of their observations when calculating the aggregated estimate.
4. Calculate the metadata to accompany the regional estimate for further aggregation, for example the sum of ALL sheep numbers for the region (including non-reporting properties). Note that this total is likely to be different from the total (denominator) used to estimate the regional attack rate as this was limited to reporting properties (to prevent underestimation due to non-reporting properties). The regional totals (area and sheep number) become the weights for the next level of aggregation.

*For example:*

*We have data from 6 wild dog action groups. These groups are in two separate districts (A and B) and all reside within a region (X). We want to know the dog attack rate of each district and also to estimate the dog attack rate for the region.*

---

[5] 'Ceiling' is the term to round-up any value to the nearest round number

[6] Note that statistics programs can calculate median, 25th and 75th percentile estimates and confidence intervals for the estimate

*Our data are as follows. Note that the metadata we will use will be the number of sheep in each WDAG. It is just as feasible to use land area as the weighting variable to estimate the attack rate per area of land – for example, if a funding model based on Local Government Areas is to be applied.*

| District | WDAG | Complete data | Estimated wild dog attack rate | Area (Ha) | Sheep |
|---|---|---|---|---|---|
| A | WDAG 1 | Y | 0.025 | 1,000 | 1,000 |
| A | WDAG 2 | Y | 0.035 | 3,000 | 3,000 |
| A | WDAG 3 | N | 0.005* | 2,000 | 4,000 |
| B | WDAG 4 | Y | 0.056 | 3,000 | 5,000 |
| B | WDAG 5 | Y | 0.020 | 2,000 | 2,000 |
| B | WDAG 6 | N | 0.010* | 1,500 | 2,000 |
| | Total | 6 groups (4 adequate) | | 11,500 | 15,000 |
| * These properties indicated that they did not undertake adequate observations and reports | | | | | |

*We first must exclude any WDAG that we know has underreported – where a low number of dog attacks is reported due to lack of observations. For the remaining WDAGs, we multiply the rate by the weighting unit (number of sheep), sum and divide the total by the sum of the weighting unit across the included groups. The calculation of a sheep-number weighted estimate for dog attacks for District A is as follows:*

| District | | Complete data | Wild dog attack rate | Sheep | Sheep * Rate |
|---|---|---|---|---|---|
| A | WDAG 1 | Y | 0.025 | 1,000 | 25 |
| A | WDAG 2 | Y | 0.035 | 3,000 | 105 |
| A | WDAG 3 | N | 0.005 | 4,000 | 20 |
| | Total | 3 WDAGS (2 adequate) | - | 8,000 | 150 |
| | Restricted to complete data | 2 WDAGS | | 4,000 | 130 |

*The sheep-number-adjusted rate of dog attacks for District A is 130/4000 = 0.033 dog attacks per sheep. The metadata for District A is 8,000 – the total sheep population for the region.*

*For District B:*

| District | | Complete data | Wild dog attack rate | Sheep | Sheep * Rate |
|---|---|---|---|---|---|
| B | WDAG 4 | Y | 0.056 | 3,000 | 168 |
| B | WDAG 5 | Y | 0.020 | 2,000 | 40 |
| B | WDAG 6 | N | 0.010* | 1,500 | 15 |
| | Total | 3 WDAGS (2 adequate) | - | 6,500 | 223 |
| | Restricted to complete data | 2 WDAGS | | 5,000 | 208 |

*The sheep-number-adjusted rate of dog attacks for District B is 208/5000 = 0.042 dog attacks per sheep. The metadata for District B is 6,500 – the total sheep population for the region.*

*Now, both District A and District B are in Region X – and are representative of Region X – so we can use these two district rates to estimate the regional dog attack rate using the same principle. The working is below.*

| Region | District | Complete data | Wild dog attack rate | Sheep | Sheep * Rate |
|---|---|---|---|---|---|
| X | A | Y | 0.033 | 8,000 | 264 |
| X | B | Y | 0.042 | 6,500 | 273 |
| | Restricted to complete data | 2 districts | | 14,500 | 537 |

*The sheep-number-adjusted rate of dog attacks for Region X is 537/14,500 = 0.037 dog attacks per sheep. The metadata for Region X is 14,500, the total sheep population for the region.*

Regional and state-based time-to-event metric calculations require aggregation of raw data from all sources and re-calculation of combined data as described in the metrics calculation section above. A mathematical average of constituent group median intervals between attacks can be used but this may not be accurate – especially if the number of observations differ greatly between groups.

## Summary

The monitoring, evaluation and reporting (MER) framework recommended by the workshop comprises:

1. A biennial survey of stakeholder perceptions in regard to wild dog control, undertaken as part of the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) survey. The metric being measured is, essentially, satisfaction with the level of wild dog control. This will have little if any value in demonstrating changes in the actual impacts of wild dogs or the effects on these impact of specific control measures. However, it will provide a broad indication of the success of the national control effort and will capture some of the social value of dog control.

   The survey will require funding.

2. The collection, analysis and reporting of metrics pertaining to inputs, activities and impacts of wild dogs (described above).

   The data for these metrics will be collected at ground level by members of WDAGs. Because it is critical that data along with group-level metadata are collected together and reported in a consistent manner, standard operating procedures (SOPs) have been described above that define the suite of parameters, how each should be collected, the form in which each is to be captured, how each should be reported and the necessary metadata that must accompany the records. This SOP should be provided to each member of each WDAG.

   Because there is a critical need for data quality oversight, and because there will be tendency to neglect data collection without prompting, regional or state coordinators with both wild dog understanding and data skills will be required across all jurisdictions. The role description for the coordinators would include ensuring that data are collected by WDAGs according to the SOP, analysing / managing the data, submitting it for aggregation upwards as required and reporting it back to WDAG level. These steps would also be carried out according to an SOP.

Resourcing will be required to:

- Develop the WDAG and coordinator SOPs;
- Pay for the coordinators;
- Train WDAG members and coordinators as required; and
- Establish and maintain data collection mechanisms and databases.

If there is inadequate resourcing of this area, there is a high risk that biases will remain unadjusted in the data resulting in incorrect inferences being drawn from any apparent relationship between activities and events. The SOPs and data template ensures capacity to control for at least some of the voluntary reporting biases that are inevitably present in raw data of this type.

3. The conduct of periodic scientific surveys of dog activity and impacts, similar to that currently undertaken in Queensland, in order to monitor and assess the quality of the data gathered from WDAGs in (2) and to provide extra information for further control for any non-reporting bias remaining in estimates.

   Resourcing will be required to undertake these surveys, which are likely to be run by the regional coordinators described in (2).

## Appendix 1: References

This project did not involve a formal literature review, however a number of published and unpublished documents were referenced to varying extents throughout the project. These include:

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## Appendix 2: Individuals consulted

Individuals consulted during the course of the project, including those who participated in the workshop on 2 December 2015, are listed below.

| | |
|---|---|
| Guy Ballard | University of New England and Department of Primary Industries (NSW) |
| Peter Bird | Primary Industries and Regions South Australia |
| Brett Carlsson | Wild Dog Coordinator Qld, AgForce |
| David Counsell | Grazier and veterinarian, Qld |
| Barry Davies | Department of Environment, Land, Water and Planning (Vic) |
| Glenn Edwards | Department of Primary Industries and Fisheries (NT) |
| Peter Fleming | NSW Department of Primary Industries |
| Duncan Fraser | Grazier and Implementation Steering Committee Chair, NSW |
| Matt Gentle | Department of Agriculture, Fisheries and Forestry (Qld) |
| Andreas Glanznig | Invasive Animals Cooperative Research Centre |
| Quentin Hart | Department of Primary Industries (NSW) |
| Michele Jackson | Action Plan Implementation Manager |
| Robert Kancans | Australian Bureau of Agricultural and Resource Economics and Sciences |
| Malcolm Kennedy | Department of Agriculture and Food Western Australia |
| Jane Littlejohn | Ex Australian Wool Innovation |
| Peter Lucas | Grazier and WDAG leader, Qld |
| Michael McCormack | Grazier and Implementation Steering Committee member, Vic |
| Kieren McCosker | Department of Primary Industries and Fisheries (NT) |
| Paul Mahon | National Parks and Wildlife Service (NSW) |
| Paul Meek | Department of Primary Industries (NSW) |
| Greg Mifsud | Invasive Animals Cooperative Research Centre |
| Heather Miller | Department of Environment, Water and Natural Resources (SA) |
| Will de Milliano | Department of Economic Development, Jobs, Transport and Resources (Vic) |
| Bruce Moore | Grazier and WDAG leader, NSW |
| Greg Patrick | Department of Environment, Water and Natural Resources (SA) |
| John Robertson | Department of Agriculture, Fisheries and Forestry (Qld) |
| Jim Rothwell | Meat & Livestock Australia |
| John Virtue | Primary Industries and Regions South Australia |
| Peter West | Department of Primary Industries (NSW) |
| Mark Williams | Primary Industries and Regions South Australia |
| Andrew Woolnough | Department of Economic Development, Jobs, Transport and Resources (Vic) |

## Appendix 3: Discussion paper

The following reproduces the major elements of the discussion paper, which formed the background to the stakeholder workshop. The workshop agreed that the material developed for the discussion paper should be captured in this final report. It has been slightly modified to complement the main body of the report and also to include modifications or corrections that were suggested at the workshop.

### 1. Purpose and scope of a set of national metrics

#### 1.1 Outcomes and benefits

Ideally, a system of jurisdictional and national metrics should provide the following outcomes and benefits:

- Allow accurate assessments of the existing wild dog population and their impacts:
    - Economically – e.g. on production animals;
    - Environmentally (e.g. on native fauna); and
    - Socially (e.g. emotional and psychological impacts on people)

  and the effectiveness of various control techniques. A key component of 'accurate' assessment is the required stability of (and confidence in) the estimate. This will depend in part on what is achievable in practice and the intended use of the metric. It is likely that both what is achievable and the main management purpose for the metric will vary across and between jurisdictions.
- Provide the ability to aggregate data from multiple sources and sites, and centralise them into a database for generation of meaningful aggregated (regional-level) statistics and further analysis. This requires universal acceptance and adoption of a data standard to ensure that data from multiple sources can be validly combined. Uniform, valid and aggregated data allows data querying that can provide benchmarks for ongoing reporting and monitoring. This is an essential part of the process of continuous improvement of wild dog management.
- Be reliable, repeatable and subject to minimal (or acceptable levels of) bias (e.g. controlled measurement, observational and attribution bias). Voluntary data reporting systems are generally incomplete and are prone to variation in reporting completeness between and within jurisdictions over time. This (unseen) bias can blur trends and mask relationships. Voluntary data requires as a minimum an agreed process or system to measure the (likely) level of completeness of recording and therefore coverage, and recording compliance by individuals, regions or states as well as processes for standardising and aggregating estimates across and within entities over time. They typically need supplementation by other smaller but targeted and controlled (and more precise) measurements.

A set of national metrics should deliver incremental value for:

- Upwards reporting / accountability where a national picture is required – for example, Federal Government, the Intergovernmental Agreement on Biosecurity (IGAB) or for industries such as wool where Australian Wool Innovation (AWI) makes significant investment decisions at a national level. Nationally-standard metrics are not needed at state level where state-appropriate metrics will suffice, except where data-sharing between jurisdictions facilitates a (relative) comparison of impacts and effectiveness of wild dog activities and controls between the jurisdictions and can guide allocation of national funds.

- Continuous improvement in dog control, through the ability to accurately and effectively compare efficacy of control programs across jurisdictions. This could be expected to deliver value for money invested in dog control additional to that gained from local or region-appropriate metrics. The realisation of this benefit requires that data are actually collected against the metrics, fed back to those responsible for decision-making or control activities, interpreted appropriately and used.

## 1.2 Elements of a national metrics 'system'

To realise the benefits described above will require:

- Definition of the metrics;
- Data capture systems – locally and centrally;
- Appropriate incentives to collect data;
- A system and commitment for reporting back to stakeholders;
- Governance, oversight;
- Appropriate intellectual property and security arrangements; and
- Funding, to support all of the above.

If any of these are limited – e.g. funding – then expectations of uptake of the metrics and the realisation of benefits should be tempered.

## 1.3 Criteria for evaluation of candidate metrics

Any metrics under consideration for use in a national system need to be evaluated against a set of criteria. The following criteria are proposed:

- *Relevance* – the metric must provide information reflecting significant, real-world impacts across all jurisdictions.
- *Reliability, precision and accuracy* **–** are estimates of the metric sufficiently accurate? And are the measures sufficiently reliable? Are they sufficiently precise? What are tolerable levels of bias and imprecision in derived estimates? Are the metric and any statistics derived from the measurements fit for purpose and adequate for drawing inference? Can the metrics accurately capture changes to the activity and effectiveness of wild dog control in a region?
- *Ease of measurement and reporting* **–** if data on a metric are too difficult to collect or to report, they are unlikely to be used. Ideally, data are already being collected.
- *Cost of measurement and reporting* – as above, if data are too expensive to collect or report, they are unlikely to be used because preference will always be given to 'doing' over 'measuring'.
- *Acceptability to policy makers, landholders and intermediaries* – are stakeholders agreed that a metric adds value? Failure of (voluntary) data providers to accept a metric or failure to transmit feedback in the form of meaningful and accurate statistics derived from the metrics to the providers of data will ultimately lead to failure.

- *Ability to meet national policy requirements and demonstrate fulfilment of national or international obligations* – collectively, the set of metrics must give jurisdictions what they need to report to their various stakeholders (and some metrics may be legally required). Ideally, there should be a suite of metrics across the triple bottom line – economic, social and environmental.

## 2. Current jurisdictional monitoring, evaluation and reporting

A review of relevant literature and consultation with key individuals indicates that the management and reporting of wild dog activities vary considerably between jurisdictions (states and territories[7]). Appendix 3.1 provides a high-level summary of the key elements on a state-by-state basis, an overview of which is provided below:

- Wild dog legislation exists in most jurisdictions and may be managed in part by one or more departments (often the state Department of Agriculture or equivalent). Of special relevance are differences between the states in the classification of the dingo and subsequent impact on control or conservation activities and requirements.
- Wild dog group committees operate in each state. Most have or are developing wild dog action plans for their state. Smaller localised versions of the plan are often developed at a regional or even group level but there is not consistency between or within states or regions.
- Wild dog action group (WDAG) coordinators exist in all states affected by wild dogs, except for Queensland where an AWI-funded coordinator operates. Government-funded coordinator roles in WA are reducing and there is no obligation for privately-established WDAGs to work with or under the coordinator. These roles are reducing as part of the contraction of government services.
- There are no compulsory reporting requirements into any state or national authority / database except in Victoria (mainly via 'doggers') and south of the dog fence in SA. In more detail:
    - The method of control (e.g. trapping, shooting) is voluntarily reported in most states with the exception being the delivery of poisons (baits). All states have strict controls over the dispensing and use of poisons such as 1080 and there is effectively a census in all states of bait dissemination. However, the pattern of use of baits within regions (e.g. aerial vs ground spread, number and extent of land areas baited) is not usually recorded. Victoria and NSW have that capability but it is not routinely used except by official employed 'doggers' – using the app DogBytes in Victoria.
    - Dog reporting (sightings, dead dogs/kills, livestock attacks/deaths) is voluntarily undertaken in all states. There appear to be no compulsory or complete records of dog impacts in any jurisdiction. The impact data therefore is most prone to reporting and recording bias.
    - There is incomplete and inconsistent use of WildDogScan to report activities and events in most states. The data reported are very WDAG-dependent. Estimating the reporting (or non-reporting) bias of non-WDAG reporters (i.e. general public) does not appear possible without independent surveys of participant populations (WDAG members and non-WDAG members). The DogBytes tool in Victoria referred to above has a smart phone app that allows events and observations to be recorded in real time (even when out of mobile range). This facility would enhance the usability

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[7] The word 'state' is used to denote 'state' or 'territory' in the discussion below.

  of WildDogScan and might increase the use of electronic recording in real time. A concerted approach to training WDAG members by the WDAG coordinator would be necessary to encourage uptake. Regular graphical presentation of reports and activities of WildDogScan data might help identify reporting 'holes'.
  - Production indicator reporting (e.g. marking rates) occurs rarely and is not uniform – either within enterprise types or between enterprises. Production data are rarely provided voluntarily. Natural farm-, enterprise- and season-related variability in production data is large and this potentially will mask wild dog impacts. Sophisticated statistical techniques can control for these non-dog effects but require capture of (detailed) farm-level metadata to allow control during analysis.
  - Reported data are predominantly voluntarily-provided ‘event’ counts. For example, it is difficult to determine the effectiveness of interventions without supporting concurrent measurements of the completeness of reporting of both control activities and interventions (let alone the wild dog population size) in a region.
  - Reporting into a central database (e.g. a central SQL database with real-time recording and spatial capability) is only undertaken in Victoria, although WA has that capability. There is no forwarding of data into a national database for further analysis. This capacity is essential to allow central aggregation of data at national level and to ensure that flexible, meaningful and timely reports can be provided back to data providers to maintain their engagement.
  - Indeed, even at the state level in Victoria, while customisable reports are possible, their request is not encouraged due to concerns about unintended use of data from a ‘public’ system.
  - Reporting back to groups is routinely undertaken in Victoria, SA and WA. Victoria in particular is very active in this regard and has developed activity reports and event reports.
  - Data aggregation across jurisdictions (and groups and systems) is likely to require implementation of a national data standard by contributors to ensure ‘like with like’ data is aggregated. This implies the capture of metadata to allow effective filtering, aggregation and summary at regional level. The development of a data standard is not trivial. The value of a national database of (current) voluntary event records needs careful consideration.
  - Of particular interest is that Victoria is currently developing correlation (activity-event) analysis of dog control and dog population activities. This is the only known state-level effort to seek to analyse method of control versus effectiveness.

- As noted above, Victoria appears at this stage to have the most effective method of recording wild dog activities and linking these activities to changes in the (relative) wild dog population size. Dedicated reporting apps such as DogBytes allow real-time point-of-activity reporting. These are supported by novel tools such as genetic sampling of individuals and sophisticated mathematical analysis of fixed camera records which can provide estimates of the underlying dog population size and stability.

- ‘Doggers’ operate in each state and are usually private operators although there are Government-employed doggers in Victoria and NSW. The reporting by doggers varies. Most government-employed doggers are obligated to report activities and events but in jurisdictions where activities are either not formally monitored or followed-up, reporting rates can decline. Other problems include different reporting tools (ranging from real-time dedicated phone apps to informal paper records) and doggers’ perceived concerns about the use and intended and unintended consequences of reporting. Native animal collateral damage is often underreported due to the concerns of the doggers on where the data may end up.

- Only in Victoria is any monitoring of the performance (member satisfaction, effectiveness, integration) of wild dog groups formally undertaken. The monitoring system in most jurisdictions focuses upon participant satisfaction of and by the local dog group members. The drivers of 'satisfaction' of individual groups can differ across the state and country and over time.
- Queensland is experimenting with quarterly snapshot surveys of samples of the WDAG membership and non-WDAG membership to try and better understand the vagaries of voluntary reporting data and to better understand trends and satisfaction by stakeholders. This trial has been running for around six months and is indicative of the type of activities that needs to be undertaken to help to manage and control for known biases in measures of wild dog activities and impacts that exist in the voluntary reporting system currently in operation.

## 3. Features of wild dog data and their implications

A metric is a defined way to measure and record a phenomenon of interest. A systematic, repeatable and defined measurement system (i.e. the metric standard) allows data from multiple observations to be combined. The combined data obtained from the population can then be summarised into a single value – a statistic – which succinctly summarises the observations. If the sample is representative of the population of interest (i.e. a sample without bias) then the statistic obtained is also an unbiased estimate of the phenomenon in the population. Unbiased statistics provide insight into the phenomenon of interest and the monitoring of the statistic over time provides insight into trends in the underlying population.

For a statistic to be representative of the target population the metric must be clearly defined such that the measurement is and can be calculated and applied reliably when used (i.e. there is no measurement error) and the samples that are measured must be representative of the population that is being studied. If either of these requirements is not met then any calculated statistic will be biased. The impact of any bias depends upon the required level of accuracy in the statistic and the magnitude of measurement and/or sampling errors. A key aspect of sampling bias is that the direction of the bias cannot be predicted; some sampling biases may increase an estimate whilst others may reduce an estimate.

The majority of wild dog data are currently provided voluntarily by interested members of WDAGs and occasionally the general public ('citizen science'). (There is one important exception – the supply of dog baits and poisons such as 1080 is tightly regulated in each state such that complete dispensing data are available. Reporting of dogs is also required annually by pastoral lease properties 'within' the dog fence in SA (and WA), although such reporting is sub-optimal.) A data capture system that revolves around voluntary reporting presents a particular challenge to the interpretation of any metrics derived from those data because voluntary data are almost always markedly biased.

Some effects of bias can be managed by data cleaning but there is no statistical method that can eliminate the effect of sampling bias in data. The most effective way to correct for bias is to estimate the bias through controlled studies. An example is provided in Appendix 3.2.

*We believe that a system wholly dependent on voluntary reports of activities or impacts cannot provide accurate or reliable estimates of the marginal effectiveness of dog controls. These reports must be supplemented by active data capture for this to be a possibility.*

Producer-managed groups cannot be expected to have the knowledge, capacity or time to undertake scientific, sample-based measurement studies without guidance. Professional wild dog coordinators, however, are ideally placed to undertake either sample-based studies or longitudinal census-type studies of a subset of observers/producers. The Queensland AWI-funded wild dog coordinator has begun such a survey-based system this year and we recommend that this initiative be considered for broader application. A key advantage of the semi-quantitative survey being developed in Queensland is the focus on both WDAG and non-WDAG members, which provides the capacity to estimate and compare the reporting bias of the two groups.

It must be emphasised that the capacity to remove reporting bias by using a direct standardisation of rates approach (see Appendix 3.2) will be dependent on the accuracy, completeness and frequency of surveys of the population to estimate the proportion of producers reporting and not reporting on wild dogs and the estimation of the metric (for example, property attack rate) within each cohort. Standardisation helps to control confounding – in this case reporting bias – in the estimate but it cannot fully remove the bias. Standardisation depends upon an ability to measure with accuracy and precision the main source of bias in order to adjust for it. In this case, this is the proportion of producers who report. It has to be emphasised again that this adjustment cannot control for incomplete reporting. It can only adjust for differences in reporting rates between groups. If there is a systematic level of underreporting across the board then the adjusted estimate will also underestimate the phenomenon of interest.

The current wild dog data across most jurisdictions can be summarised as counts of events and activities such as dog attacks, dogs killed, baiting runs and sums of activities (such as amount of bait dispensed, person-hours on dog control). Counts and totals do not reveal the full story – they need a denominator/comparator to extract value. For example, '375 properties reported dog attacks' carries less information than either '375 out of a total of 560 properties in the region reported dog attacks' or '75% of the farming land in the region reported dog attacks'. Wild dog controls and impacts occur at individual, across-enterprise, within-region and over-time levels. More value will be extracted from the simple count data by converting them to appropriate 'rate' or 'density' estimates against some or all of these levels.

For example, participation rate may be defined as the proportion of landholders that participate in wild dog control activities or report wild dog impacts within a region. This carries with it extra data capture requirements such as knowledge of individual memberships and member activities of wild dog control groups along with background demographics of the farming and non-farming population. Much of this information may be held at local government level and, in states where local government is charged with administration and delivery of wild dog controls, it may be obtainable. The participation rate can be used both to generate more robust control and impact statistics by filtering out under-reporting groups and to identify regions where insufficient activity is being undertaken (or reported). Effective wild dog control requires co-ordinated, generalised and synchronised regional control (the 'nil tenure' approach) and a necessary metric is the rate of participation within a region.

Similarly, participation rate may be described as the proportion of land within a region where managers are participating in wild dog control and reporting.

Impacts and participation at the enterprise level add another layer of difficulty. Sheep are more prone to attack and wild dog impacts than are cattle so combining the livestock attack data from varied livestock enterprises within regions may not be valid or meaningful. What does a change to an average livestock attack rate mean if the enterprise mix in a region is also changing? Are separate sheep and cattle wild dog attack indices required for regions with both enterprises present? Is it possible to differentiate stock class in voluntary recorded data? Is the ability to describe stock class impacted required?

The intended use of the summary statistic – at regional, state or national level – also requires examination. For example what does a state or national average wild dog attack rate mean to a cattle producer north of the dog fence in South Australia? Does it mean the same thing to a sheep producer south of the dog fence? Similarly, does a national statistic have any intrinsic value to the producer or wild dog action group? Does a statistic have merit at government level? Can valid economic assessments be obtained from combining state-based control and impact statistics?

We believe that reliable aggregated group/region/state-level estimates of the control and impact activity are necessary because they underpin any economic assessment. Sound economic assessments (based on sound and reliable estimates of impact and cost) would inform all levels of the wild dog control hierarchy from local groups to state and national level. New studies are warranted and necessary as the ABARES report *An integrated assessment of the impact of wild dogs in Australia*[8] is in our opinion flawed. It is neither reasonable nor tenable to assume that producers experiencing a 20% increase in annual dog attack rates up to a maximum of 50% of calves killed or 100% of sheep killed would continue to take no action across a twenty-year period to avert any losses. This makes the net present value estimate of total losses from across the period to be a gross overestimate of individual producer losses. The impact of this assessment is a serious overestimation of the upper limit of potential losses for each region and enterprise. The economic method applied by Chudleigh et al (*Economic analysis of the national wild dog facilitator project*) provides a more rational approach to assessing the impact of wild dogs in a steady-state control environment. Accurate estimates of the total regional-national control cost and the impacts (i.e. stock losses) may inform such an analysis.

## 4. Candidate national metrics

### 4.1 A 'long list'

A suggested 'long list' of metrics is provided in Table 5 below. This list is not exhaustive, by any means, but is intended to demonstrate the range of metrics that are currently in use or might be considered for use.

Table 5 has been organised using an adaptation of Bennett's Hierarchy, a program monitoring, evaluation and reporting (MER) framework that has been successfully applied to many agricultural programs and projects (especially in extension) in Australia and overseas. Bennett's Hierarchy comprises a series of steps

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[8] Wicks, S et al 2014, 'An Integrated Assessment of the Impact of Wild Dogs in Australia', research report no. 14.4, Australian Bureau of Agricultural and Resource Economics and Sciences

from ‘inputs’ to ‘social, economic and environmental conditions (outcomes)’. Metrics to demonstrate impact can be developed for each level.

Higher-level metrics are more meaningful than lower level ones – for example, it is more important to know that a particular intervention delivered $2m in higher profits to a group of farmers than to know that 50 of them attended workshops. However, changes at higher levels are more difficult and expensive to measure and more difficult to attribute to the intervention under consideration.

Usually, an MER framework will involve a range of metrics at different levels of the hierarchy, sufficient to reasonably demonstrate a chain of effect. DEDJTR in Victoria has taken this approach, and its specific group of metrics has been identified in the table.

The table also provides some discussion of the strengths and weaknesses associated with each of the individual metrics. For a selection of metrics, these strengths and weaknesses are discussed in further detail below.

**Table 5: A 'long list' of wild dog metrics, their strengths and weaknesses**

| Bennett's Hierarchy level | Metric | Strengths | Weaknesses | Data source |
|---|---|---|---|---|
| **Social, economic, environmental outcomes** | Social outcomes – levels of producer stress, community satisfaction with control approach | Demonstrate real and important impacts if done correctly | Difficult and expensive to measure – may require focus groups for meaningful data | Stakeholder surveys, focus groups |
| | Change in profitability across industry and enterprises associated with stock losses (herd / flock performance statistics e.g. lambing percentage, marking percentages) | Could potentially capture unseen kills and impacts<br>Would be highly motivating for producers, demonstrating a relationship between improved dog control and improved herd/flock performance<br>Producer group networks such as BestWool BestLamb (Vic) could effectively integrate wild dog management practices into general farm management | Drivers of herd/flock performance are wide and varied and wild dogs for many producers are only one source of variation – season and enterprise will be far more influential on performance than wild dogs for the majority of producers (except within the most severe attack zones)<br>Producers may be unwilling or unable to share production and profitability data (and most don't routinely collect much more than lamb or calf marking rates) | Survey or focus-farm dependent methods to ensure data is representative of the group or region<br>Database analysis<br>Benefit/cost analysis |
| | Abattoir trim / carcase condemnation due to wild dogs | Trim and condemnation impact on farmer payments so this system provides meaningful economic feedback<br>Ante- and post-mortem inspections are mandatory<br>Sheep and cattle industries (Meat & Livestock Australia, Animal Health Australia) are working on a centralised, industry real-time abattoir database (Livestock Data Link, National Sheep Health Monitoring Project) | Would not capture on-farm kills, stock not fit for transport to or processing by the works, would not discriminate bites from working dogs (most bites identified at works)<br>Abattoirs are often wary of sharing data | Abattoir monitoring |

| Bennett's Hierarchy level | Metric | Strengths | Weaknesses | Data source |
|---|---|---|---|---|
|  | Environmental outcomes (native fauna losses) | Demonstrate real and important impacts if done correctly<br>Provide metrics beyond the purely commercial to attract greater public empathy and 'public good' funding justification for government | Very difficult (impossible?) and expensive to measure accurately | Structured surveys |
| **Control program results** | Number of dog attacks*<br>Average interval between dog attacks (25th, 50th and 75th percentiles) | The average, 25th, 50th and 75th percentile intervals of the distribution of time interval between attacks per property in a region may indicate the level of wild dog pressure within a region<br>Interval metrics would bypass some of the issues of incomplete voluntary reporting and would be transportable between properties<br>Would resonate well with producers | Assumes constancy of detection of wild dog attack events – this may not be the case in extensive areas – may need 'super-observers' who commit to providing complete, longitudinal data for their properties may control this bias<br>Benchmark intervals between attacks that are acceptable/unacceptable are not known and may be too property and region specific to be transportable<br>The benchmark will change according to season and the production cycle of the farm<br>Many producers regard dog control as 'the Government's job' and may not be inclined to provide data<br>Low participation rates in WDAGs will result in incomplete and inaccurate measurements | Surveys of WDAGs<br>Surveys of producers<br>Longitudinal studies of a subset of 'super-observers' |
|  | Total livestock killed / maimed by wild dogs | Provides an important direct measure of the impact of wild dogs | Difficult to aggregate to regional and national level<br>Sensitive to non-reporting bias<br>Difficult to measure kills, especially in extensive systems | Reporting by producers<br>Abattoir monitoring (see above) |

| Bennett's Hierarchy level | Metric | Strengths | Weaknesses | Data source |
|---|---|---|---|---|
| | Number of dogs destroyed (total and by method)*<br>Number of dogs sighted | Is appealing and tangible as a measure of effectiveness of control interventions and may reflect an effect on stock losses | Totals will be dependent upon level of dog activity, reporting rate and completeness of observation and reporting<br>Attribution of stock losses (especially in extensive properties) is problematic<br>Sensitive to non-reporting bias | Reporting by producers |
| **Practices** | Positive changes made in dog control practices by WDAGs and individual producers | Provides a better surrogate for actual impact than lower-level metrics | Challenges of identifying 'best practices' – and are these comparable between regions?<br>Is adoption of best practices the main issue, or simply participation? | Surveys of WDAGs<br>Surveys of producers |
| | Positive changes made in stock management practices | | | |
| **Human responses – knowledge, attitudes, skills, aspirations, reactions** | New things learnt | Arguably, human satisfaction is the only metric that matters!<br>May indicate the sustainability of individual WDAGs | Do not necessarily reflect impact at economic, social, environmental levels<br>Can only be obtained by regular survey which may be expensive, especially if objective measures of increased skill levels are sought | Surveys of WDAG members |
| | Confidence to make changes | | | |
| | Level of satisfaction with group and activities – value, continuance | | | |
| **Activities / participation** | Number of WDAGs operating* | All are useful measures of the activity of the surveillance system within regions, and indicate the strength of local engagement of WDAGs, degree of activity of the WDAGs etc<br>Accurate measurement provides opportunity for gauging change | No intrinsic information on whether the number is 'good' or 'bad'<br>Need a divisor/denominator - but difficult to define. What is a desirable target?<br>In some cases, may be difficult to record hours correctly (e.g. checking the boundary fence is not just for dog control) or completely recall<br>Reliance on voluntary data only will result in erroneous conclusions, counter-intuitive associations between level of activity and control and inability to monitor anything but the most obvious and severe change<br>A 'bad' metric may be worse than no metric | WDAG measures<br>Database analysis (e.g. WildDogScan) |
| | Number of attendees at WDAGs | | | |
| | Number of properties engaged within WDAGs* | | | |
| | Area of properties engaged in WDAGs | | | |
| | Participation in group activities, webinars etc | | | |
| | Number of coordinated activities undertaken by WDAGs | | | |
| | Scope of WDAG activities | | | |

| Bennett's Hierarchy level | Metric | Strengths | Weaknesses | Data source |
|---|---|---|---|---|
| | Input into WildDogScan | | | |
| | Person hours spent on dog control | | | |
| | Number/amount of baits used, traps used/set* | | | |
| | Number of surveillance activities undertaken / in place | | | |
| | Number of recording activities undertaken (e.g. sand traps, cameras)* | | | |
| | Number of properties / area where controls were undertaken* | | | |
| **Inputs** | Money invested | Often sought and quoted by governments and other funders<br>Easily measured | No intrinsic information on whether the number is 'good' or 'bad' | Project plans at regional and state level<br>Budgets at regional and state level |
| | People – number, hours contributed by all participants* | | | |

## 4.2 Proposed short-list of metrics

We propose a short-list set of national metrics as shown in Table 6.

**Table 6: Proposed wild dog metrics**

| Metric | Comments |
|---|---|
| **Social, economic, environmental outcomes** | |
| Stakeholder satisfaction | Periodic (biennial?) survey of stakeholders with statistical power to the jurisdiction level<br>Standard set of questions |
| **Control program results** | |
| Interval between dog attacks (median, quartiles) | Highly sensitive to observational and reporting bias but use of interval avoids some statistical challenges<br>Voluntary data must be supplemented by surveys or subset longitudinal census data to allow biases to be (partially) controlled and to provide an adjusted estimate that can be used to monitor effectiveness. Essentially, this requires census data from sufficient observers for a stable and true average interval to be calculated. Providing continuous and complete data from a property is a big commitment. A sample of recruited, briefed and supported 'super-observers' will be essential for this metric to be of use[9]<br>Will require systems to define confidence in regional data (from surveys or longitudinal data) such that incomplete or low-confidence data can be excluded from regional and upwards-aggregated estimates<br>Will generally be region-, season- and enterprise specific<br>Acknowledged to be less applicable in extensive systems<br>Aggregating 'rates' to regional and state and national level will present interpretation problems. What does the average interval between attacks mean? Who does it relate to? How do you combine across species (cattle vs sheep) and enterprise (e.g. wether wool vs. lambs)? |
| **Activities, participation, human responses, practices** | |
| Number regions with WildDogScan reports | Number of regions with 'active' reports as geo-referenced by WildDogScan. This can inform the level of reporting activity and provide some indication of spread of wild dogs (if reported). Level of under-reporting may not be easily estimated (if at all) |

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[9] An approach is to engage a sample of 'super observers' who record all activities in dog control and commit to daily and comprehensive recording of wild dog impacts on their properties. The data from the 'super observers' need to be uniquely identifiable to person, place, time and class (of control or livestock etc.) The distribution of time between events (impacts) from these super observers can then be related to the quality of control provided by the individual operator (and the region) and metrics such as the average time between attacks (or its inverse the average number of attack-free days) can be calculated and monitored. The rate of attacks and therefore the interval between attack events should be correlated to the level of wild dog pressure in a region. This is in turn dependent on the number of wild dogs in the region, the species and class of stock present on the properties of the 'super observer', the sources of other food for the dogs and (importantly) the effectiveness and extent of wild dog control activities undertaken by the individual and the surrounding neighbours. The metric will therefore be enterprise-, season- and region-specific but can be expected to change according to the quality of wild dog control on a seasonal basis. Importantly, it is not influenced by the number of voluntary reporting properties in a region. A usable statistic does depend on sufficient and representative 'super observers' being recruited as well as their adherence to the recording protocol. There may be difficulties in application of this approach in the extensive grazing regions where observation of all stock on a daily or near-daily basis is not possible or feasible.

| Metric | Comments |
|---|---|
| Number of WDAGs | Requires a co-ordinator to collect and maintain the information |
| Number of members in WDAGs | As above. Can inform a 'completeness' index for a group or region – consisting of the proportion of potential members (landholders) that are actual members. This index can be used as a measure of the confidence that the metrics calculated for the group are reflective of the region. The index can both identify less active groups for targeting (by a local coordinator) and may be used to exclude data from underreporting groups from aggregated regional estimates. Adds a layer of complexity to data collection (metadata) and collation |
| Number WDAG with up-to-date plans | As above |
| Number of activities undertaken by WDAGs<br>-Baiting<br>-Trapping<br>-Shooting, etc. | Collection of information via a voluntary reporting system alone is inadequate and will produce biased and erroneous estimates and associations. Inferences drawn from analysing only voluntary data could potentially be more harmful than the (qualitative) opinion of experts<br>Must be supported by surveys to estimate coverage and allow for (partial) adjustment of biases and/or supported by subset longitudinal studies by committed observers<br>This has database implications. Reports have to be identified to user, place, time (and enterprise type) so that adjusted estimates (from surveys / longitudinal studies) at the regional, state and national level can occur<br>Requires commitment and resourcing of a regional and trained co-ordinator |
| Number of co-ordinated region-level activities undertaken<br>-e.g. aerial baiting | As above |
| Number of surveillance activities undertaken: sand trapping, surveillance cameras, drones, etc. | As above |
| Number of person-hours spent on dog control activities | As above |
| **Inputs** | |
| Money invested | |

## 4.3 Notes on the recommended metrics

Whilst lower-level metrics (inputs, activities, participation, human responses, practices) are generally less informative than higher-level ones, they are easier to measure and in many cases well (if irrationally) accepted as key metrics – for example, level of government spending. Any that are currently being collected should continue. We have recommended key ones above.

Some activity metrics may be able to be reported 'raw'. Baiting is the main control and the dispensing of baits is regulated and therefore complete (note: this is unlikely to be the case for trapping and shooting activities). Most jurisdictions and regions will capture complete information on the *dispensing* of baits. This may not exactly correlate to the *administration* or *dispersal* of baits.

We believe it is essential that 'raw' activity counts first be filtered for grossly incomplete reporting (which are deleted from calculations), then converted into an appropriate rate (by dividing by an appropriate denominator such as number of reporting properties, area of land, number of livestock etc) and finally adjusted for reporting biases (to control for variation in the completeness of reporting within and between regions). These standardised rates would then be sent forward for aggregation into regional- or higher- level statistics with the appropriate (metadata) weighting factor (e.g. total livestock in the region).

We can only identify two metrics at the higher levels – stakeholder satisfaction and interval between dog attacks – that hold any real promise for national application.

We are specifically recommending against two metrics that are, on the surface, quite attractive, but which do not stand up to scrutiny:

Changes in lambing or calving rates

There are two practically insurmountable problems with identifying changes in lambing or calving rates due to dogs or interventions to control dogs (as described in Table 5):

1. In all regions, reproductive rates are highly influenced by non-dog factors, notably season, enterprise (for example, Merino enterprises tend to have much lower reproductive rates than those of dedicated sheepmeat breeds), reproductive disorders, sire management and so on. These factors will be far more influential on reproductive performance than wild dogs for the majority of producers except within the most severe attack zones.
2. Producers may be unwilling or unable to share production and profitability data. Most do not routinely collect much more than lamb or calf marking rates. Very few can or do make systematic observations of causes of perinatal mortality. A survey conducted at a wild dog meeting may result in an attribution bias (over-reporting) of wild dog impacts.

Wild dog impact on reproductive rate could only be estimated from semi-quantitative surveys involving producers estimating their losses due to wild dogs. Without significant and expensive guidance, this is likely to be of limited accuracy (especially in low-moderate dog impact regions) and therefore of limited value.

The limitations of these metrics are further explored in Appendix 3.3.

Abattoir trim / carcase condemnation due to wild dogs

The problems with abattoir-derived metrics are that they:

- Would not capture on-farm kills or stock not fit for transport – a constraint that would apply to most animals that have been attacked. The Land Transport of Livestock Standards and Guidelines states: *'Livestock must be assessed as fit for the intended journey at every loading by a person in charge. An animal is not fit for a journey if it is:…iv) showing visible signs of severe injury or distress; or v) suffering from conditions that are likely to cause increased pain or distress during transport…'*[10]. There are severe penalties for owners and/or transporters who load livestock not meeting these or similar standards according to various state regulations.

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[10] Animal Health Australia 2012, 'Australian Animal Welfare Standards and Guidelines: Land Transport of Livestock', version 1.1

- Are obtained from across a wide and varying catchment such that the metric derived from a single abattoir may not represent the same region or producers over time.
- Would not discriminate bites from working or other domestic dogs, which comprise the greater proportion of sheep bites identified at abattoirs
- Would not provide significant information in relation to the total impact of wild dogs as data from previous studies[11] indicate that losses in saleyards and abattoirs accounted for approximately 3% of total costs from wild dogs in Queensland.

Cattle abattoir condemnation data collected at the property level would prove more reliable as there will generally be constancy in the effectiveness of pre-sale inspection of stock and saleyard removals such that change in the rate of condemnation at property level may be reflective of the level of dog attack currently being experienced. However, this would negate much of the attractiveness of using abattoir data as many individual producers per region would be required to provide kill sheets on a regular basis.

## 4.4 Aggregating and combining metrics

There are two essential steps for aggregating data to allow regional-national statistics to be generated:

1. Data quality

The dependence on voluntary data means that there is significant variation between groups in the level of activity and the quality of recording. An absence of evidence (reports) from a region is not proof of an absence of wild dogs. Inclusion of under-reporting regions will result in underestimation of the regional and aggregated metric. Aggregation of data only from groups that have sufficient reports but where there is a significant positive reporting bias by group members (typically under higher levels of attack) will result in overestimation of impacts. The combined effect of the biases in both directions is that a regional estimate will be wildly variable without filtering of data for under-reporting and adjustment of data for any (positive) reporting bias. The regional estimate will be of limited value in monitoring trends or in assessing effectiveness of the marginal intervention.

Defining the minimum data quality requirements will require further analysis of existing and prospective data. There will be need to be data exclusion criteria (insufficient activity and/or recording from a group or region for data to provide an estimate with sufficient accuracy) and data standardisation (a system to control (adjust) for differences in reporting propensity over time within and between groups).

2. Weighting the estimate

Regional averages are essentially weighted averages. The key questions are how to weight the (filtered and standardised) estimate from component reporting groups or individuals into a regional estimate. A number of adjusters may be used such as number of participants, area of land and livestock units. More than one adjuster may be used.

An example demonstrating the requirement and the process of weighting is provided in Appendix 3.4.

The weight value to carry forward is essential metadata to allow meaningful aggregation to the next level up in the hierarchy. Groups and regions will differ in size and therefore their relative contribution to an

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[11] Hewitt, L 2009, 'Major Economic Costs Associated with Wild Dogs in the Queensland Grazing Industry', AgForce

aggregated statistic are typically different. In order to calculate aggregated statistics it is essential that the contributing metrics are all calculated identically and they are accompanied by appropriate (and consistent) weights.

Implicit in these calculations is the capture of the necessary metadata (no. properties, area and total stock) for the group, region and state. This demands a relational database with associated costs, resourcing and maintenance issues.

## Appendix 3.1: Wild dog monitoring, evaluation and reporting across jurisdictions

**Key:** A – available and undertaken (universal), C – capable (but not undertaken), G – government sector, GC – group committee, L – locally available if required, N – no or not undertaken, P – private sector, U – unknown, V – voluntary, Y – yes, or undertaken

| | Qld | NSW | Vic | Tas | SA | NT | WA |
|---|---|---|---|---|---|---|---|
| REPORTING ENTITIES | | | | | | | |
| *WD Action Groups* | | | | | | | |
| Professional coordinator available | Y (Authorised officers – local govt.) | Y (Pest control officers) | Y | | Y (spread thin) | Y (1080 officer - head office only) | V (reducing) |
| Reporting system | V | C (Via dogger – producers do not report) | C (but no GP access – via doggers) | | V | N | V |
| Effectiveness reporting | N | N | Y | | N | N | N |
| Management | GC | GC | GC | | GC | GC | GC |
| Reporting obligations | N | N | C (via dogger) | | N (north); Y (south) | N | N |
| *Doggers* | | | | | | | |
| Engagement | L,P | G | G | | L,P | L,P | L,P |
| Reporting | Y | Y | Y | | N | Baits only | Y (not enforced) |
| *Entity performance monitoring* | | | | | | | |
| Member satisfaction | N | N | Y | | N | N | N |
| Effectiveness | N | N | Y | | N | N | N |
| Integration | N | N | Y | | N | N | N |

| | Qld | NSW | Vic | Tas | SA | NT | WA |
|---|---|---|---|---|---|---|---|
| REPORTING | | | | | | | |
| *Activity reporting* | | | | | | | |
| Baiting | V | C (dogger) | C | | V | C (chemical control) | V |
| Trapping | V | C (dogger) | C | | V | N | V |
| Shooting | V | C (dogger) | C | | V | N | V |
| *Dog reporting* | | | | | | | |
| Sightings | V | V | V | | V | N | V |
| Dead dogs /kills | V | V | V | | V | N | V |
| Livestock attacks/deaths | V | V | V | | V | N | V |
| Production indicator reporting | N | N | N | | N | N (proposed studies) | N |
| *Dog population monitoring* | | | | | | | |
| Population size longitudinal studies | N | N | Y (some sites) | | N | N | N |
| DATABASE | | | | | | | |
| Central SQL database | | N | Y | | N | N | Y |
| Real-time recording | | - | Y | | N | - | C |
| Spatial capability | | - | Y | | N | - | C |
| State-level analysis | | - | Y | | N | - | C |
| Data forward nationally | | - | N | | N | - | N |

| | Qld | NSW | Vic | Tas | SA | NT | WA |
|---|---|---|---|---|---|---|---|
| Customisable reports | | - | Y (but rarely done and not encouraged) | | N | - | C |
| Local reporting access only | | - | Y (for groups) | | Y | - | Y |
| JURISDICTIONAL MONITORING | | | | | | | |
| Activity reports | | Manual | Y | | N | Y (baits only) | N |
| Event reports | | N | Y | | N | N | N |
| Correlation (activity-event) analysis | | N | Y (developing methods) | | N | N | N |
| Coverage (underreporting) analysis | | N | N | | N | N | N |
| Feedback reporting | | N | Y | | N | N | N |
| National summary reporting | | N | N | | N | N | N |
| COMMENTS | Single AWI-funded wild dog control officer is managing activities of individual WDAGs in the state | Govt trying to transfer responsibility to landholders | Vic govt is obligated to control dogs. Govt has longer-term view – understands need to study popn trends | | Dingos and dog fence divide state | 85% NT producers use baits each year | Diverse state with many absentee landlords in north; cattle and sheep districts generally separate |

## Appendix 3.2: The problem of observational bias

Consider the following example:

| | WD attacks occurring | | No WD attacks | |
|---|---|---|---|---|
| | **WDAG member** | **Non-member WDAG** | **WDAG member** | **Non-member WDAG** |
| **Reporting** | 700 | 100 | 100 | 20 |
| **Non-reporting** | 100 | 50 | 75 | 250 |

In the example, the *actual* percentage of properties suffering dog attacks in the region is 950/1,395 = 68%. The apparent percentage suffering dog attacks – that is, those *reporting* them – is 800/920 = 87%, a difference of nearly 20% from the true estimate. This is because of the voluntary reporting bias arising because members of the wild dog action group are more likely to report than non-members and producers under wild dog attack are more likely to report than producers not experiencing attacks. The bias in the estimate is almost 20%.

Now if the *actual* attack rate stays the same but more farmers leave the WDAG (and this changes their reporting propensity) the figures change, as follows:

| | WD attacks occurring | | No WD attacks | |
|---|---|---|---|---|
| | **WDAG member** | **Non-member WDAG** | **WDAG member** | **Non-member WDAG** |
| **Reporting** | 300 | 200 | 100 | 20 |
| **Non-reporting** | 37 | 400 | 75 | 250 |

The actual percentage of properties experiencing dog attacks remains at 937/1,382 = 68% but the apparent percentage reporting attacks has reduced to 500/620 = 81%.

The absolute error in the estimate of around 20% is less concerning than the 6% change in the estimate arising simply from a change in reporting rate (without an underlying change in dog attacks). An absolute error in an estimate does not totally invalidate the statistic as it still tracks trends (if consistently present) but the capricious and unpredictable changes in a biased estimate simply due to altered voluntary participation rate will obscure all subtle trends in attacks.

Some form of controlled survey could be undertaken, and repeated on a regular basis, to allow the overestimation of the proportion of properties experiencing dog attack to be adjusted downwards.

In the example above, if a survey identified that at the first time point around 60% of the producers in a region were actively reporting and at the second time point only 35% were engaged in reporting, then the overall property attack rate could be adjusted to reflect a 'standard' population of producers (with a constant reporting frequency). If we assume that 50% of the standard population reports then we can adjust the observed reporting rates for reporting producers and non-reporting producers within each time point to this standard population as follows:

Period 1

| | **% Producers** | **Attack rate** |
|---|---|---|
| **Reporting** | 62.4% | 86.2% |
| **Non-reporting** | 37.6% | 38.1% |

Period 2

| | **% Producers** | **Attack rate** |
|---|---|---|
| **Reporting** | 44.9% | 80.6% |
| **Non-reporting** | 55.1% | 57.3% |

Standard population (50% reporting)

| | **% Prod. (A)** | **Strata attack rate (B)** | **Contr. to popn attack rate (A*B = C)** |
|---|---|---|---|
| **Reporting** | 50% | 86.2% | 43.1%% |
| **Non-reporting** | 50% | 38.1% | 19.0% |
| | Adjusted attack rate (∑C) | | 62.1% |

| | **% Prod. (A)** | **Strata attack rate (B)** | **Contr. to popn attack rate (A*B = C)** |
|---|---|---|---|
| **Reporting** | 50% | 80.6% | 40.3%% |
| **Non-reporting** | 50% | 57.3% | 28.7% |
| | Adjusted attack rate (∑C) | | 69.0% |

So, after adjustment for the proportion of producers reporting within each time period the adjusted property attack rate *estimates* are 62.1% for time period 1 and 69.0% for time period 2. The *actual* attack rates at each time period were 68.1% at time period 1 and 67.8% at time period 2. Thus whilst direct standardisation has not eliminated all biases in the estimates they are much closer to the real rate and (importantly) much more stable.

## Appendix 3.3: Discerning attack trends in reproductive data

Monitoring of production data has inherent appeal. Wild dogs can be expected to contribute to decreased physical production (for example, reduced lambing percentage) and reduced farm operating profit through the combined effects of increased costs (for control) and reduced income (from sales). However, the natural variation in farm performance is likely to swamp the effects of wild dogs in all except the most threatened regions of Australia. To demonstrate the variation in performance the Livestock Farm Monitor Project[12] is a 40-year long farm physical and financial study of commercial livestock producers across Victoria within each production category conducted by the Department of Economic Development, Jobs, Transport and Resources and Rural Finance. Detailed and consistent longitudinal data from a large sample of producers in each region of the state are monitored for trends and analysed to identify the features of successful producers.

These data provide insight into the level of natural variation in performance between and within enterprises over time. Importantly, we can examine the performance range of sheep producers in regions not affected by wild dogs to gain insight into the non-wild-dog related (background) variation. The data for the South-West of Victoria for 2013/14 are presented below (Figure 3). As the figures show, there is wide variation in financial performance between farms and within farm from year to year.

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[12] Victorian DEPI 2014, 'Livestock Farm Monitor Project – Victoria 2013/14', Melbourne

Figure 21. Earnings before interest and tax

Figure 24. Return on equity

Figure 22. Net farm income

Figure 25. EBIT history

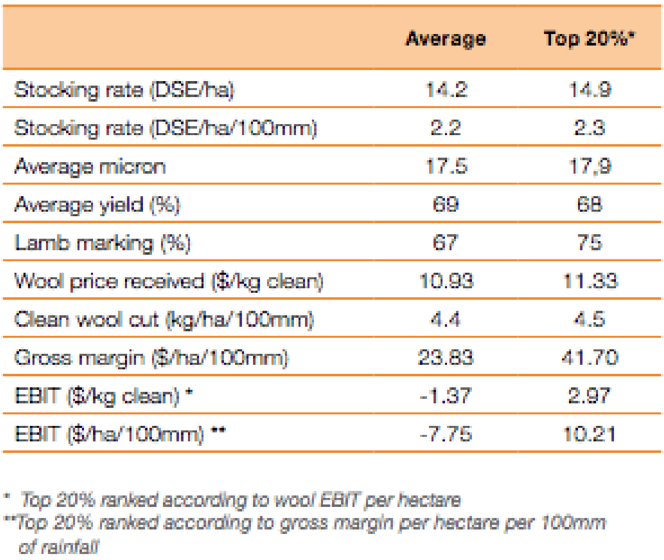
Figure 23. Return on assets

Figure 26. RoA and RoE history

**Figure 3: Summary financial data from study sheep producers in SW Victoria in 2013/14**

There is a difference of 8% in lamb marking percentage between the average wool producer and those in the top 20% of businesses (Table 7). The equivalent figure for prime lamb producers is (paradoxically) -8% (Table 8). These non-wild-dog fluctuations are large and are highly season- and management-dependent. The capacity to identify and monitor wild dog impacts within farm physical and financial data given the size of non-dog variation in performance regions will be limited. The risk of observing spurious (non-causal) associations will be high.

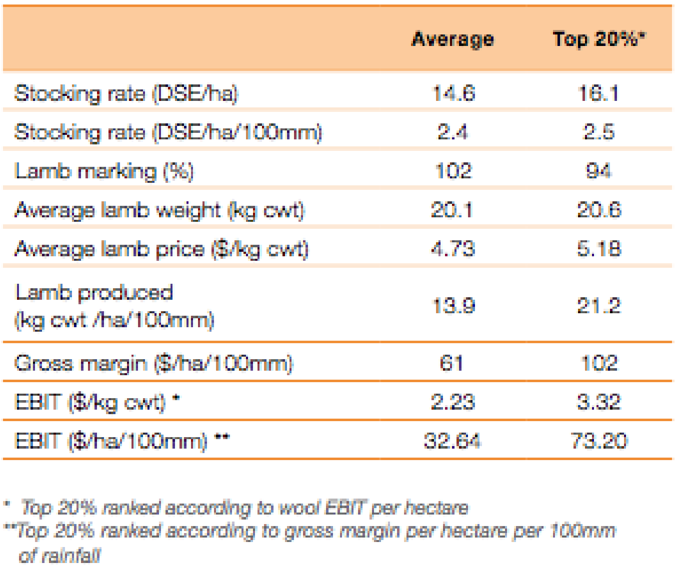
**Table 7: South West Victoria wool enterprise physical and financial summary**



| | Average | Top 20%* |
|---|---|---|
| Stocking rate (DSE/ha) | 14.2 | 14.9 |
| Stocking rate (DSE/ha/100mm) | 2.2 | 2.3 |
| Average micron | 17.5 | 17.9 |
| Average yield (%) | 69 | 68 |
| Lamb marking (%) | 67 | 75 |
| Wool price received ($/kg clean) | 10.93 | 11.33 |
| Clean wool cut (kg/ha/100mm) | 4.4 | 4.5 |
| Gross margin ($/ha/100mm) | 23.83 | 41.70 |
| EBIT ($/kg clean) * | -1.37 | 2.97 |
| EBIT ($/ha/100mm) ** | -7.75 | 10.21 |

** Top 20% ranked according to wool EBIT per hectare*
***Top 20% ranked according to gross margin per hectare per 100mm of rainfall*

**Table 8: South West Victoria lamb enterprise physical and financial summary**



| | Average | Top 20%* |
|---|---|---|
| Stocking rate (DSE/ha) | 14.6 | 16.1 |
| Stocking rate (DSE/ha/100mm) | 2.4 | 2.5 |
| Lamb marking (%) | 102 | 94 |
| Average lamb weight (kg cwt) | 20.1 | 20.6 |
| Average lamb price ($/kg cwt) | 4.73 | 5.18 |
| Lamb produced (kg cwt /ha/100mm) | 13.9 | 21.2 |
| Gross margin ($/ha/100mm) | 61 | 102 |
| EBIT ($/kg cwt) * | 2.23 | 3.32 |
| EBIT ($/ha/100mm) ** | 32.64 | 73.20 |

** Top 20% ranked according to wool EBIT per hectare*
***Top 20% ranked according to gross margin per hectare per 100mm of rainfall*

## Appendix 3.4: Weighting estimates for data aggregation

An example of weighting to aggregate metrics is provided in Table 9.

**Table 9: Example of filtering and standardising metrics**

| | Wild dog reporting | Wild dog attacks | Area | Sheep |
|---|---|---|---|---|
| Property 1 | Y | 15 | 1,000 | 1,000 |
| Property 2 | N | - | 3,000 | 3,000 |
| Property 3 | N | - | 2,000 | 4,000 |
| Property 4 | Y | 25 | 3,000 | 5,000 |
| Property 5 | Y | 20 | 2,000 | 2,000 |
| Total | 5 properties | 60 | 11,000 | 15,000 |
| Total | 3 reporting properties | 60 | 6,000 | 8,000 |

The raw average in the example is 60 attacks across 5 properties. This provides an estimate of 60/5 = 12 attacks per property. However, not all properties were engaged and reported dog controls or impacts. By removing the non-reporting properties from the calculation we calculate the average number of attacks per property is (15+25+20)/3 = 20.

Not all properties in the region are equivalent size or stocking rate. If we adjust the calculation for land area we arrive at a weighted average number of attacks per property (by land area) of (15 * 1,000 + 25 * 3,000 + 20 * 2,000)/(1,000 + 3,000 + 2,000) = 21.7.

Similarly, we can adjust for number of sheep carried. The weighted average number of attacks per property (by sheep numbers) is (15 * 1,000 + 25 * 5,000 + 20 * 2,000)/(1,000 + 5,000 + 2,000) = 22.5

All property-average estimates adjusted for non-reporting are between 22 and 23 attacks per property. These estimates differ markedly from the raw average of 12. Whilst the area- and stocking rate-adjusted estimates do not differ greatly from the raw attack rate per property in this example this will not always be the case. The differences in land area and stocking rates are likely to vary more widely between than within regions and as such a weighting system is essential to combine estimates from different regions into a regional or state-level average with any accuracy.

For aggregating to regional level the numbers to carry forward are presented in Table 10.

**Table 10: Weights and associated metrics for aggregated statistics**

| | Estimate | Regional area weight |
|---|---|---|
| Attacks per property | 20 | 5 (no. of properties in region) |
| Attacks per property (weighted by area) | 21.7 | 10,000 (ha) |
| Attacks per property (weighted by sheep number) | 22.5 | 13,000 (sheep) |

## Appendix 4: Accuracy, precision and sample size matrix for varying attack rates

| Required confidence interval accuracy | Required precision estimate | Attack rate | Sample size required | *Example number impacted* | *Example rate estimate* | *Example confidence interval* |
|---|---|---|---|---|---|---|
| 90% | 5% | 10% | 98 | 10 | 0.102 | 0.062-0.163 |
| | | 20% | 174 | 35 | 0.201 | 0.156-0.256 |
| | | 30% | 228 | 68 | 0.298 | 0.251-0.350 |
| | | 40% | 260 | 104 | 0.4 | 0.351-0.451 |
| | | 50% | 271 | 136 | 0.502 | 0.452-0.552 |
| | | 60% | 260 | 156 | 0.6 | 0.549-0.649 |
| | | 70% | 228 | 160 | 0.702 | 0.650-0.749 |
| | | 80% | 174 | 139 | 0.799 | 0.744-0.844 |
| | | 90% | 98 | 88 | 0.898 | 0.837-0.938 |
| | 10% | 10% | 25 | 2 | 0.08 | 0.027-0.215 |
| | | 20% | 44 | 9 | 0.205 | 0.123-0.320 |
| | | 30% | 57 | 17 | 0.298 | 0.210-0.405 |
| | | 40% | 65 | 26 | 0.400 | 0.306-0.502 |
| | | 50% | 68 | 34 | 0.500 | 0.402-0.598 |
| | | 60% | 65 | 39 | 0.600 | 0.498-0.694 |
| | | 70% | 57 | 40 | 0.702 | 0.595-0.790 |
| | | 80% | 44 | 35 | 0.795 | 0.680-0.877 |
| | | 90% | 25 | 22 | 0.880 | 0.735-0.951 |
| | 20% | 10% | 7 | 1 | 0.143 | 0.033-0.452 |
| | | 20% | 11 | 2 | 0.182 | 0.062-0.427 |
| | | 30% | 15 | 5 | 0.333 | 0.173-0.545 |
| | | 40% | 17 | 7 | 0.412 | 0.241-0.607 |
| | | 50% | 17 | 8 | 0.471 | 0.290-0.660 |
| | | 60% | 17 | 10 | 0.588 | 0.393-0.759 |
| | | 70% | 15 | 11 | 0.733 | 0.521-0.874 |
| | | 80% | 11 | 9 | 0.818 | 0.573-0.938 |
| | | 90% | 7 | 6 | 0.857 | 0.548-0.967 |
| 95% | 5% | 10% | 139 | 14 | 0.101 | 0.061-0.162 |
| | | 20% | 246 | 49 | 0.199 | 0.154-0.254 |
| | | 30% | 323 | 97 | 0.300 | 0.253-0.352 |
| | | 40% | 369 | 148 | 0.401 | 0.352-0.452 |
| | | 50% | 385 | 192 | 0.499 | 0.449-0.548 |
| | | 60% | 369 | 221 | 0.599 | 0.548-0.648 |

| Required confidence interval accuracy | Required precision estimate | Attack rate | Sample size required | *Example number impacted* | *Example rate estimate* | *Example confidence interval* |
|---|---|---|---|---|---|---|
| | | 70% | 323 | *226* | *0.700* | *0.648-0.747* |
| | | 80% | 246 | *197* | *0.801* | *0.746-0.846* |
| | | 90% | 139 | *125* | *0.899* | *0.838-0.939* |
| | 10% | 10% | 35 | *4* | *0.114* | *0.045-0.260* |
| | | 20% | 62 | *12* | *0.194* | *0.114-0.309* |
| | | 30% | 81 | *24* | *0.296* | *0.208-0.403* |
| | | 40% | 93 | *37* | *0.398* | *0.304-0.499* |
| | | 50% | 97 | *48* | *0.495* | *0.397-0.593* |
| | | 60% | 93 | *56* | *0.602* | *0.501-0.696* |
| | | 70% | 81 | *57* | *0.704* | *0.597-0.792* |
| | | 80% | 62 | *50* | *0.806* | *0.691-0.886* |
| | | 90% | 35 | *32* | *0.914* | *0.776-0.970* |
| | 20% | 10% | 9 | *1* | *0.111* | *0.020-0.435* |
| | | 20% | 16 | *3* | *0.188* | *0.066-0.430* |
| | | 30% | 21 | *6* | *0.286* | *0.138-0.500* |
| | | 40% | 24 | *10* | *0.417* | *0.245-0.612* |
| | | 50% | 25 | *12* | *0.480* | *0.300-0.665* |
| | | 60% | 24 | *14* | *0.583* | *0.388-0.755* |
| | | 70% | 21 | *15* | *0.714* | *0.500-0.862* |
| | | 80% | 16 | *13* | *0.812* | *0.570-0.934* |
| | | 90% | 9 | *8* | *0.889* | *0.565-0.980* |

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