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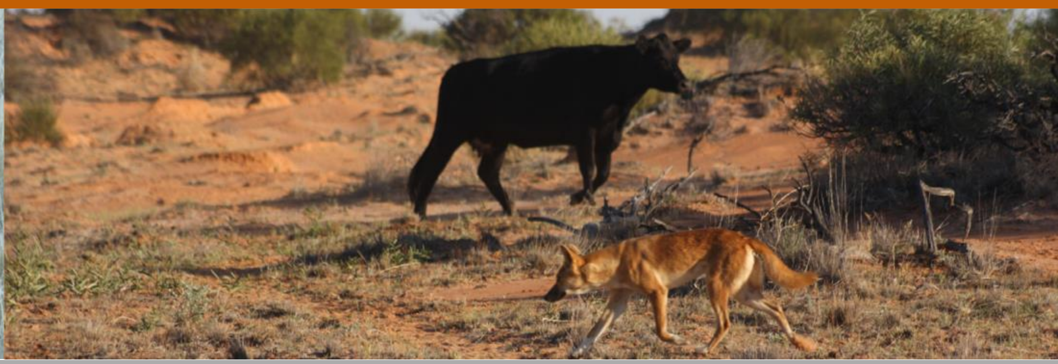

April 2016

South Australian Arid Lands Natural Resources Management Board

The effect of wild dog control on cattle production and biodiversity in the South Australian arid zone

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For the purpose of this report, the term 'wild dog' refers to dingoes (*Canis lupus dingo*), domestic dogs that are wild-living (*Canis lupus familiaris*) and their hybrids.

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Definition of Acronyms

DEWNR	Department of Environment Water and Natural Resources
NR SAAL	Natural Resources, SA Arid Lands
PIRSA	Primary Industries and Regions South Australia
SAALNRMB	South Australian Arid Lands Natural Resources Management Board
MAR	Mean Annual Rainfall
NDVI	Normalised Difference Vegetation Index
PTI	Passive Tracking Index
NSWDPI	New South Wales Department of Primary Industries

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Peter Bird	Biosecurity SA
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Anthony Brook (4 years)	Cordillo Downs Station
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Contents

EXECUTIVE SUMMARY

Throughout Australia, wild dogs (i.e. dingoes, feral domestic dogs and their hybrids) are widely recognised as a significant threat to livestock production systems. In the rangelands, where cattle predominate, most producers consider poison baiting of wild dogs to be a critical component of economically viable cattle production. Yet, recent research has demonstrated that baiting may not always be effective in reducing predation impacts on cattle. Moreover, other studies have shown that economically significant damage to cattle production does not occur routinely, and that wild dog control may not always be necessary.

At times when they are not causing economic harm to cattle, wild dogs may actually have a net benefit to livestock production, through limiting the abundance of herbivores such as kangaroos which compete with livestock for food, and also regulating populations of feral animals such as pigs, goats, cats and foxes which are all known to be seriously detrimental to the environment. Balancing the negative and positive impacts of wild dogs may be critical to achieving best practice management of rangeland beef cattle. However, this is not possible without a good understanding of the relationships between wild dogs and their prey in the area to be managed.

In northern South Australia's pastoral zone, wild dog management is the responsibility of the South Australian Arid Lands (SAAL) NRM Board. The Board identified a need for more information to help predict when wild dogs are likely to cause economic harm in this region, so that an optimal strategy for wild dog management could be developed that minimises the economic impacts of wild dogs, yet harnesses the benefits associated with the continued presence of wild dogs in the landscape (albeit at manageable levels). A 6-year study began in mid-2008 to investigate the effect of 1080 poison baiting for wild dogs on beef cattle production and biodiversity in the far north of South Australia. The study was conducted on five individual cattle stations with the objective of identifying potential indicators of predation risk (or "triggers") that would enable pastoral land managers to apply lethal wild dog control optimally according to risk and the likelihood of significant calf loss.

Using paired treatment areas on each property (one nil-treatment area and the other subjected to broad-scale poison baiting for wild dogs), the impact of poison baiting on calf production was measured by comparing lactation failure rates in cows between treatments. Sand plot activity indices were used to examine the impact of poison baiting on the relative abundance of predators and prey species. Wild dog diet was assessed by analysing the content of scats collected throughout the study. Water point usage by wild dogs was examined by tracking the movements of 11 individuals fitted satellite GPS transmitters.

On average, wild dog activity was 60% lower in baited areas during the study, suggesting that poison baiting caused at least temporary reductions in wild dog activity. Despite this, no consistent effect of poison baiting on calf production was identified. Numerous predation events on cattle were witnessed by researchers and pastoralists during the project, so there was definitely predation happening, but the study found no consistent evidence that it was lessened by baiting. Within properties, substantial differences in lactation failure rates occurred over time and also between treatments, but this variation was inconsistent and likely to be due to a range of property-specific variables. Cow age was the only factor found to have consistently affected lactation failure, with rates in first lactation heifers almost double that of adult cows.

Importantly, wild dog activity was never reduced completely to zero in the baited treatment areas, indicating that the baiting treatment (which was modelled on conventional baiting techniques in northern South Australia) never completely eradicated wild dogs.

As well as the observed differences in wild dog activity between treatments, we also found considerable temporal variation. The study period was characterised by a 2-year period (2010-2011) of unusually high rainfall at all sites. Either side of this period, rainfall was generally average to below average. A general increase in wild dog activity was evident in late 2011/early 2012 which is likely to have resulted (at least in part) from higher birth rates and increased survival of pups in the flush climatic period that began about 18 months previously. Temporal variation was also evident in the activity of wild dog prey species (e.g. small mammals, kangaroos and rabbits) and other predators (e.g. foxes). In some species, this fluctuation was related to variation in seasonal conditions but in others, other factors appear to have been responsible. But in all cases, temporal fluctuation tended to occur equally across both treatments and was not associated with poison baiting.

Wild dog diet did not differ between baited and unbaited treatments. However, it did vary considerably between properties and there appeared to be different dietary staples on each property (e.g. rabbits on Quinyambie, rodents and rabbits on Cordillo Downs and kangaroos on Todmorden). Moreover, when small mammal populations increased in response to above average rainfall in 2010/11, they became the principal component of wild dog diet across all properties. Once conditions deteriorated and small mammal populations declined, wild dogs switched back to their staple prey.

Cattle remains were commonly detected in wild dog scats, but their occurrence was not affected by poison baiting. It was, however, influenced by the availability of alternative prey, with consumption of cattle declining to almost negligible levels when small mammal populations increased after the 2010/11 rains.

Implications for Wild Dog Management

Unfortunately the study did not yield the anticipated clearly defined trigger points for wild dog control in northern South Australia. However, it did contribute significantly to the knowledge and general understanding of wild dog predation in northern South Australia. Following are the key management outcomes arising from the project.

1. The disappearance of cattle from wild dog diet when alternative prey availability was high indicates that the risk of calf predation by wild dogs during flush climatic periods is quite low.
2. The finding that poison baiting (using conventional techniques) never completely removed wild dogs.
3. Satellite tracking found that wild dogs tended to visit water points more frequently in summer. This suggests that a greater number of wild dogs will be exposed to baits if they are laid around water points in the hotter months, particularly as this period also coincides with the emergence of juvenile wild dogs from their dens.
4. The observed variation in wild dog diet between properties suggests that the drivers for calf predation differ from property to property. Thus, a “one-size-fits-all” approach to wild dog management is not likely to be successful. The study has shown that there are so many property-level variables that affect calf production that strategies for wild dog management need to be tailored to individual properties.
5. There are still many unknowns around the predation dynamics of wild dogs in northern South Australia. This calls for a “learn by doing” approach to wild dog management, where careful monitoring and evaluation of management practices is used in conjunction with other new information as it comes to hand to continually improve the effectiveness of wild dog management. The current SAALNRM Wild Dog Management Plan fits well with this approach. It provides for landholders to have access to baits if and when they need them, while promoting the responsible use of baits and acknowledging the benefits of maintaining a certain number of wild dogs in the system. It endeavours to work with pastoralists and other stakeholders equitably and provides them with a level of ownership of wild dog management on their own property. Maintaining communication between stakeholders, and between landholders and government agencies will be key in ensuring wild dog impacts continue to be managed optimally across all land tenures.

1.0 INTRODUCTION

Wild dogs are present across mainland Australia and can be a major pest to livestock production enterprises through predation and disease transmission (McLeod, 2004; Rural Management Partners, 2004). As such, wild dogs are often controlled to protect livestock in all mainland states and territories (Fleming *et al*., 2001).

Throughout the rangelands, wild dog control is perceived by most beef producers as a critical component of economically viable cattle production. Yet, research in the mid to late 1990's in Queensland and Northern Territory has demonstrated that 1080 baiting can have little or no long-term effect on wild dog populations when applied at an individual property level, and can even increase the frequency and intensity of livestock losses in some situations (Allen, 2006; Allen, 2013; Allen, 2014). Although. when applied on a much larger regional level, 1080 baiting can dramatically reduce and prevent calf losses sustainably over the long term (Allen and Gonzalez, 1998; Fleming *et al*., 2001). However, regional control programs are often difficult to coordinate and implement, as varying production imperatives amongst land users within a region can lead to differences in the perceived level of threat posed by wild dogs. Moreover, previous studies have shown that economically significant predation impacts on calf production do not occur routinely (Allen, 2015; Wicks & Allen, 2012) suggesting that both regional and property level control campaigns may not always be necessary. Thus, information is needed to help predict the occurrence of calf predation events and develop optimal strategies to mitigate them.

Wild dogs are also thought to play a role in limiting the impacts of other vertebrate pest species that compete for pasture, such as rabbits and kangaroos (Newsome *et al*., 1997). In addition to the effects that wild dogs may have on livestock production, wild dogs also prey on a variety of wildlife species and excessive numbers can sometimes have serious negative effects on some rare and threatened species populations (Corbett, 2001; Johnson, 2006; Salo *et al*., 2007; Allen & Leung, 2012). For this reason, wild dogs are also controlled to protect wildlife in some places (Banks *et al*., 2003; Lundie-Jenkins and Lowry, 2005) and are listed as a key threatening process in New South Wales (Major, 2009). Conversely, several other studies have suggested that wild dogs may limit the abundance of other mesopredators, such as foxes (*Vulpes vulpes*) and feral cats (*Felis catus*), and may have a net positive role in protecting smaller prey species from excessive predation (Glen *et al*., 2007; Robley *et al*., 2004; Visser *et al*., 2009, Moseby *et al*. 2011). Therefore, besides studying cattle predation, the impact of wild dog control on lower trophic levels also requires investigation (Glen and Dickman, 2005; Glen *et al*., 2007).

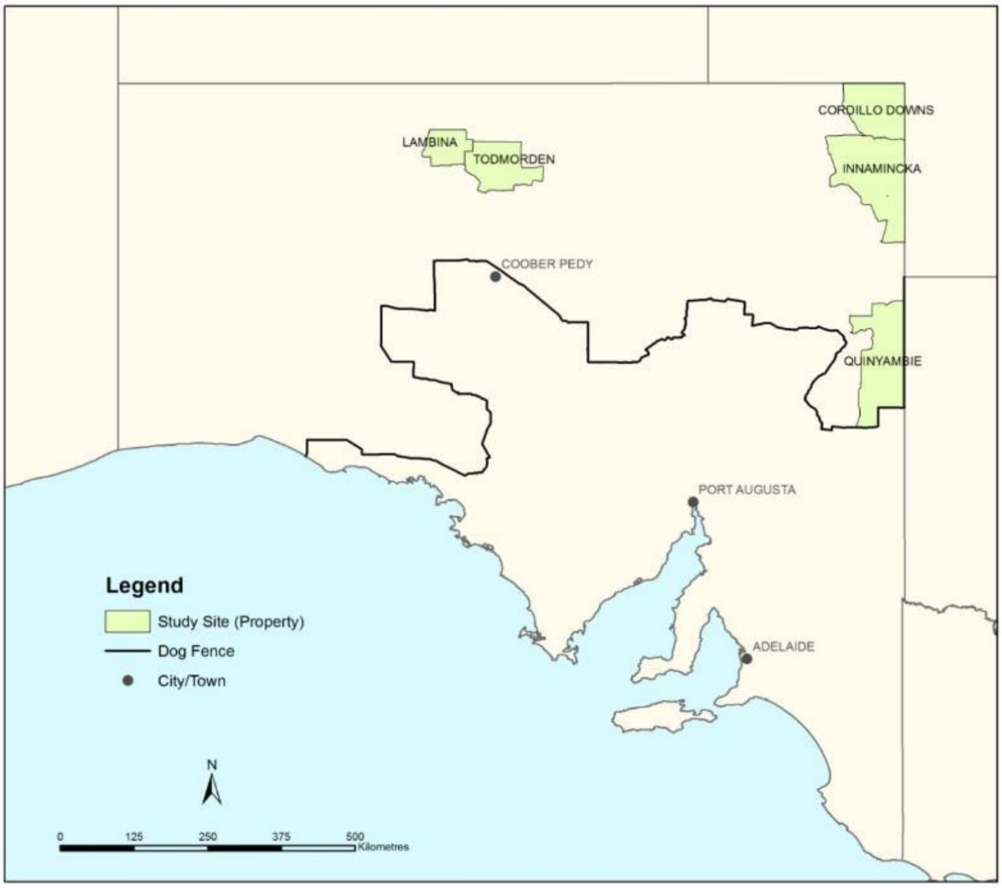
While addressing similar issues, the study sites used in Allen (2014) and Eldridge *et al.* (2002) are dissimilar to the cattle production areas of northern South Australia – they receive higher rainfall and represent different ecosystems. As such, the applicability of their findings to the South Australian arid zone systems is not known. To address these issues, the SAALNRM Board began undertaking similar research in 2008.

1.1 Aim

This project aimed to investigate the impacts wild dogs have on foetal/calf loss of beef cattle and biodiversity in baited and unbaited areas in the arid zone of South Australia, with the objective of determining optimum wild dog management strategies for the South Australian arid zone outside the Dog Fence. In particular, it was anticipated that the study would identify initiation triggers (trigger points) for lethal wild dog control to optimise (and balance where appropriate) production and environmental outcomes in real life scenarios.

2.0 STUDY AREA

The study was conducted on 5 operational cattle stations north of the Dog Fence in South Australia (Figure 2.1). Site selection and landholder negotiations began in April 2008. By the end of that year three properties had agreed to assist with the study; Quinyambie, Cordillo Downs and Todmorden. In 2009 Lambina was introduced and Innamincka in 2012 (Box 1). Detailed maps of each property showing the location of sand plot transects and treatment areas are presented in Appendix A.



Quinyambie Station is located in the Strzelecki Desert with a Mean Annual Rainfall (MAR) of approximately 160 mm. Parallel sand dunes are interspersed with broad clayey swales and are dominated by a sparse overstorey of cypress pine (*Callitris glaucophylla*), black oak (*Casuarina pauper*), umbrella wattle (*Acacia ligulata*) and narrow-leaf hopbush (*Dodonaea viscosa*). The herbage layer comprises mainly of buckbush (*Salsola kali*), kerosene grass (*Aristida contorta*), woolly oat grass (*Enneapogon polyphyllus*) and a variety of copper burrs (*Sclerolaena* spp.).

Treatment areas on Innamincka Station were located in the Della dune system, a series of red parallel sand dunes with sandhill canegrass (*Zygochloa paradoxa*) and umbrella wattle separated by broad clayey swales with sparse whitewood (*Atalaya hemiglauca*) and bloodwood (*Corymbia terminalis*), barley Mitchell grass (*Astrebla pectinata*), narrow-leaf neverfail (*Eragrostis setifolia*), kerosene grass, woolly oat grass and copper burrs. MAR is 170 mm.

Cordillo Downs is in the far north-east corner of South Australia, has a MAR of 167 mm and has a mix of large irregular sand dunes and extensive stony gibber slopes and plains. Sand dunes are dominated by spinifex (*Triodia* spp.) and sandhill canegrass with emergent whitewood, umbrella wattle and narrow-leaf hopbush. Dunes are separated by loamy swales and vegetated with sparse bloodwood over a mix of annual and perennial grasses. Barley Mitchell grass (*Astrebla pectinata*) dominates the treeless plains which are dissected by drainage channels lined with coolabah (*Eucalyptus coolabah ssp. arida*) and miniritchi (*Acacia cyperophylla*).

Todmorden and Lambina Stations lie on the margins of the Pedirka Desert in the central-north of the state with a MAR of approximately 180 mm. Treatment areas include wooded dunes and sandplains dominated by mulga (*Acacia aneura* and *A. ramulosa*) and adjacent sparsely vegetated stony slopes and plains interspersed with drainage channels lined with gidgee (*Acacia cambagei*) and coolabah. Sampling on Todmorden began in July 2008 and continued until Jun 2014. Data collected on Todmorden over this period were the most comprehensive and consistent of all the study sites. Lambina joined the project in 2009 at the end of the drought. Whilst infrastructure allowed for treatments to be separated during the drought through limited watering points, once the rain came in 2010 and the creek and river systems filled, the cattle moved across the property following the waters. This meant the cattle from the treatments mixed and the data could not be used.

3.0 METHODOLOGY

3.1 Experimental design

We used the same experimental design as Allen (2014) and Eldridge *et al.* (2002), which was later recommended by Glen *et al.* (2007) as an appropriate design to evaluate the ecological role of wild dogs. The project is a predator removal experiment with a BACI (before-after, control-impact) design and randomly allocated replicated treatments and controls. Each study site was divided into a baited (treatment) and unbaited (control) area, with sample sites being separated by a buffer zone (>20km) to improve statistical independence (Figure 3.1).

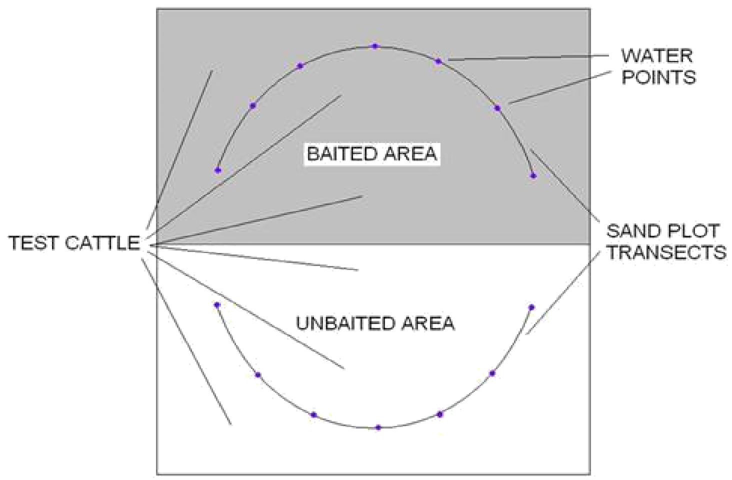


Figure 3.1 A diagrammatical representation of the experimental design applied at each study site

3.2 Baiting procedure

Wild dogs were lethally controlled in baited treatment areas only, according to local practices and poison-use regulations. Manufactured DOGGONE® baits (Animal Control Technologies, Melbourne) or fresh beef or kangaroo (*Macropus* spp.) meat injected with 6 mg of liquid 1080 were distributed, unburied, along vehicle tracks and around water points in the baited treatment area up to twice each year in spring and autumn. Quinyambie and Cordillo Downs used DOGGONE® on most occasions, while Todmorden and Lambina used fresh meat on most occasions. Both bait types are lethal to wild dogs (APVMA 2008). Baits distributed along roads were laid at a rate of 4 per km while a maximum of 20 baits were laid at water points.

3.3 Measuring foetal/calf loss

Monitoring the fate of individual calves is extremely difficult and impractical to do in an open rangeland setting, so as the best alternative, lactation failure in cows was measured to assess calf losses (as done in Eldridge *et al.* 2002; Allen 2014). The underlying assumption behind this method was that on each property, factors such as breed, age, condition, disease status, feed and water availability, and management regime were the same across treatments (i.e. baited and unbaited). Thus, differences in lactation failure rates were logically attributable to treatment effect as manifested by changes in calf predation.

To determine lactation failure rates, cattle of all ages were pregnancy tested by palpation of the uterus on each property in each treatment area by a qualified, experienced cattle veterinarian. Initially a sample of approximately 200 pregnant cows was recruited from each treatment area, then additional cows were added to the sample at subsequent musters. Each cow was tagged with a unique tag and number before being released back into its respective breeding herd. Tagged cows formed a sample of the total cattle in each treatment area, which varied between sites and over time. Quinyambie and Innamincka Stations ran the Santa Gertrudis breed while Todmorden and Cordillo Downs ran the Poll Hereford breed. Breeds were the same for each paired treatment but cow age varied.

Breeding herds in each treatment area were re-mustered at intervals of 5-13 months. When tagged cattle were re-mustered, lactation failure (indicated by a "dry" udder) was recorded as evidence of calf loss (either through abortion or post birth) if the cow was predicted to have an unweaned calf. Where lactation status was in doubt on visual udder appraisal ('wet' cows having full udders, distended teats, bare skin and/or wet hair around the teats), the cow's teats were stripped by hand to determine milk presence or absence. Tagged cows were also assigned a body condition score to complement udder assessment. Tagged cows were monitored over the 2008-09 year on Quinyambie, 2009-2014 at Todmorden and Cordillo Downs and 2012-14 at Innamincka.

The associations between lactation failure (calf survival) and treatment (baiting) were explored through the development of a Generalised Linear Mixed Model (GLMM) using the Asreml package (Butler 2009) under R (R Core Team 2013). To fit the model, Asreml uses the methods of Penalised Quasi-likelihood (Breslow and Clayton 1993).

From 2010 the pregnancy diagnosis included foetal ageing to the nearest month so the calving month could be determined. The pregnancy testing prior to 2010 did not allow calving outcomes to be date matched to draw relationships to other data collected as part of the study and so these pregnancy data were discarded. Thus, no pregnancy data were analysed for Quinyambie as part of this report.

In cases where muster intervals exceeded 9 months, we were unable to differentiate between cows that had dried off because their calf had self-weaned and those that were dry as a result of losing their calf. To eliminate these ambiguous cases from the analysis, we developed a decision matrix using the expected calf age derived from the foetal age, cow body condition, current pregnancy and lactation status to determine pregnancy outcome and eliminate cows whose calves may have self-weaned (Table 3.1).

Table 3.1 Criteria used for cattle data analysis and interpretation

	Expected Age of calf	1-6 months		7-9 months		10-12 months		13+ months	
	Condition Score	1-3	4-5	1-3	4-5	1-3	4-5	1-3	4-5
Wet	Pregnant	OK	OK	OK	OK	OK	OK	Ambiguous	Ambiguous
	Empty	OK	OK	OK	OK	OK	Ambiguous	Ambiguous	Ambiguous
Dry	Pregnant	Lost	Lost	OK	Lost	Ambiguous	Lost	Ambiguous	Ambiguous
	Empty	Lost	Lost	Lost	Lost	Ambiguous	Ambiguous	Ambiguous	Ambiguous

To investigate the possibility that reproductively important pathogens (abortifacient disease) could be contributing to calf loss, blood samples from 100 cows across three properties were sent to a laboratory for serological assay. The sample comprised 20 mixed age cows from each treatment at Innamincka (tested in 2013), 20 heifers from the baited treatment at Todmorden (tested in 2012), 20 mixed age cattle from the unbaited treatment at Todmorden (tested in 2013) and 20 mixed age pregnant cows from the unbaited treatment at Cordillo Downs (tested in 2013). Blood samples were analysed for Pestivirus, Leptospirosis (*Leptospira interrogans* serovars *hardjo*, *pomona*, and *tarrasovi*) and Neosporosis (*Neospora caninum*), which have all been associated with increased rates of abortion in cattle (Parkinson *et al*. 2010).

3.4 Assessing the activity of wild dogs, other predators and their prey

The activity of wild dogs, other predators and their prey was monitored in each treatment area by conducting quarterly surveys. During each survey, indices of activity were determined for a range of relevant species using sand plots established along fixed transects. In addition, counts of diurnal species (eg. wild dogs, kangaroos, emus, bustards and birds of prey) observed along each transect were recorded and wild dog scats (faecal pellets) were collected for dietary analysis. Additionally, wild dogs were fitted with GPS tracking collars in some treatment areas to investigate their movement patterns and water point usage.

Associations between activity (PTI) and treatment (baiting) were explored through the development of a Generalised Linear Mixed Model (GLMM) as described in Section 3.3 (above).

A pre-determined schedule for activity surveys and baiting was adhered to for the duration of the survey (Table 3.2). In order to maintain scientific integrity, sampling was conducted in the preferred survey period whenever possible. However, factors such as poor weather, vehicle access and competing station priorities occasionally affected survey timing and so alternative survey periods were also scheduled (Table 3.2). A summarised log of actual sampling activities is presented in Box 1 and data collection on each property is chronicled in detail in Appendix B.

Table 3.2 Schedule for activity surveys and baiting

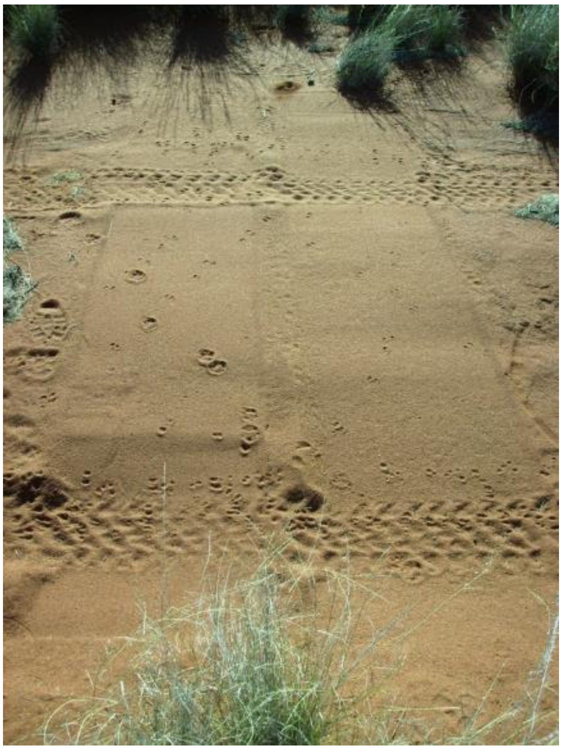
B baiting | preferred survey period | alternative survey period

	January wk 1-2	January wk 3-4	February wk 1-2	February wk 3-4	March wk 1-2	March wk 3-4	April wk 1-2	April wk 3-4	May wk 1-2	May wk 3-4	June wk 1-2	June wk 3-4
Quinyambie					B							
Cordillo Downs							B					
Todmorden									B			
Lambina									B			
Innamincka							B					

	July wk 1-2	July wk 3-4	August wk 1-2	August wk 3-4	September wk 1-2	September wk 3-4	October wk 1-2	October wk 3-4	November wk 1-2	November wk 3-4	December wk 1-2	December wk 3-4
Quinyambie					B							
Cordillo Downs							B					
Todmorden										B		
Lambina										B		
Innamincka							B					

3.4.1 Sand plot activity monitoring

The activity of wild dogs, other predators and their prey was assessed using a Passive Tracking Index determined from the daily number of tracks recorded on sand plots established along permanent transects in each treatment area (Figure 2.2). Each track (not individual footprint) of each species intercepting the sandplot was counted. Transects were established along existing vehicle access roads and contained 50 sand plots located at least 1km apart. Sand plots were 1m wide and spanned the width of the road. Plots on clay or gibber areas used the existing substrate, rather than importing sand, and the detectability on these hard transects was improved by raking the clay and breaking up clumps where possible.



Left: Typical sand plot used for determining passive tracking index. Sand plots spanned the width of vehicle tracks and were 1m in length. The daily number of individual tracks was recorded for each species on up to three consecutive days.

During each monitoring survey, all sand plots were initially smoothed (using hand tools such as hoes, rakes, brooms and spreaders) then for up to three consecutive days, the number of individual animal tracks observed on each sand plot was recorded. For small mice and hopping mice, the number of tracks recorded was capped at 15, as it was not possible to distinguish individual tracks once numbers exceeded this value. An index of activity was then determined for each species by determining the average number of individual tracks per plot per day. This is known as a Passive Tracking Index, or PTI. Fauna monitored using this technique included wild dog, fox, feral cat, kangaroo, rabbit, bustard, goanna, small lizard, small bird, hopping mouse, long-haired rat, and 'mouse' (incorporating small rodents as well as dasyurid marsupials), although detectability varied between different species.

3.4.2 Direct observation of diurnal species

While sand plot activity indices were the primary methods for assessing mammal, bird, and reptile activity, other techniques were employed to provide supporting data. Tallies of diurnal species (such as wild dogs, kangaroos, emus and birds of prey) observed while conducting daily sand plot assessments were recorded to supplement sand plot activity data.

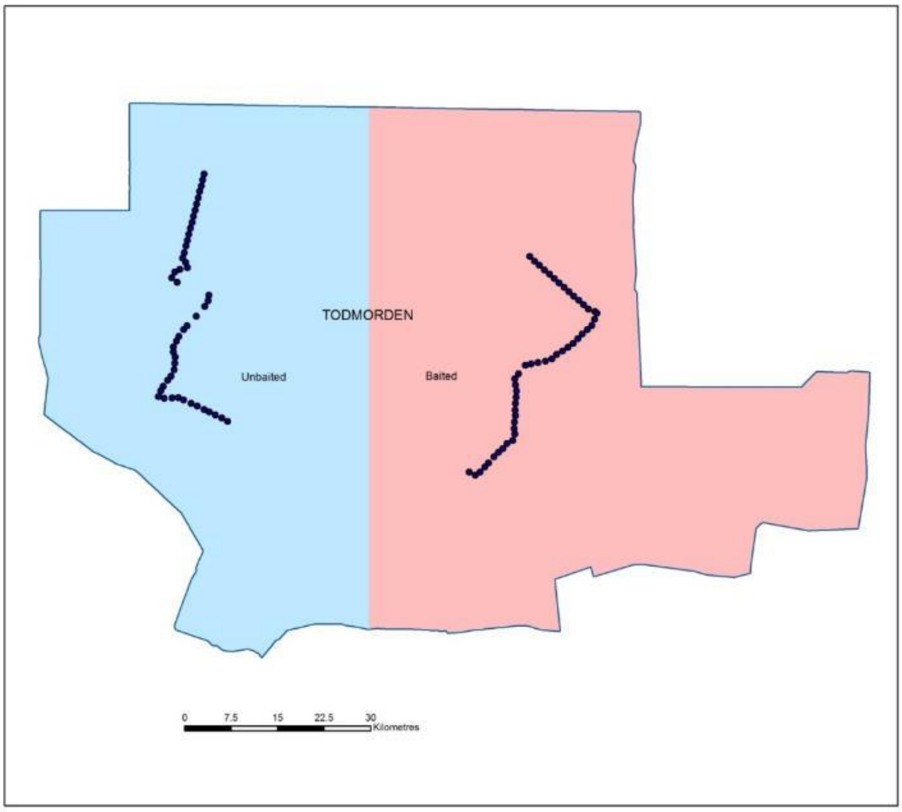


Figure 3.2 Simplified map of Todmorden Station showing treatment areas and sand plot locations. Sand plots were established at least 1km apart along permanent transects in each treatment area. This design is typical of all 5 study sites.

3.4.3 Assessing wild dog diet

Wild dog scats (faecal pellets) were collected to assess wild dog diet, and provide information on relationships between prey availability and diet. Scats were collected from a variety of areas within each treatment area. Searches were usually most profitable around water points, at road intersections, creek crossings, and other landscape features frequented by wild dogs. As a result, regular locations were sampled during each survey and we attempted to "clear" a location of scats at each survey in order to ensure they were collected from the season we attributed them to. Scats were analysed by Dr Barbara Triggs and results were expressed as percent occurrence of food items in scats.

3.4.4 Effect of water points on wild dog activity

To investigate the spatial behaviour and water point usage of wild dogs, GPS tracking collars were fitted to 11 wild dogs captured using “Jake” soft-catch leg-hold traps. Information from the collars was not used specifically in relation to sand plots or treatment effects. Collars were programmed to continuously record GPS points at 30min intervals for 10-12 months. While data from GPS collars provides a wide variety of useful information, their primary purpose in this project was to investigate the frequency of water point usage. Collars were retrieved by humanely euthanizing the wild dog or after it had died of natural causes.

Water point usage was determined by viewing each recorded GPS point (in ArcGIS 9.3) in chronological order and counting the number of times a water point was visited. A visit was recorded when the preceding movements indicated travel towards the water point followed by movements away from the water point. Prolonged time spent at a water point was recorded as only one visit, and multiple visits in one day indicate that the wild dog left the water and came back again. This subjective approach was necessary because of the variable affinity that wild dogs had for water points, and as such, it was more useful than arbitrary objective measures (eg. all GPS points within 500m of a water point) because it provided a greater ability to account for individual behaviours.

Box 1 Data collection summary for each study site (property) over the study period.

- Undertaken
- Not undertaken
- Problems with data

A: Activity (sand plot) assessment
B: Baiting
P: Pregnancy testing
L: Wet/dry assessment
S: Scat collection

Year	2008					2009					2010					2011					2012					2013					2014				
Property	A	B	P	L	S	A	B	P	L	S	A	B	P	L	S	A	B	P	L	S	A	B	P	L	S	A	B	P	L	S	A	B	P	L	S
TODMORDEN																																			
CORDILLO DOWNS																																			
QUINYAMBIE																																			
LAMBINA																																			
INNAMINCKA																																			

Sampling on Todmorden began in July 2008 and continued until Jun 2014. Data collected on Todmorden over this period were the most comprehensive and consistent of all the study sites.

Cordillo Downs is an accredited organic property that musters annually. Because 1080 cannot be used on organic farms, baiting on Cordillo Downs ceased in May 2012 after accreditation was granted. However, activity monitoring and foetal/calf loss assessment continued to ascertain if there was a difference in stock loss and/or biodiversity activity.

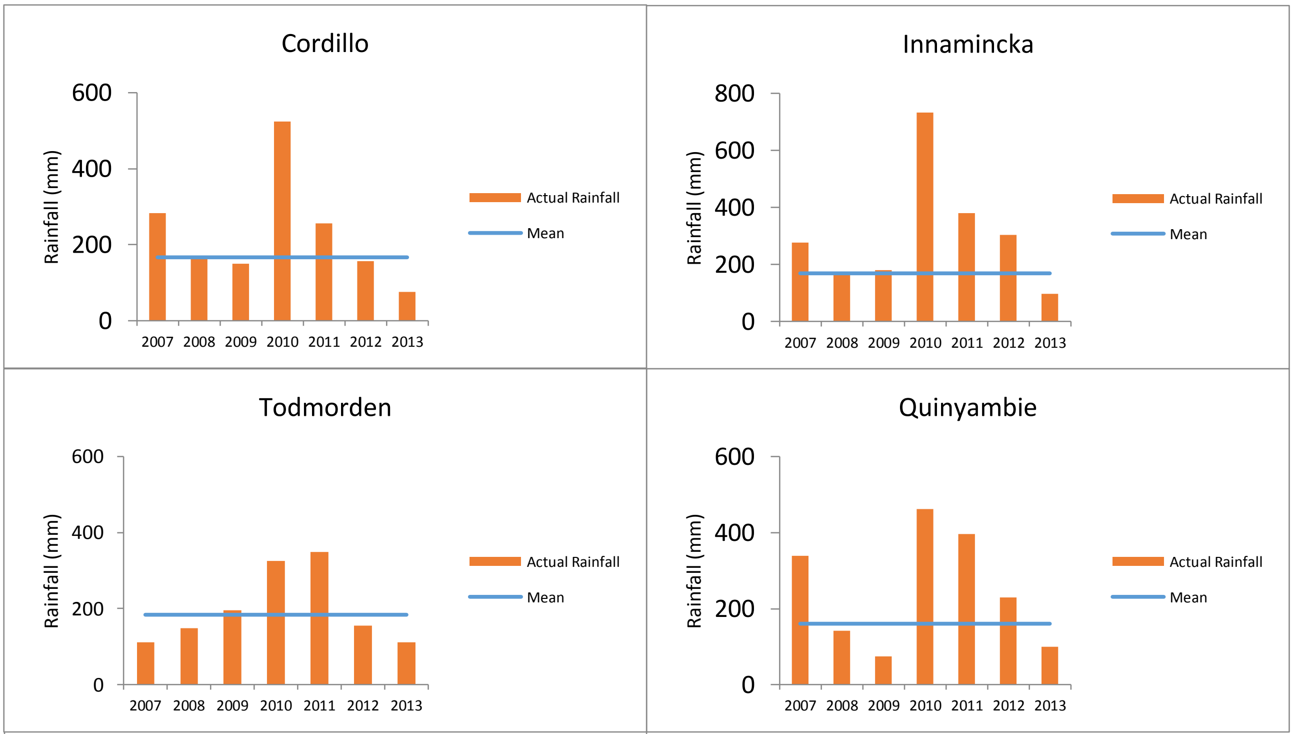
Sampling on Quinyambie began in April 2008. Although cattle pregnancy data were collected in 2008 and 2009, the information was unable to be assessed using the criteria to determine lactation success or failure. In 2009 Quinyambie was rapidly destocked due to worsening drought conditions. Quinyambie remained in the project to continue collecting activity survey data. In September/October 2012 the baited area on Quinyambie was exposed to a bushfire and remained unstocked until March 2013, when both treatments were restocked.

Innamincka joined the project in June 2012 to account for Cordillo Downs' inability to bait as well as to provide more robust data on lactation failure as Innamincka musters biannually. Roughly 10% of the unbaited treatment area was subjected to fire in October 2012.

Lambina joined the project in 2009 at the end of the drought. Whilst infrastructure allowed for treatments to be separated during the drought through limited watering points, once the rain came in 2010 and the creek and river systems filled, the cattle moved across the property following the waters. This meant the cattle from the treatments mixed and the data could not be used.

3.5 Climatic context

The first two years of the study (2008-2009) were at the end of a 10 year period of generally below average rainfall. Conditions changed dramatically in early 2010 with the onset of a two year period of consistently higher than average rainfall which resulted in a flush in vegetation growth and pasture condition and triggered a breeding response in a variety of native fauna (Fig 3.3). Historical records for the study area indicate that rainfall of this magnitude occurring over a 2 year period is highly unusual and probably only occurs every 20-30 years (Bureau of Meteorology). Conditions began to deteriorate early in 2012 with the end of the period of high rainfall and continued to decline across the study area during 2013 and 2014 due to below average rainfall.



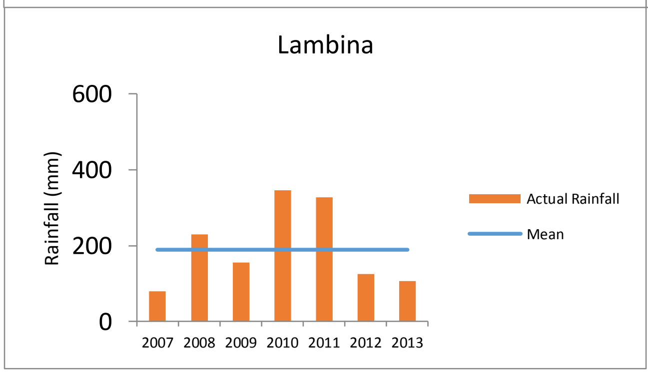


Figure 3.3 Annual rainfall at each of the properties for the entire study period. Most data are from the respective station homestead with any missing records taken from closest Bureau of Meteorology recording station. **Note that the Y-axis scale on the Innamincka chart differs from the remainder

4.0 RESULTS

4.1 Wild dog activity

4.1.1 Effect of baiting

Wild dog activity, as measured by the Passive Tracking Index (PTI) was on average 60% lower in Baited treatment areas than in Unbaited treatment areas (Figures 4.1 and 4.2). Statistical analysis determined that for a randomly selected property, the estimated average number of wild dog tracks expected per plot across all sites in Baited areas was 0.22, compared with 0.55 tracks per plot in Unbaited areas. These two means were significantly different at the 0.05 level.

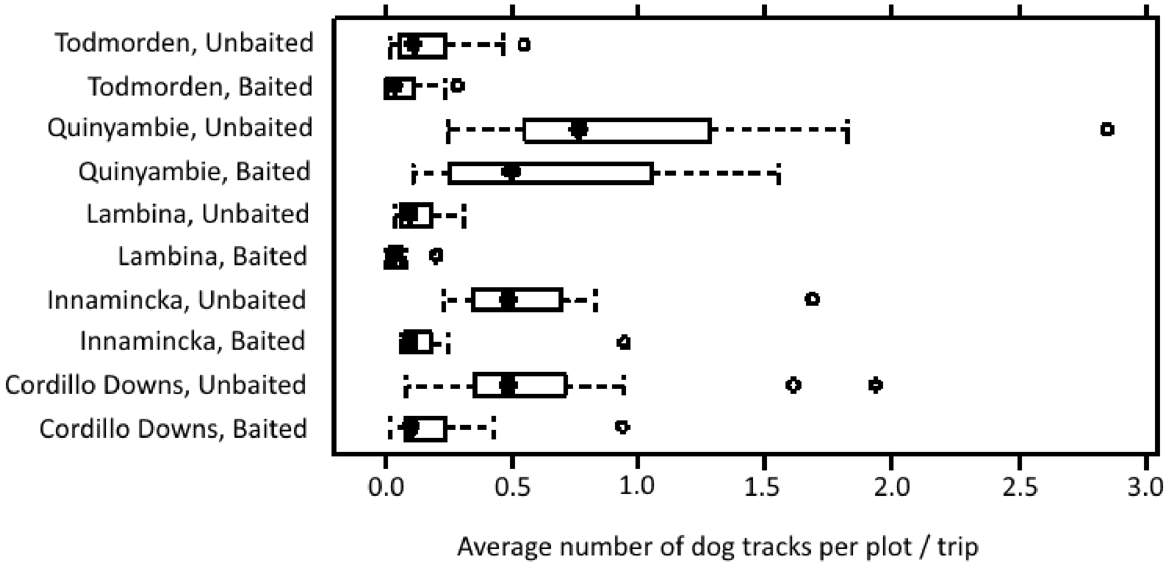


Figure 4.1 Box plot of the average number of wild dog tracks per treatment area per trip for each treatment area.

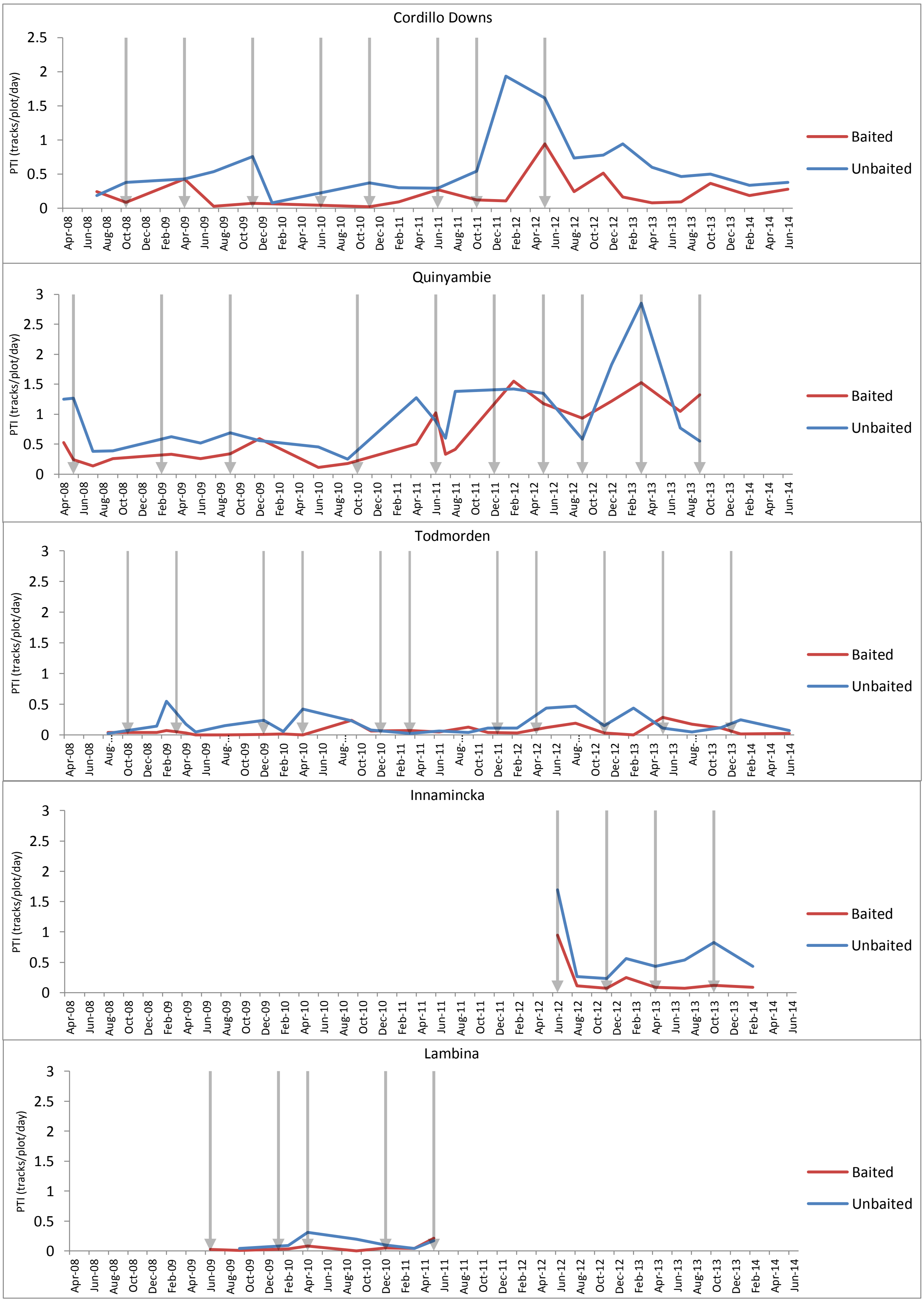


Figure 4.2 Trends in Wild Dog Activity at the five study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

Box 2 *Do lower tracking index (PTI) values equate to a lesser number of wild dogs?*

Currently there is debate in the scientific literature over the use of footprint indices (eg. PTI) as indicators of abundance due to uncertainty about what they are really measuring (Hayward and Marlow 2014; Nimmo *et al*. 2015). Are they measuring abundance, activity or some mix of both? The answer is probably some mix of both but the mix almost certainly varies between species, and may vary within species over time. In the case of wild dogs, activity in a given area is likely to be influenced by their complex social and breeding behaviours, and changes in the number of footprints on sand plots along roads may not necessarily reflect changes in abundance. This uncertainty represents a disadvantage with respect to other more direct methods of estimating population abundance such as Distance Sampling, Mark-Recapture and Occupancy Modelling, but these techniques rely on the capture and/or identification of an adequate sample of individuals from each target population. When dealing with large carnivores that are typically cryptic, low in abundance and not easy to detect, achieving an adequate sample size usually involves lengthy periods in the field and this is rarely feasible in remote locations. Despite their disadvantages, indices of abundance provide a more efficient and cost effective way of measuring treatment effects on predator populations. In remote arid regions, where field work is expensive and logistically difficult, using indices such as PTI usually represent the only feasible option to monitor wild dog populations as they are relatively quick and inexpensive to measure and allow the simultaneous monitoring of some other species, albeit with lesser precision. However, caution is required in the interpretation of results derived from index data. Other complimentary measures, such as opportunistic observations, camera trap data and dietary (scat) analysis can be employed simultaneously to aid in the interpretation of index data.

4.1.2 Other influences on wild dog activity

Within properties, wild dog activity varied considerably over time, with multiple peaks and troughs in activity occurring throughout the study. This temporal variation tended to occur equally across both treatments and was independent of 1080 baiting (Figure 4.2). Wild dogs are typically most active in the mating season in April/May and when pups are gaining independence in October/November (Fleming *et al*. 2001). We looked for an effect of season on wild dog activity but found that variation in wild dog PTI occurred independently of breeding season in this study.

A general increase in wild dog activity was evident in most treatment areas in late 2011/early 2012. Widespread above-average rainfall across the study area in 2010 and 2011 (Figure 3.3) resulted in a flush of vegetation growth, irruptions in rodent populations and increased pasture production. It is likely that the increase in wild dog activity resulted from higher birth rates and survival of pups in the 2010 and 2011 seasons in response to an increase in prey abundance resulting from improved seasonal conditions. In order to investigate the relationship between wild dog activity and the availability of small prey, we determined an index of small prey availability based on PTI values for small mice (including dasyurid marsupials), hopping mice, long-haired rats and rabbits (See Table 4.1). We found a positive correlation between wild dog PTI and small prey availability (Figure 4.3). Correlation was strongest between wild dog PTI and prey availability 18 months prior.

Table 4.1. Small mammal availability index calculation procedure for rabbits, hopping mice, small 'mice' (including small dasyurid marsupials) and rats. The index was predicated on mean PTI values calculated for each category per survey. Index values for each species/category were summed to produce an index of overall small mammal availability for each survey.

Availability	Rabbit	Hopping Mouse	Small mouse	Rat
1=Low	<0.2	<2	<2	0
2=Medium	0.2-0.6	2 - 4	2 - 4	0.001 - 0.05
3=High	>0.6	>4	>4	>0.05

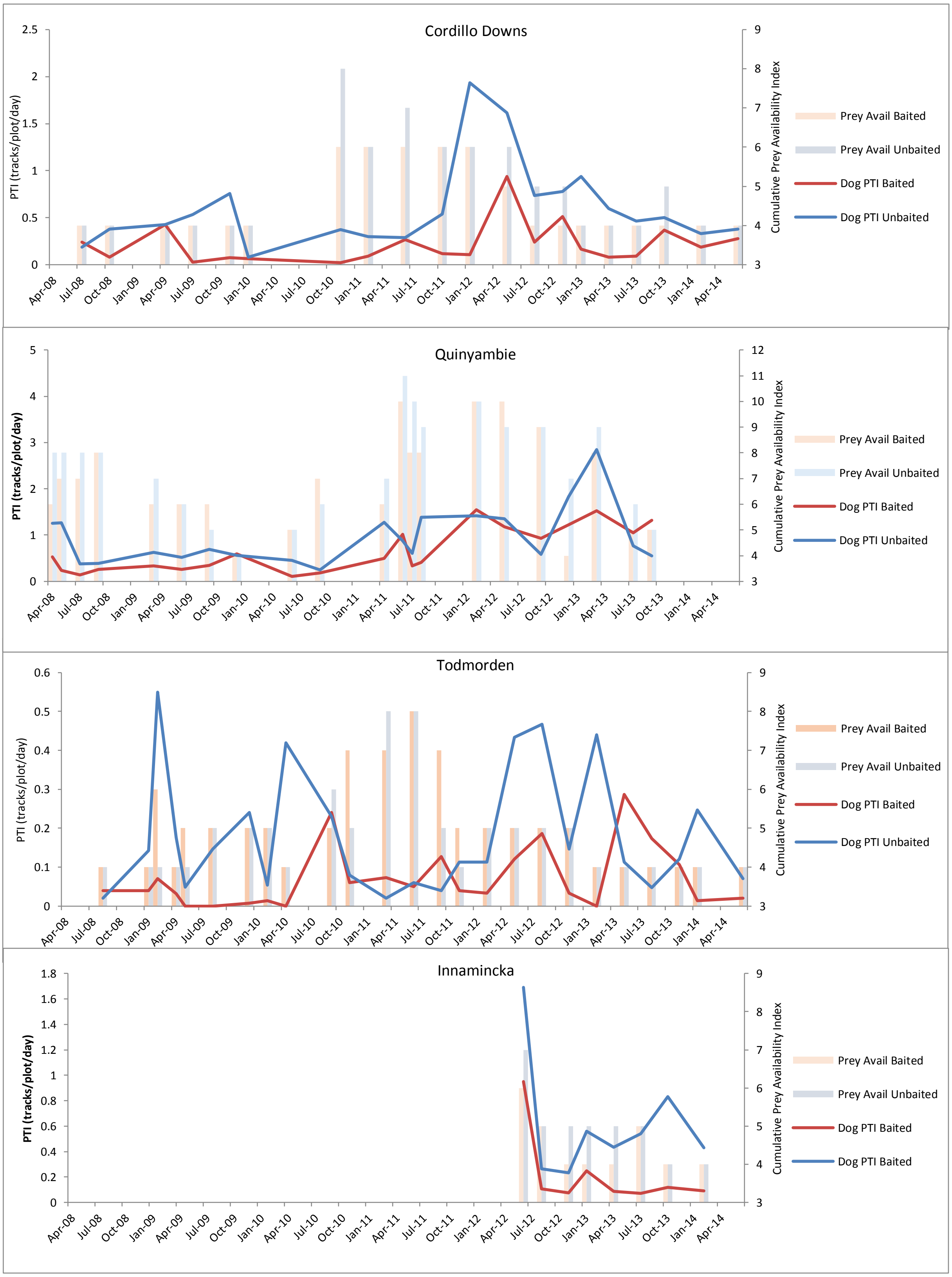


Figure 4.3 Wild dog PTI plotted with small prey availability index at each site over the entire study area. Prey availability is represented by the faint bars and plotted using the right-hand vertical axis. Wild dog PTI is represented by the lines and plotted using the left-hand vertical axis. A delayed response in wild dog PTI to increased prey availability is evident in most treatment areas.

4.2 Foetal/ calf loss

4.2.1 Effect of baiting

Results presented here represent calf loss data collected from three of the five study sites. Quinyambie was forced to de-stock in late 2009 due to lack of feed and measurement of lactation failure had to be abandoned. On Lambina sampled cattle ended up moving between treatment areas, invalidating lactation failure data. Thus, data from three properties (Todmorden, Cordillo Downs and Innamincka) are were analysed.

Overall, across the three properties, foetal/calf losses averaged 18.6% of 3,004 assessed pregnancies. The losses in baited sites were 17.2% of 1,398 pregnancies and in unbaited sites were 19.4% of 1,606 pregnancies. The rate of successful pregnancies was not significantly different between baited and unbaited treatments ($\chi^2 = 2.54$, df 1, P>0.05). There was no significant relationship between foetal/calf loss (calf survival) and wild dog activity when aggregated for unbaited sites (r = -0.30, df 25, P >0.05) or baited sites (r = 0.25, df 24, P>0.05) (Figure 4.4).

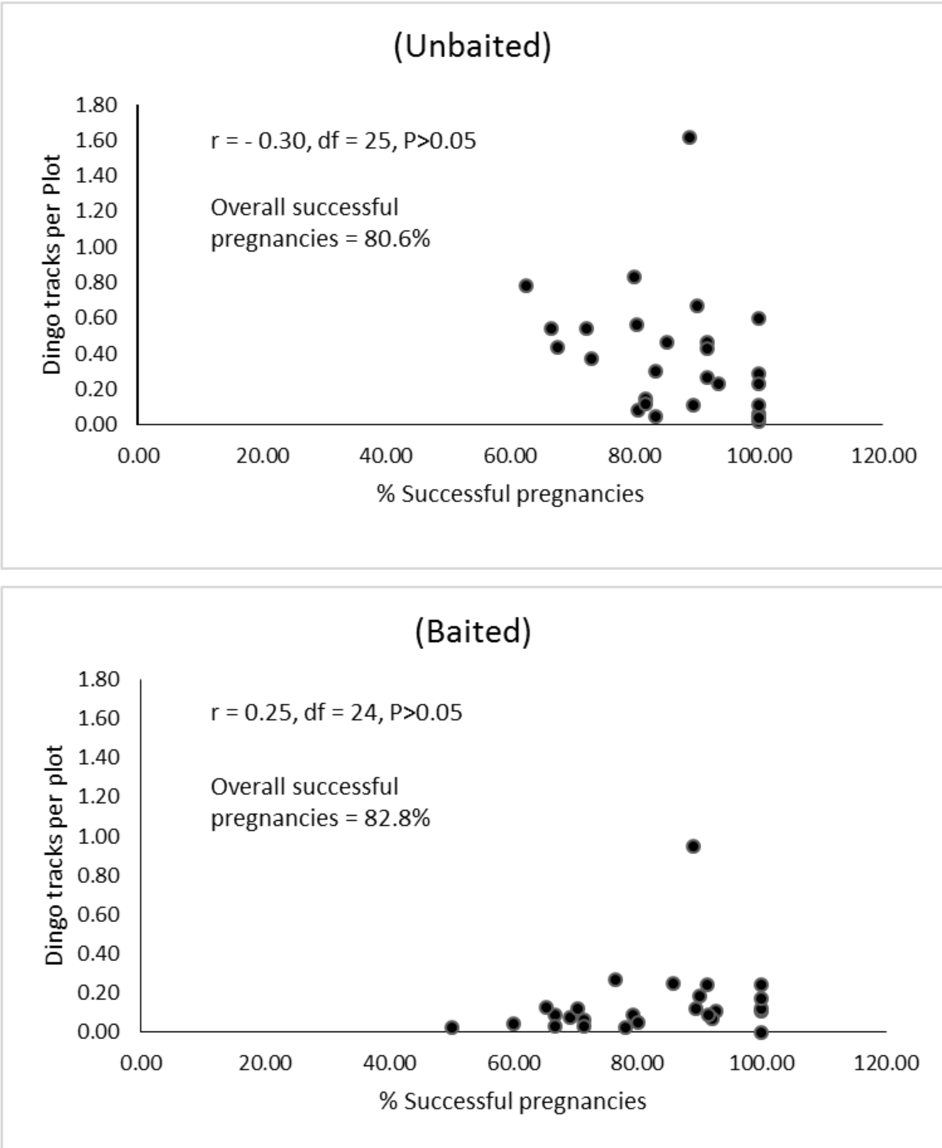


Figure 4.4. Relationship between pregnancy outcomes for monthly calving groups and those months when wild dog activity (tracks/plot) was assessed. Aggregated pregnancy outcomes were not significantly correlated to wild dog activity for either the three baited sites nor for the three unbaited sites.

There were however, notable differences in foetal/calf losses between adult cows and first lactation heifers. Overall losses were 27.3% for heifers and 14.7% for adult cows. Heifer sample sizes were too small (<50) on one side of the paired treatments on two properties for robust between-treatment analysis, although it is worth noting that average losses in baited sites for heifers were very high at 52% (n = 25) and 37.9% (n = 153) for Cordillo Downs and Todmorden respectively.

No significant Treatment (baiting) effects and no significant differences in calf survival rates across Properties were identified at the 0.05 or even at the 0.1 level (Table 4.2). The variation in Treatment effects across properties was negligible, but there was variation in survival rates across pregnancy groups (*i.e.* heifers *versus* adult cows); marginally so across properties on average, but more so within treatment areas within properties.

Table 4.2. Summary for the fit of the GLMM to 3,004 pregnancy records.

Wald statistics for fixed effects.

	DF	denDF	F. inc	F. con Margin	Probability
(Intercept)	1	8.1	104.900	104.900	0.0000
Property	2	8.2	1.439	1.587	0.2628
Treatment	1	9.5	1.725	1.725	0.2184

Variance components:

	Component	Std. error	Z. ratio
Property: Treatment	0.0000	NA	NA
Property: Pregnancy Group	0.1099	0.1866	0.5890
Property: Treatment: Pregnancy Group	0.2917	0.1765	1.6524

Since foetal ageing at the pregnancy test allowed the month of calving to be reasonably determined, it was possible to look for an effect of seasonality (time of year) on pregnancy outcomes. Monthly calving outcomes were grouped into seasons by property and treatment. Four of the 24 combination groups were excluded due to inadequate sample size (less than 50 pregnant cows).

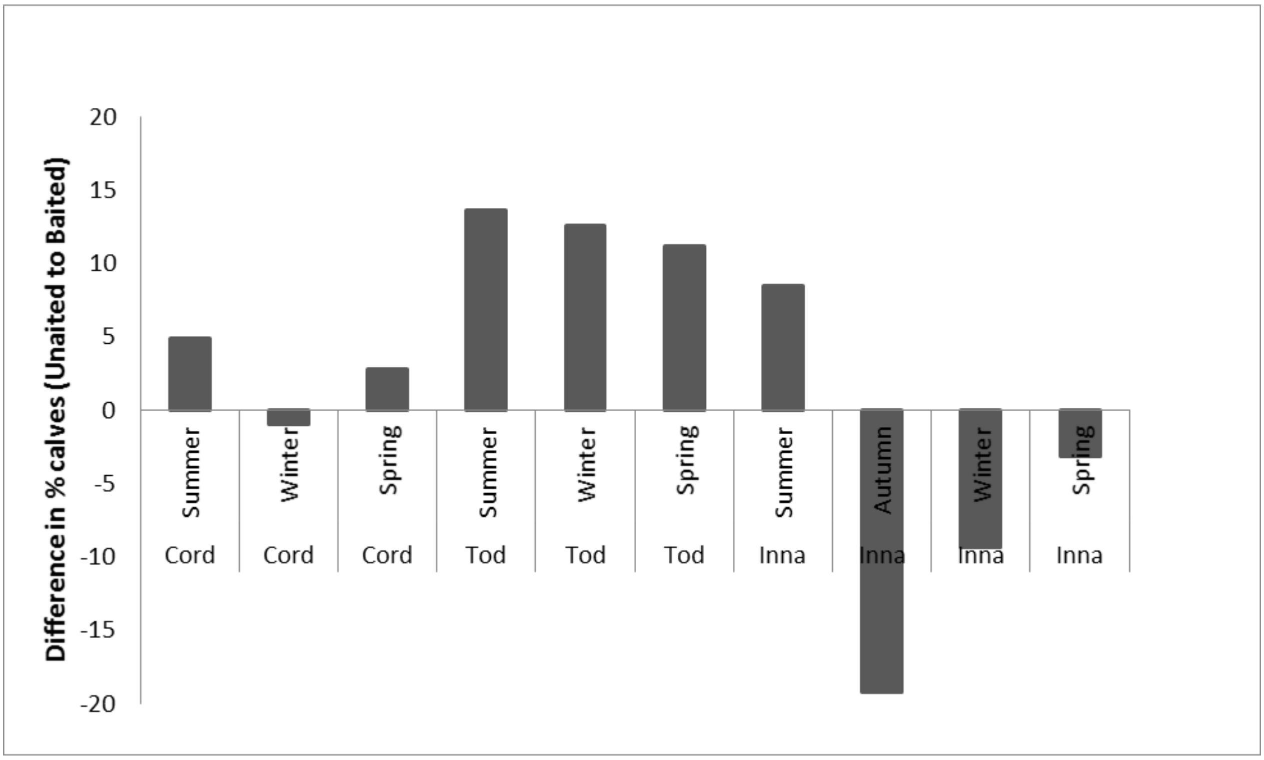


Figure. 4.5. Difference in % calves for unbaited versus baited treatments according to season of year and property. Positive values indicate higher losses in Baited treatments relative to Unbaited.

A two way between groups Analysis Of Variance (Table 4.3) indicated no significant treatment or seasonal differences in pregnancy outcomes across the baited and unbaited sites on the three properties. While this indicates foetal/calf losses to summer heat or annual wild dog activity cycles to be insignificantly different to those at other times of year, there was a consistent trend on the three properties (Figure 4.5) for higher losses (5-14%) in baited sites in summer.

Table 4.3. Analysis of Variance for the effects of treatment and season of year on pregnancy outcomes.

Source	N parm	df	Sum of Squares	F. ratio	Pr > F
Season	1	1	0.0144	0.2321	0.6352
Treatment	1	1	0.0869	1.4026	0.2502
Season: Treatment	1	1	0.0162	0.2619	0.6144

Throughout the project the prevailing seasonal conditions were fair to excellent and almost all cows maintained body condition scores of 2 or above on a 1-5 basis. There was no consistent relationship between calf survival and the quality of the prevailing season (NDVI Greenness), although there was one significant inverse correlation for the Todmorden baited site where calf production was lower in the better seasons (Table 4.2), suggesting disease, rather than poverty or predation to be the cause.

4.2.2 Other influences on foetal/calf loss

Track counts of the most common small prey (long haired rat, hopping mouse, rabbit, small mice) were used to construct a small prey index of availability (see section 4.1.2). There was no consistent significant association between the availability of small prey and calf production/survival (Table 4.4), except for the Todmorden unbaited treatment area, where calf production was higher when small prey were more available (r = 0.55, df 9, P<0.05). The most common large prey across the study area was red kangaroo. Yet, there was no significant or consistent association between calf production/survival and kangaroo availability (Table 4.4). Small prey availability was strongly associated with the quality of the prevailing season (NDVI Greenness) (Table 4.4) but more so with the average NDVI prevailing 2 months prior to animal track count events. Kangaroo availability was less consistently linked to the prevailing season but was significantly so for the Quinyambie unbaited and Cordillo baited sites (Table 4.4).

Wild dog scats were not collected at Innamincka and therefore, the percentage of cattle in scats could only be related to calf production/survival at two paired trial sites (Todmorden and Cordillo Downs). The relationship between percentage occurrence of cattle in scats and calf production/survival was highly variable and inconsistent (Table 4.4).

There was a consistent tendency for the percentage occurrence of cattle hair in wild dog scats to increase as the quality of the season declined (Figure 4.6). This varied from highs of 50% cattle occurrence during the seasonal lows and drought of mid to late 2009, to a consistent low of zero occurrence during the lush season of 2010/2011. While the trend for cattle content to rise in poor seasons was not significant in the baited sites, the correlations were significant in the unbaited sites for both Cordillo Downs and Todmorden (Table 4.5). The fact that cattle hair in wild dog scats can be a product of either calf predation or carrion feeding is later discussed. Under extreme drought in mid to late 2009 at Quinyambie, when all cattle had been removed from both treatments, cattle content in scats was consistently between 5 and 10%, derived entirely from carrion.

Testing for abortifacient disease was undertaken once it became evident that variation in lactation failure rate across treatments was inconsistent and could not be easily explained. It was not a planned component of the study and was conducted only once to assess disease prevalence at study sites. Thus, it was not possible to quantify the impact these diseases were having on calf production during the study. Nonetheless, several observations relating to the existence of aborting diseases at study sites are worth noting. *Neospora*, which has the wild dog as a life cycle host, was present in 15% of cows overall. Pestivirus was found in 99% of cattle tested. At least one of three serovars tested for Leptospirosis was found in 75 of the 100 cows. *Leptospira hardjo* and *L. tarassovi* were the most common. Three cows in the Todmorden unbaited site (2013) and two in the Innamincka baited site (2013) had very high blood titres for *L. tarassovi*, suggesting recent exposure. Two cows in the Todmorden baited site (2012) and one cow in the Innamincka unbaited site (2013) had high titres for *L. hardjo*. Antibodies for more than one serovar of Leptospirosis occurred simultaneously in 28% of cows tested, being highest at Todmorden with 45%. Pregnancy outcomes were recorded only for cows sampled at Innamincka and sample size was too small to determine the impact of disease on calf production. However, for information purposes, data from Innamincka sampled cattle are presented in Appendix

	Innamincka	Cordillo	Todmorden	Quinyambie	Innamincka	Cordillo	Todmorden	Quinyambie	Innamincka	Cordillo	Todmorden	Quinyambie	Innamincka	Cordillo	Todmorden	Quinyambie	Innamincka	Cordillo	Todmorden	Quinyambie	Innamincka	Cordillo	Todmorden	Quinyambie
	Calf Survival				*Dog Tracks*				*% Cattle in Scats*				*Kangaroo Tracks*				*Small Prey Index*				*NDVI - 2 months*			
Calf Survival	X				**0.47**	**-0.3**	**-0.33**	**ND**	**ND**	**0.61**	**-0.49**	**ND**	**0.37**	**0.14**	**-0.03**	**ND**	**-0.25**	**-0.26**	**0.55***	**ND**	**0.19**	**0.01**	**0.16**	**ND**
Dog Tracks	0.23	-0.58*	0.42	ND	X				**ND**	**-0.31**	**0.26**	**-0.43**	**0.25**	**0.33**	**-0.06**	**0.31**	**0.7***	**0.21**	**-0.25**	**0.38**	**0.46**	**0.23**	**0.11**	**0.01**
% Cattle in Scats	ND	-0.46	0.62*	ND	ND	-0.18	-0.32	-0.23	X				**ND**	**-0.19**	**-0.23**	**-0.41**	**ND**	**-0.58***	**-0.69***	**-0.22**	**ND**	**-0.7***	**-0.63****	**-0.3**
Kangaroo Tracks	0.37	0.5	-0.17	ND	0.09	0.16	0	-0.2	ND	-0.39	-0.1	0.18	X				**0.53**	**-0.13**	**-0.11**	**0.63****	**0.58**	**0.04**	**0.09**	**0.63****
Small Prey Index	0.54	0.49	-0.47	ND	0.76*	-0.05	-0.02	0.22	ND	-0.71*	-0.35	-0.72*	0.41	-0.01	-0.23	-0.07	X				**0.87****	**0.66***	**0.52****	**0.47***
NDVI-2 months	-0.05	0.26	-0.35*	ND	0.73*	0.23	-0.1	-0.09	ND	-0.42	-0.37	-0.27	0.39	0.63*	-0.09	-0.31	0.91**	0.54*	0.6**	0.43*	X			
	Unbaited (Above)			Baited (Below)									** Significant at 0.05*			*** Significant at 0.01*								

Table 4.4. Correlation matrix presenting correlation coefficients and statistical significance for a range of comparisons.

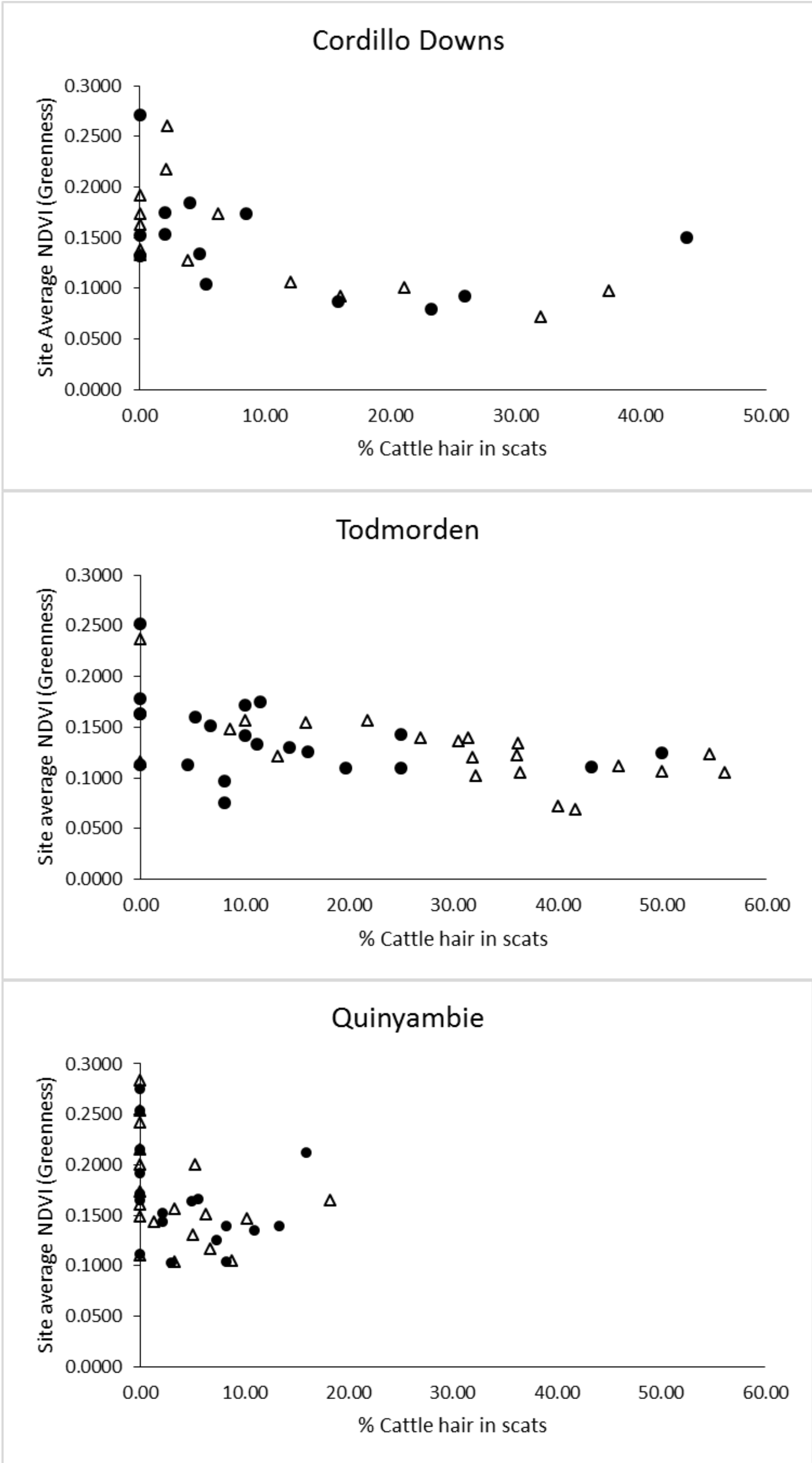


Figure 4.6. Percentage occurrence of cattle hair in wild dog scats plotted against the site average NDVI (Normalised Difference Vegetation Index). Solid points represent the baited sites and hollow triangles the unbaited sites.

4.3 Activity of wild dog prey species

4.3.1 Rabbits

Baiting had no consistent effect on rabbit activity within study sites. However, differences between treatment areas were observed on certain properties. For example, rabbit activity was noticeably higher in the Unbaited treatment area on Cordillo Downs, yet higher in the Baited treatment area on Todmorden. These differences were probably due to disparity in habitat suitability between treatment areas on these properties. Whereas the Unbaited treatment area on Cordillo Downs contained sand dunes and areas of sandy soil, the Baited area was characterised by open cracking clay plains with limited shelter and low suitability for burrowing. Similarly, the Baited area on Todmorden contained outcrops of calcrete which provided ideal burrowing habitat for rabbits but such habitat was absent in the Unbaited treatment area. No differences in rabbit activity between paired treatment areas were identified on the remaining properties.

Little evidence of seasonal influences on rabbit activity was observed. (Figure 4.7). Rabbit activity was generally low at all sites for the duration of the study, with the exception of Quinyambie where for the first 12 months of the project, PTI values were at least double those of the other properties (Figure 4.7). Rabbit PTI at Quinyambie dropped dramatically in late 2009 (particularly in the Unbaited treatment area) and remained lower for the rest of the study, despite the onset of favourable climatic conditions in 2010 and 2011.

4.3.2 Kangaroos

Kangaroo PTI fluctuated from survey to survey, but fluctuation appeared to be independent of the baiting treatment (Figure 4.8). Notably, there appeared to be no apparent response in kangaroo activity to improved seasonal conditions at most sites, with the exception on Todmorden where kangaroo activity increased in late 2011 and peaked in February 2012. Elsewhere, seasonal condition had no observable effect on Kangaroo PTI within study sites and this result was consistent across all properties (Figure 4.8). The number of kangaroos sighted fluctuated from survey to survey but again, these data showed no obvious response to baiting or to seasonal fluctuations.

Within properties there was no correlation between the number of kangaroo tracks recorded on sand plots and the number of kangaroos sighted.

4.3.3 Rodents and other small mammals

Small mammal species were difficult to distinguish by footprints alone and therefore, sand plot data for these species were pooled for the purpose of statistical analysis. Species in this category included house mouse (*Mus musculus*), small native rodents (eg. *Pseudomys* spp., *Leggadina forresti*) and small marsupials (*Sminthopsis* spp., *Ningaui* spp.). However, distinctive species such as hopping mice and long-haired rats were analysed separately.

As expected, small mammalian prey species showed a strong response to seasonal fluctuations (Figure 4.9). Tracks of these species on sand plots increased dramatically soon after the onset of favourable conditions. Within properties, the correlation between small prey PTI and “greenness” (NDVI) values 2 months prior was highly significant (see Table 4.4), indicating an almost immediate response in rodents to improved conditions.

The baiting treatment had no discernible effect on the activity of rodents and other small mammals (Figure 4.9).

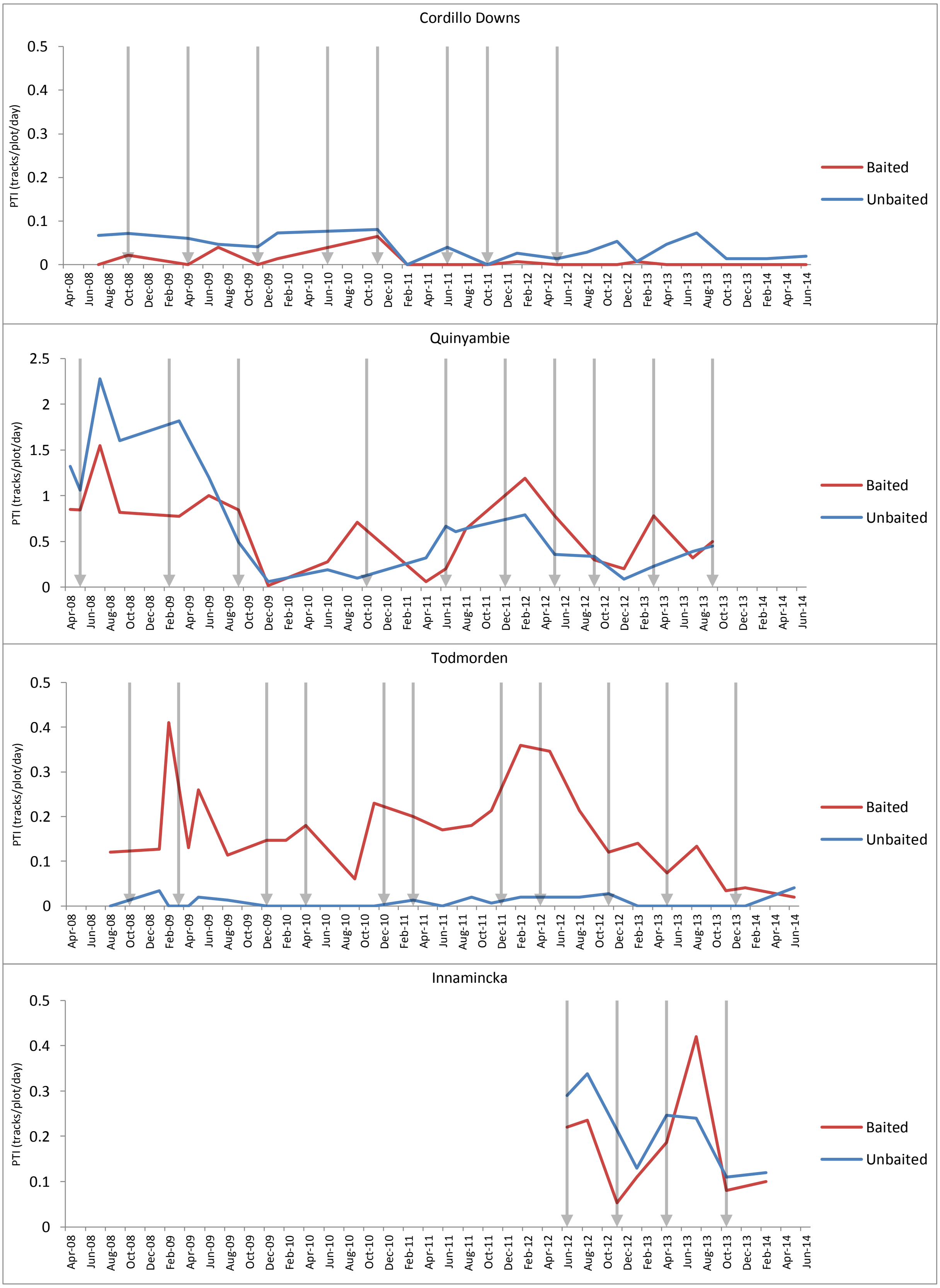


Figure 4.7 Trends in rabbit activity at the four main study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

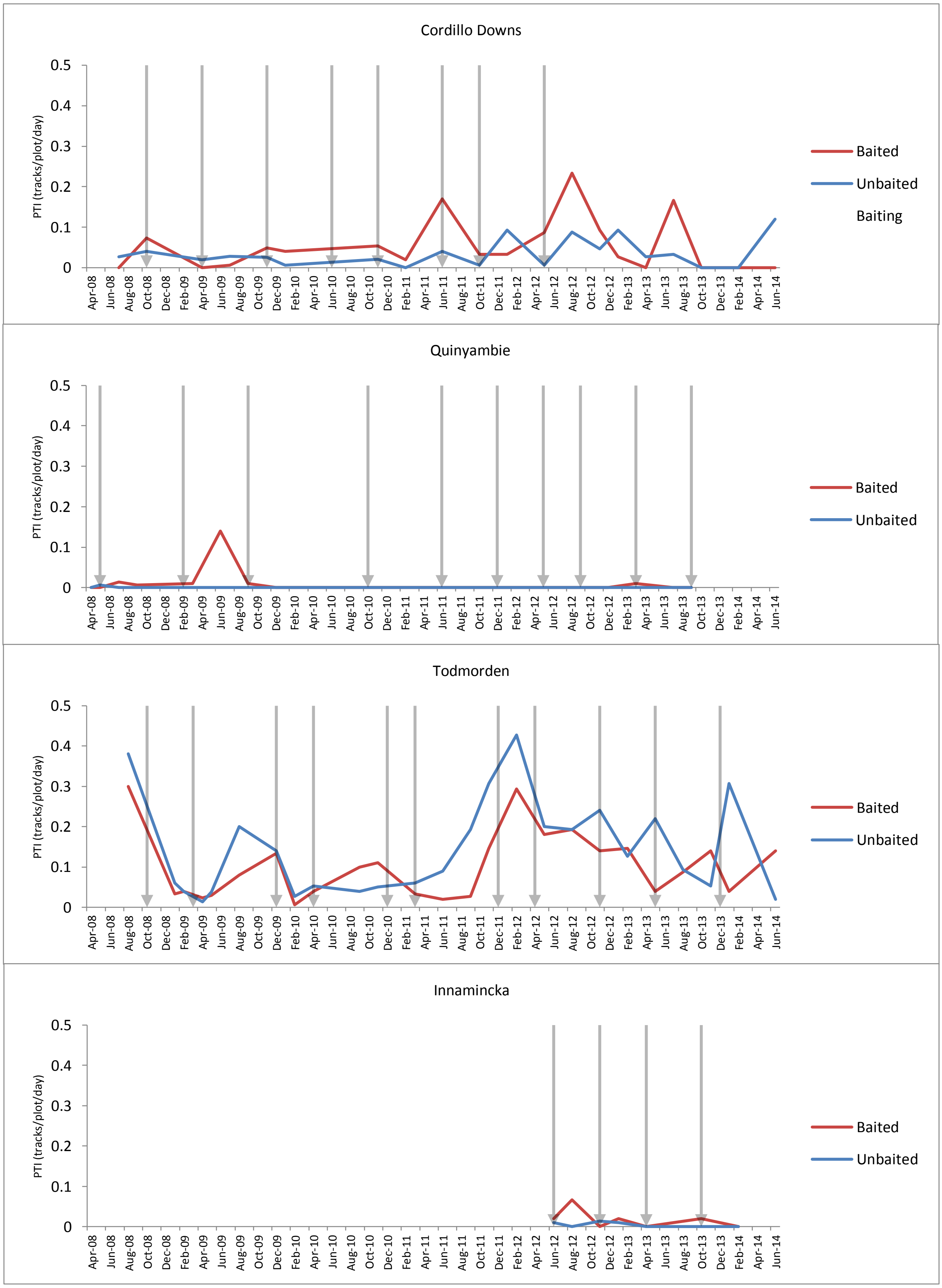


Figure 4.8 Trends in kangaroo activity at the four main study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

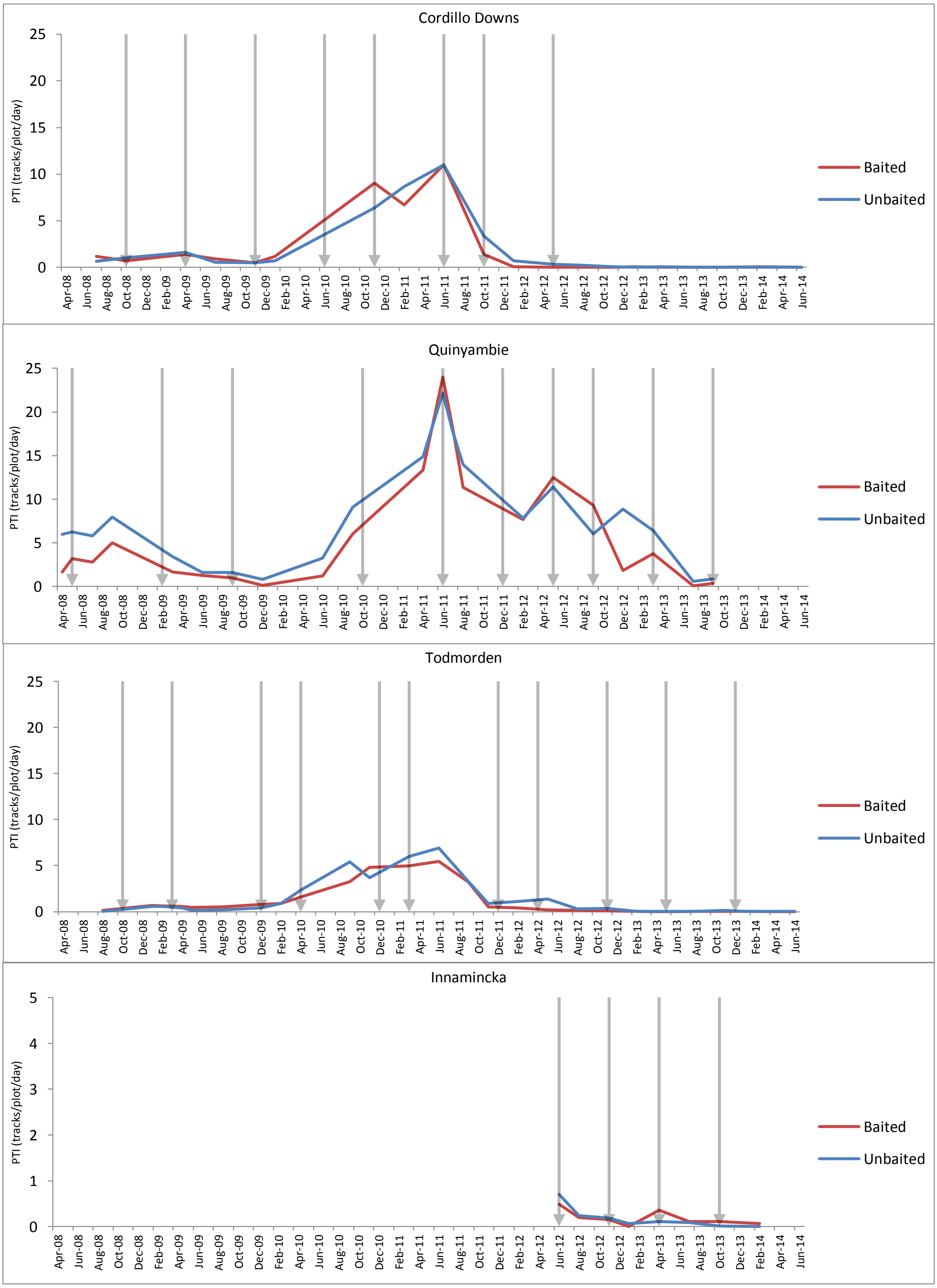


Figure 4.9 Trends in small mammal activity at the four main study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

4.4 Other predators

Recent studies have suggested that wild dogs limit the abundance and distribution, or change the behaviour of smaller predators such as foxes and feral cats (see Letnic *et al*. 2012). By extension, the presence of wild dogs may therefore reduce the impacts of foxes and cats on their prey, and wild dogs may provide a net benefit to smaller prey species. Conversely, removing wild dogs may result in an increase in foxes and cats, which may increase the impacts of these predators on smaller prey. This has led some researchers to claim that wild dog control may allow fox and cat populations to increase (in a process known as 'mesopredator release'), ultimately increasing their impacts on native prey species.

4.4.1 Foxes

We found no consistent effect of 1080 baiting. Baiting appeared to have a noticeable effect on fox activity at some study sites (i.e. on Cordillo Downs and Quinyambie), where fox PTI values were lower in baited treatment areas (Figure 4.10). This could be partly due to uptake of poison baits by foxes, but circumstantial evidence suggests that other factors may also have been involved. We found a correlation between fox activity and the presence of rabbits on sand plots on these properties, suggesting the distributions of the two species were linked. Rabbit activity was generally higher in the unbaited treatment areas on Cordillo Downs and Quinyambie due to the presence of favoured habitat in these areas and the observed differences in fox activity may also have been related to differences in rabbit availability between treatment areas. No apparent baiting effect was identified on Todmorden or Innamincka stations.

Positive correlation between fox activity and small mammal availability was identified on some properties, indicating a response of foxes to improved prey availability in these areas. (Figure 4.10)

4.4.2 Cats

The detection rate of cats on sand plots was particularly low at all sites, with PTI rarely exceeding 0.05. No trends or patterns in cat activity relating to either the baiting treatment or to changes in prey availability were identified (Figure 4.11).

4.4.3 Birds of Prey

Birds of prey sighted while conducting sand plot surveys were tallied for each survey, but no differences between Baited and Unbaited treatment areas were identified. The number of small and medium-sized birds of prey (including kestrels, falcons and kites) varied according to small mammal abundance. Sightings of both these groups were highly correlated with small mammal PTI.

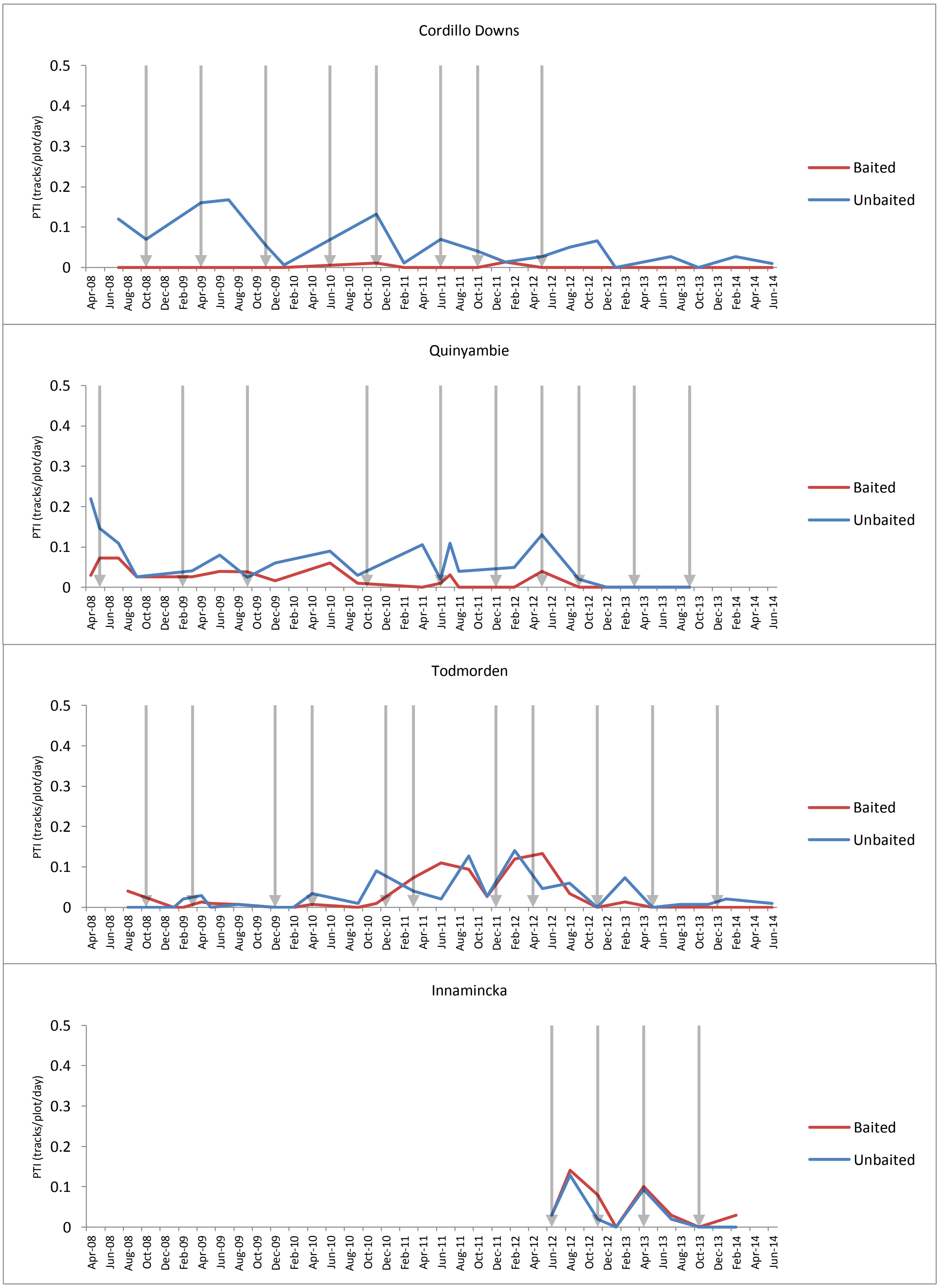


Figure 4.10 Trends in fox activity at the four main study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

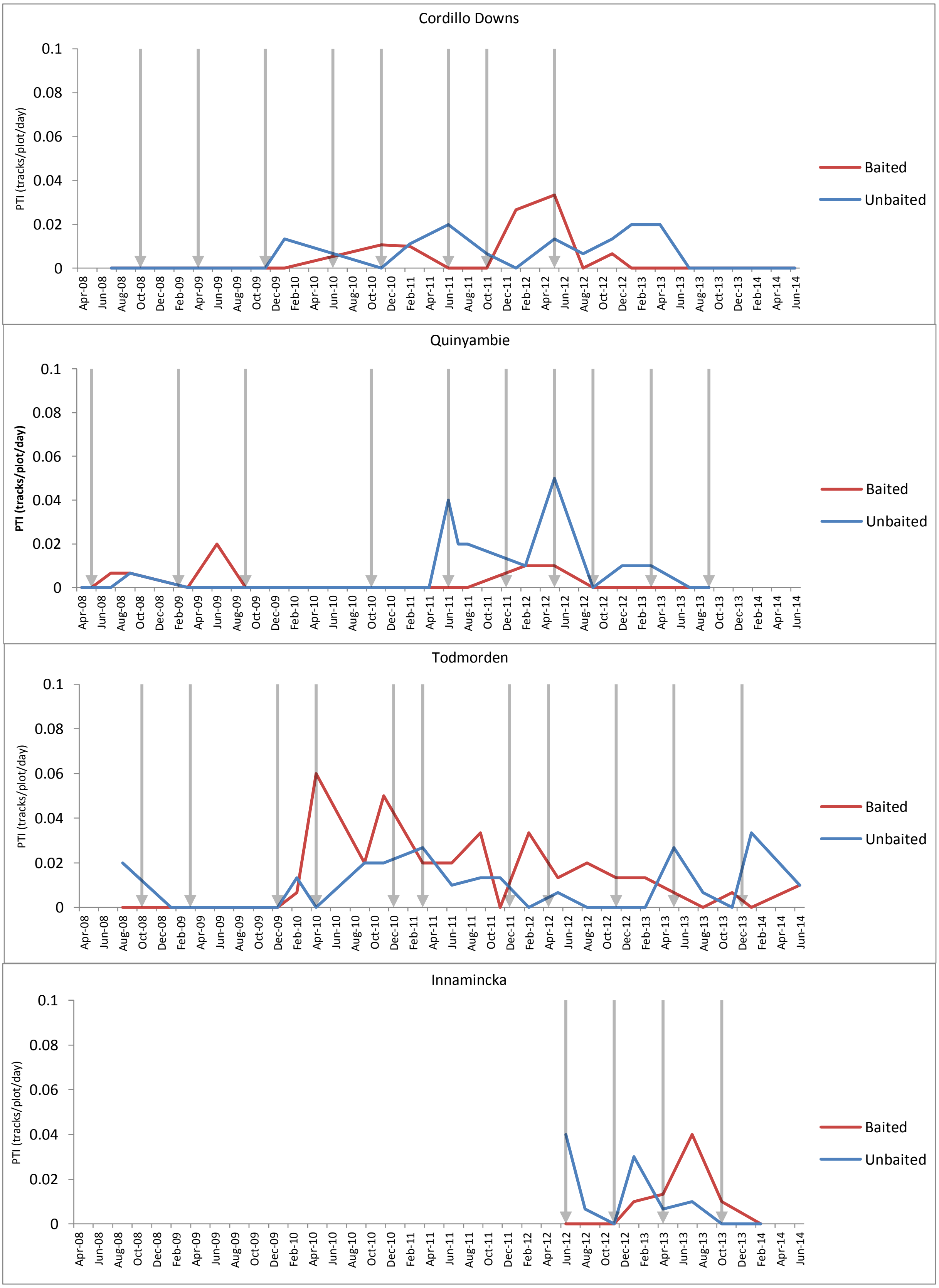


Figure 4.11 Trends in feral cat activity at the four main study sites as measured using a Passive Tracking Index (PTI; the number of individual sets of tracks per plot per day). Baiting events are indicated by the grey vertical arrows.

4.5 Wild dog diet

A total of 6,320 wild dog scats collected from baited and unbaited treatment areas within each property were analysed. We found no difference in wild dog diet between treatments and this result was consistent across all properties.

Considerable variation in overall wild dog diet between properties was identified (Figure 4.12). At Quinyambie, the prey item most commonly consumed by wild dogs was rabbit, while at Todmorden, kangaroo and cattle were the principal prey items. Rodents comprised the highest proportion of wild dog diet at Cordillo.

Within each property, wild dog diet over time showed clear evidence of prey switching, where the relative importance of different prey species changed significantly and rapidly (Figures 4.13, 4.14 & 4.15). For example, when long-haired rats irrupted at Cordillo Downs with the onset of favourable climatic conditions, wild dogs temporarily switched their dietary preference almost completely to rats (Figure 4.13). Once conditions dried and the long-haired rat population declined, wild dogs switched back to their staple prey, mainly rabbits. Similar transitions occurred on Quinyambie and Todmorden during the flush period. At Quinyambie, a switch in prey preference to hopping mice was evident, with a strong relationship identified between hopping mouse consumption by wild dogs and hopping mouse activity on sand plots (PTI; Figure 12). At Todmorden, a similar correlation was identified for small 'mice' (eg. *Mus musculus*, *Pseudomys* spp. and *Sminthopsis* spp.), indicating that wild dogs switched their preference to these species when they became abundant in the flush period (Figure 4.15). We found a negative correlation between kangaroo consumption and small mammal consumption by wild dogs at Todmorden, indicating a decline in kangaroo predation by wild dogs during periods with high small mammal availability (evidence of prey switching or 'alternation of predation', Corbett & Newsome, 1987)

In continually stocked parts of the study area, cattle remains were found in 18% of scats and this percentage did not differ between Baited and Unbaited treatment areas. (Quinyambie was de-stocked for part of the study period and data from this period were not included in the calculation). However, cattle content in wild dog scats varied markedly according to climatic conditions and small prey availability at all sites. When the availability of rodents and other small mammals was high, the amount of cattle consumed by wild dogs declined (Figure 4.13). While this negative correlation was clear, it is not known whether the reduction in cattle consumption was due to less calf predation in flush periods, a lower availability of carrion in these times or a combination of both.

Vegetation was a frequent component of wild dog diet at all sites. This was consistent for the entire study and did not vary according to season or baiting treatment. No correlation between the consumption of vegetation by wild dogs and Greenness (NDVI) was identified. Bush tomatoes (*Solanum* spp.) are likely to have made up a large proportion of the "Vegetation" category in wild dog diet. Invertebrates were also found to consistently occur in wild dog scats throughout the study.

We found little evidence of wild dog predation on subordinate predator species. Fox remains were not detected at all in wild dog scats but cat remains were recorded at very low levels (average 0.33%, ranging between 0.2 and 0.8% of scats). There was no identifiable relationship between wild dog consumption of cats and the 1080 baiting treatment. Similarly, no relationship between cat consumption by wild dogs and alternative prey availability was identified.

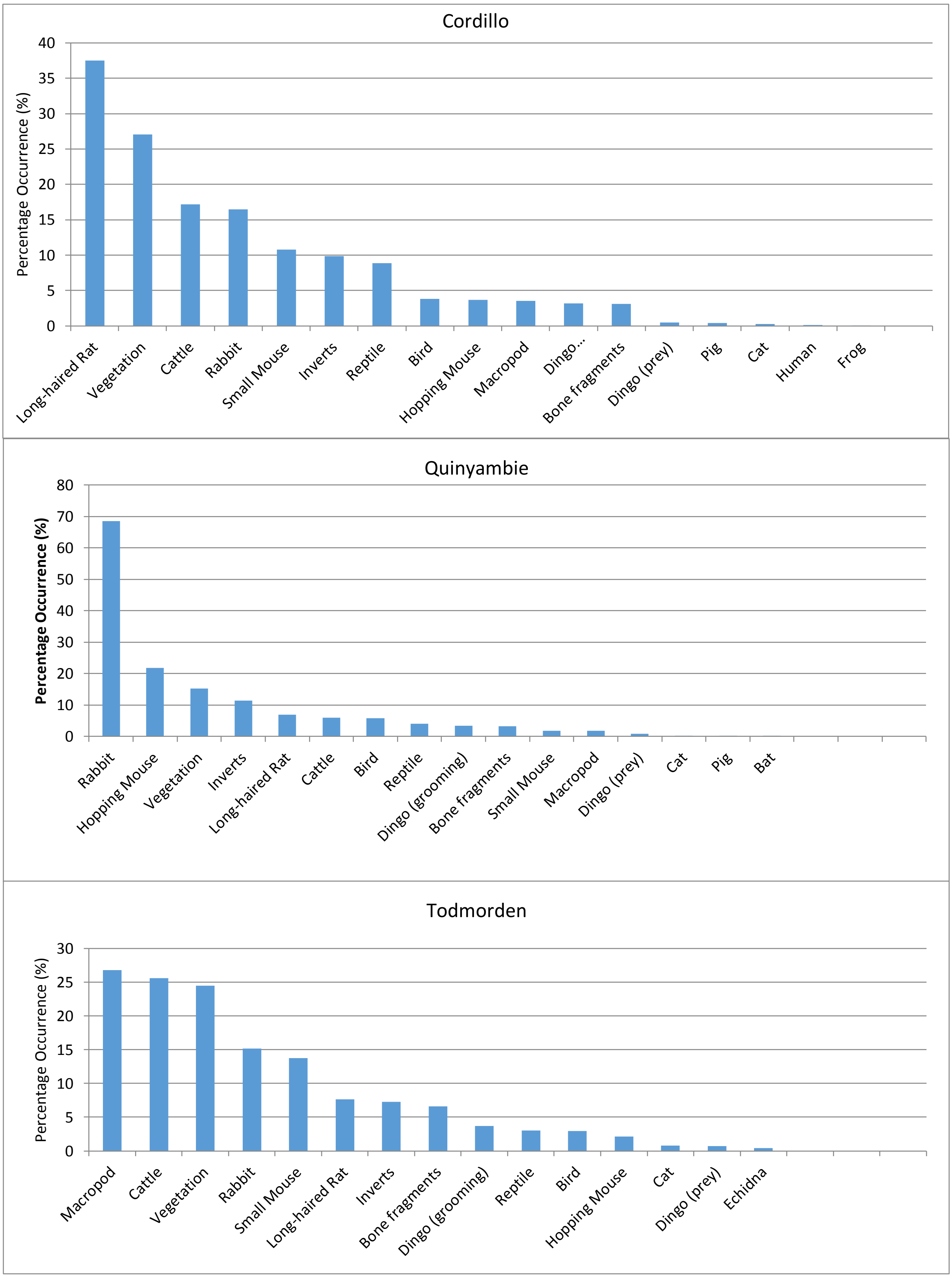


Figure 4.12 Differences in overall wild dog diets between Cordillo Downs, Todmorden and Quinyambie stations. Categories at the far right of the x-axis on these graphs with apparently zero values were actually present, but occurred in less than 0.1% of scats.

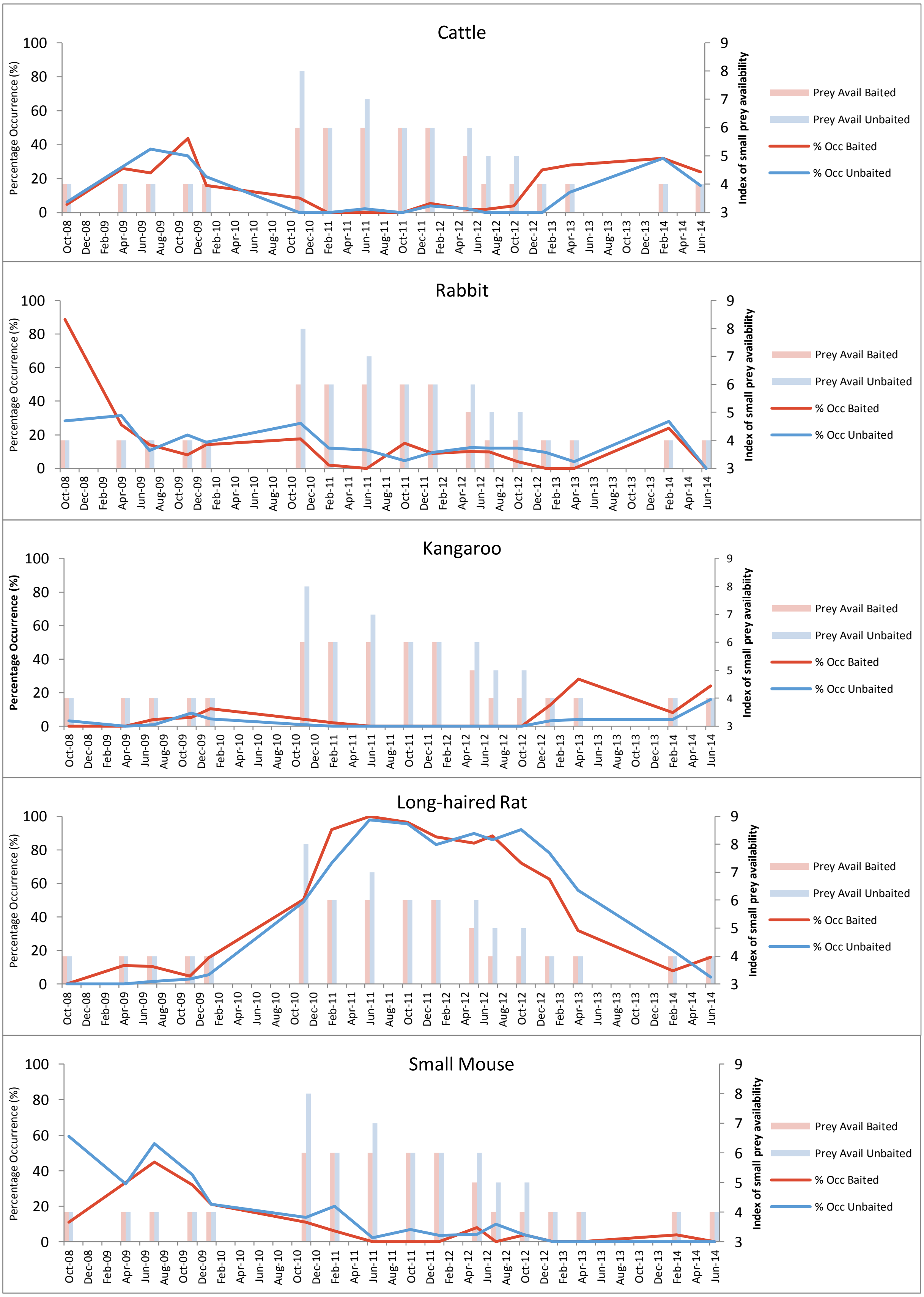


Figure 4.13 Trends in the percentage occurrence of primary prey remains found in wild dog scats at Cordillo Downs Station, plotted with the index of small prey availability. The consumption of long-haired rats by wild dogs was positively correlated with small prey availability. Negative correlations were identified between small prey availability and the consumption of cattle* and kangaroo by wild dogs.
*Includes carrion consumption as well as predation

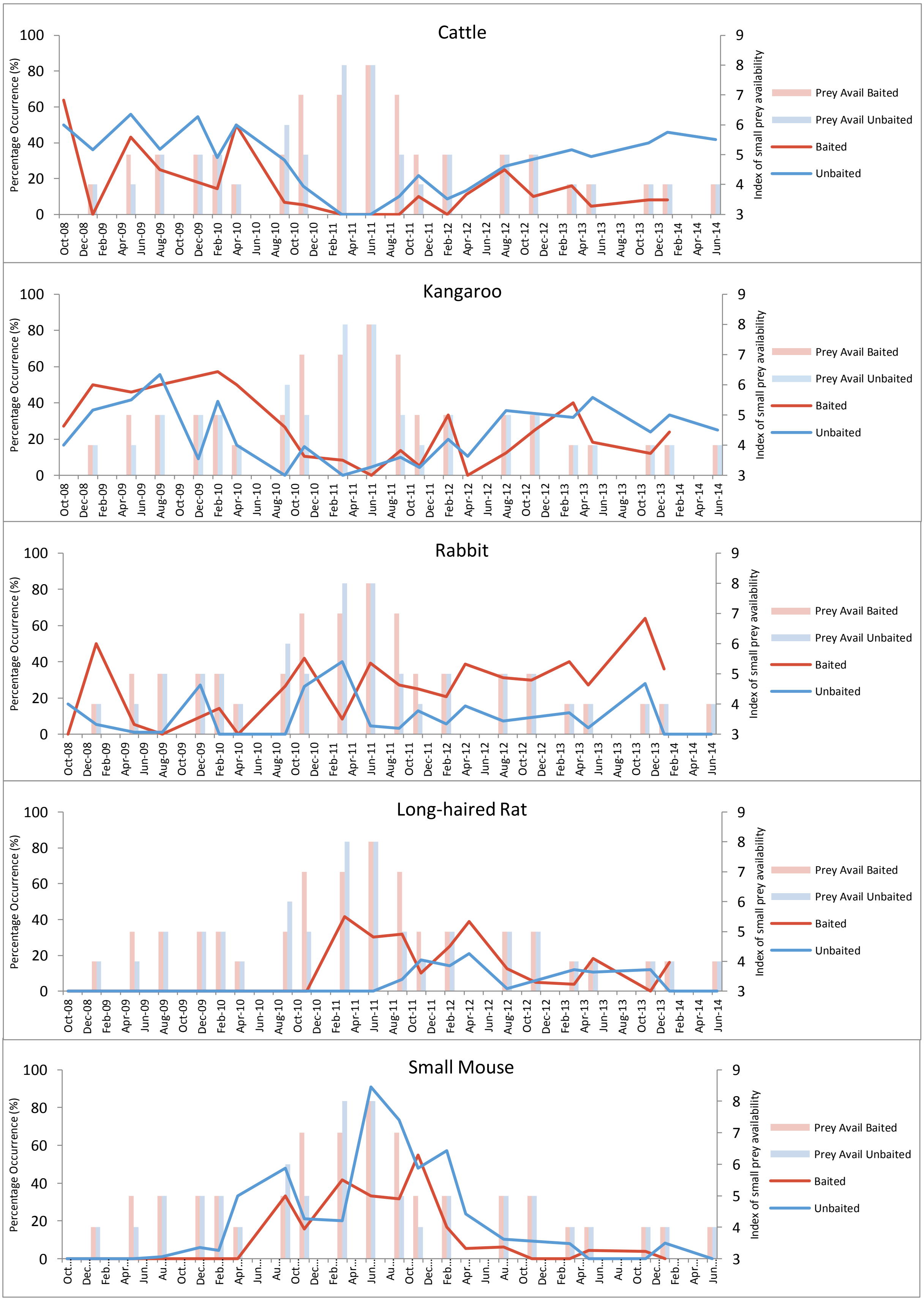


Figure 4.14 Trends in the percentage occurrence of primary prey remains found in wild dog scats at Todmorden Station, plotted with the index of small prey availability. The consumption of small mice by wild dogs was positively correlated with small prey availability, while significant negative correlations were identified between small prey availability and consumption of kangaroo and cattle* by wild dogs.

*Includes carrion consumption as well as predation

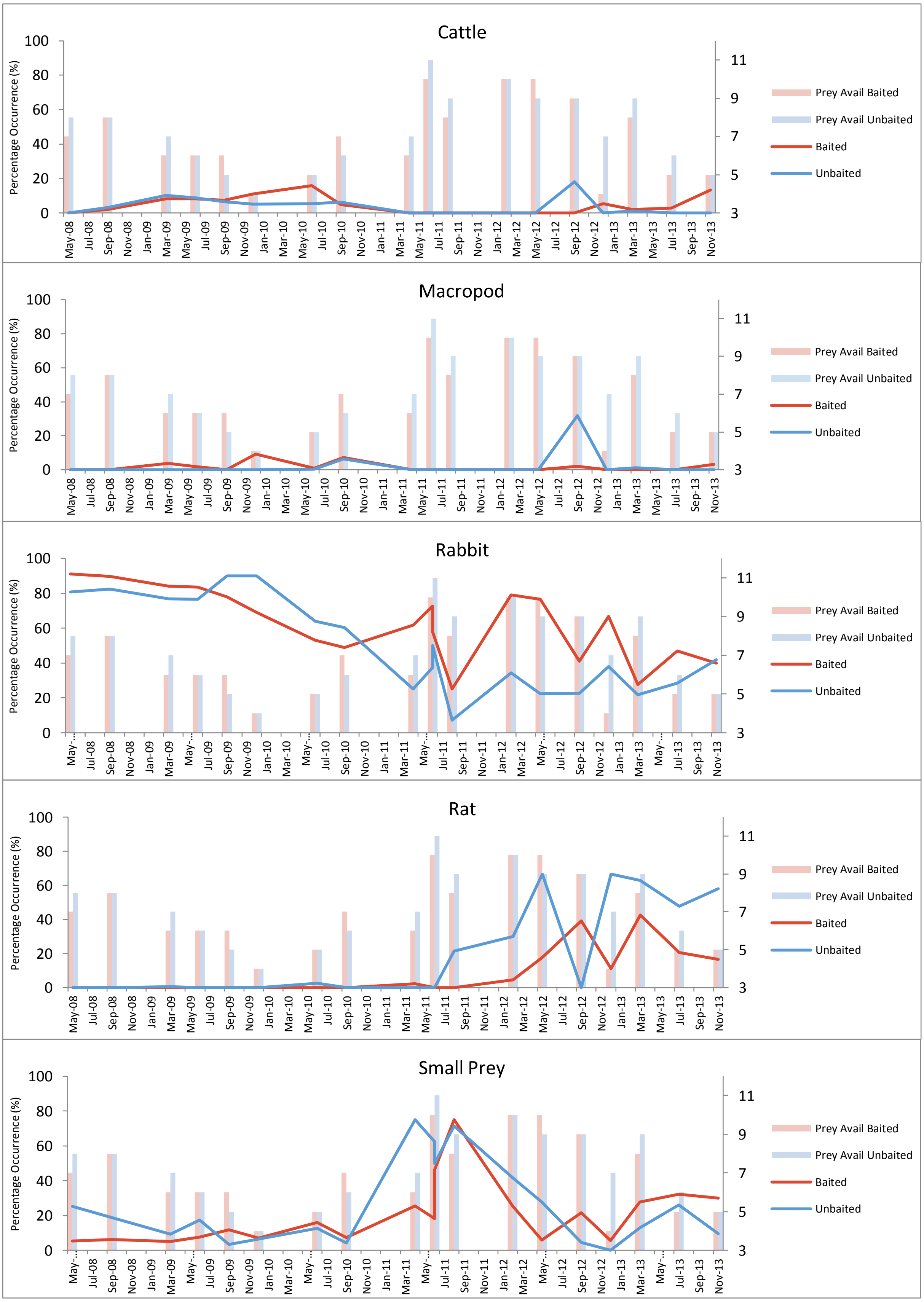


Figure 4.15 Trends in the percentage occurrence of primary prey remains found in wild dog scats at Quinyambie Station, plotted with the index of small prey availability. The consumption of small mice was positively correlated with small prey availability. Negative correlations were identified between small prey availability and the consumption of cattle* by wild dogs.

*Includes carrion consumption as well as predation

4.6 Water point visitation by wild dogs

Of the eleven wild dogs collared, one dog (a 10kg juvenile) slipped the collar on the first day, a second dog slipped the collar on the third day (visiting water only once during this time) and a third (Dog011) died within three weeks (visiting water only five times during this period). The remaining eight wild dogs were monitored from 11/12th November 2008 until:

07/08/09	Dog001
25/01/09	Dog002
28/12/08	Dog003
07/08/09	Dog004
31/01/09	Dog005
24/03/09	Dog006
03/02/09	Dog009
05/08/09	Dog010

Daily visitation rates for these eight wild dogs are shown in Figure 4.16. Monthly visitation rates for nine wild dogs are shown in Figure 4.17.

Individual dogs exhibited markedly different water point visitation rates. Members of the same pack, utilising the same water point, did not always visit water points at the same time or with the same frequency (Figure 4.16). In one pack, Dog005, Dog006, and Dog009 (all females) displayed different, but relatively consistent spacing between daily visits. Dog009 never visited water more than once in a day, but Dog005 and Dog006 often returned twice and sometimes three times in a day. A male of the same pack (Dog010) displayed irregular patterns. This may be related to his later dispersal, which occurred towards the end of May 2009. Immediately after taking residence in another territory, he did not return to water for 22 days. In another pack, Dog002 and Dog003 also visited water points at different frequencies (Figure 4.16).

Tracking data (not shown) indicated that resident wild dog packs did not monopolize the water point, suggesting that they shared the resource with other packs. Individuals from each of the two packs arranged in Figure 4.17 used different water points separated by ~10km, and rarely did any resident wild dog visit the water point used by the other pack. The only two occurrences of this were when Dog003 and Dog005 were captured at the water point used by the other pack, but never returned again.

Dog004 (who was most closely associated with Dog001, Dog002, and Dog003) was the most widely travelled of the collared wild dogs, and appeared to have little affinity to any particular site. Tracking data indicate that no more than 3-6 weeks were spent in any temporary 'home range' area—each area changing size and shape dramatically over the period. The 22 day period in summer when Dog004 travelled the furthest coincided with local rainfall events, which may have facilitated this exploratory foray during the hot weather. This behaviour is consistent for an individual preparing to disperse (Thomson 1992; Corbett 2001). Strangely, Dog001 appeared to be a member of two packs. He regularly used both waterpoints, and was the only wild dog with a home range that completely overlapped both pack areas.

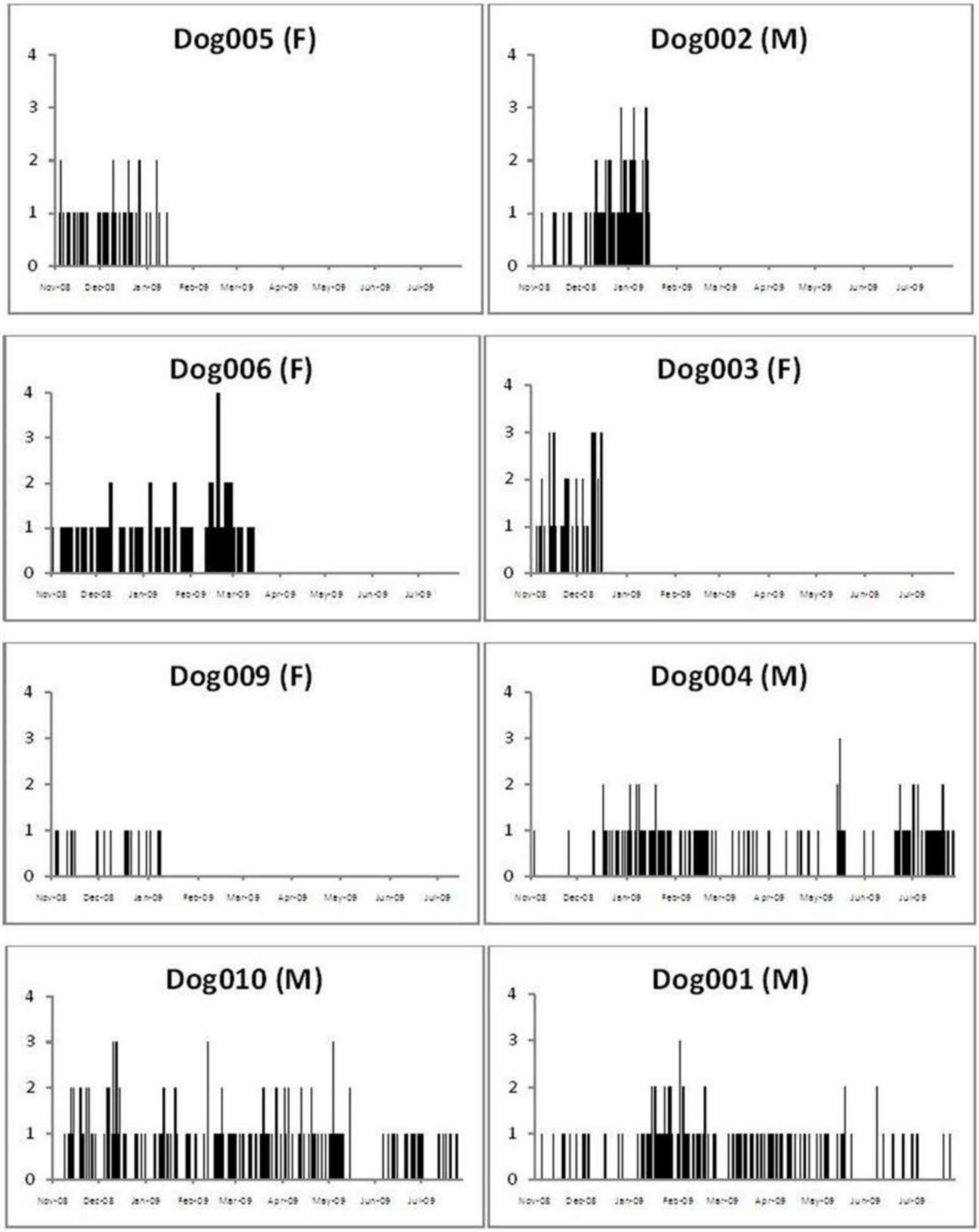


Figure 4.16 Daily visitation rates of eight wild dogs at Quinyambie. Columns arranged by pack.

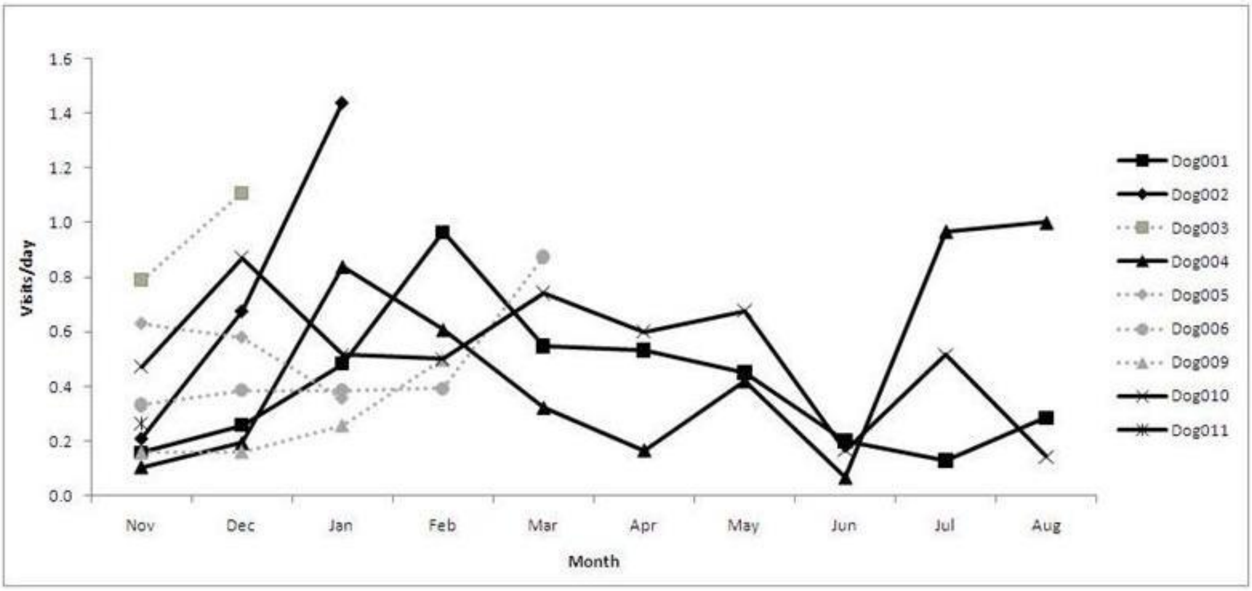


Figure 4.17 Monthly waterpoint visitation rates of nine wild dogs on Quinyambie Station (Males in black, Females in grey)

4.7 Results Summary

1. Wild dog activity was 60% lower in baited treatments areas, indicating that 1080 baiting caused at least a temporary reduction in wild dog activity. However, activity was never reduced completely to zero.
2. Yet despite this, no consistent effect of baiting on calf production was identified. Numerous predation events on cattle were witnessed by both researchers and pastoralists during the project, but the study found no evidence that predation was lessened by baiting. Although this might appear to indicate that there is no economic benefit of wild dog baiting on pastoral cattle properties, in reality this is not the case. We concede that the problems encountered in the collection of lactation failure data during the study, which affected prediction of calving dates and pregnancy outcomes, reduced sample size considerably and confounded our ability to detect treatment responses. Within properties, substantial differences in lactation failure rates occurred over time and also between treatments, but this variation was inconsistent and as a result, the overall effect of 1080 baiting on calf production was not statistically significant. Differences in herd age structure had a significant effect on calf production and other factors including the incidence of abortive disease, breed differences, and different cattle husbandry interventions imposed by the pastoralists involved in the study to maintain herd condition were also implicated.
3. The reductions in wild dog activity in baited areas was not sufficient to impact on the PTI values of wild dog prey species (e.g. small mammals, reptiles, rabbits and kangaroos) or subordinate predator species (i.e. feral cats and foxes) during the study. However, we make this statement with caution, as we suspect the sand plot monitoring technique for some species lacked sensitivity for some species. For cats in particular, very low detection rates on sand plots affected the ability of the study to identify of trends and relationships associated with the baiting treatment.
4. The study also demonstrated the dominance of seasonal variation as a driver of predator and prey population fluctuation. No evidence that baiting affected seasonal fluctuation in either prey activity or wild dog diet was identified.
5. Wild dogs at all study sites altered prey consumption according to prey availability but the staple prey for wild dogs on each property varied considerably.

5.0 DISCUSSION

Consistently lower wild dog PTI values in Baited treatment areas suggests that poison baiting reduced wild dog activity. While this is the likely explanation, we cannot be completely certain that the observed difference in wild dog PTI between treatments was due solely to the effect of baiting because:

1. wild dog activity was only assessed once in each treatment area prior to implementation of the baiting treatment; and
2. wild dog activity was only ever assessed immediately prior to baiting events.

Had wild dog activity also been assessed immediately following each baiting event it would have been possible to identify a “before-after” effect if present (R. Van de Ven, NSWDPI, pers. comm.). However, other influences likely to result in consistent differences in wild dog activity between treatments were few. For example, opportunistic shooting of wild dogs, which occurred on all properties, may have affected wild dog PTI. However, shooting occurred at equal intensity across paired treatments on all properties, and is highly unlikely to have caused the observed difference in wild dog PTI between treatments. Contrasting baiting histories on neighbouring properties may also have influenced wild dog PTI. However, with PTI values in Baited areas consistently at 40% of PTI values in Unbaited areas throughout the project, we believe it is possible to conclude that baiting at least temporarily reduced wild dog activity in Baited areas. Notably, wild dog activity was never reduced to zero in any of the baited treatment areas, indicating that the baiting treatment (modelled on conventional baiting procedures in northern South Australia) never resulted in complete eradication.

In addition to the variation in dingo activity attributable to the baiting treatment, the study also found considerable temporal variation in wild dog activity. The peak in activity observed approximately 18 months after the onset of favourable climatic conditions in 2010 indicated a delayed (lagged) response to increased prey availability. Assuming PTI is to some degree reflective of relative abundance, this is not surprising as the wild dog’s single annual breeding cycle might be expected to limit population growth and therefore delay response times. The delay also suggests that immigration into treatment areas in response to the increase in prey availability was less influential than local recruitment, since immigration, had it occurred, might have resulted in a more immediate increase in wild dog activity. This observation is not unexpected, as previous studies have shown that dispersal of wild dogs is lowest when food supply is plentiful (Fleming et al. 2001).

Although lower wild dog PTI in Baited treatment areas does not necessarily equate to lower wild dog abundance in these areas (see Box 2), consistent differences in wild dog activity observed between properties were most likely reflective of variation in the relative abundance of wild dogs between properties. PTI values for wild dogs (and the number of wild dogs sighted) were, on average, consistently highest on Quinyambie, indicating that relative abundance was highest on this property. PTI values were lowest on Todmorden and Lambina in the western part of the study area. This suggests that potential for calf predation is likely to vary geographically between properties in the study area

Despite lower wild dog activity in baited treatment areas, the study did not identify a significant effect of 1080 baiting on calving success. Although multiple incidences of calf predation were observed during the study, we found no consistent evidence that this predation was lessened by 1080 baiting. Having to discard lactation failure data collected prior to 2010, along with additional data affected when mustering period exceeded self-weaning age, considerably reduced the amount of data available for analysis. Thus, differences between treatments would have been less readily detected by statistical analysis. Nonetheless, within properties, differences in lactation failure rates occurred over time and also between treatments. However, the observed variation was inconsistent and likely to be more strongly linked to property-specific variables. Cow age was the only factor found to have consistently affected lactation failure, with rates in first lactation heifers almost double that of adult cows. Disease (e.g. Leptospirosis, Pestivirus and Neosporosis) was implicated as possibly contributing to the observed inconsistency, but serological testing was not sufficient to make conclusive determinations. Other contributing factors could include fine scale (within-property) variation in pasture quality, wild dog abundance, land type and cattle grazing behaviour.

While there was no consistent effect of baiting on the activity of alternative wild dog prey species, considerable temporal variation was observed during the project. Most of the temporal variation observed in small mammalian prey species occurred in response to the onset of flush climatic conditions in 2010. In larger species such as red kangaroos and rabbits, this response was less obvious and less consistent. Temporal variation in rabbits was most obvious at Quinyambie, where the highest levels of activity occurred. Quinyambie is renowned for its rabbit plagues, with densities of up to 1,600 rabbits per km^2 reported in past boom years (B. Cooke, pers. comm.). Rainfall equivalent to that of 2010/11 would normally have promoted a plague, but this time it failed to do so. Two factors probably conspired to prevent a population irruption. Firstly rabbits were at extremely low abundance leading into the flush climatic period (after the 2009 drought year) and the population was not able to rebound immediately. Secondly, the increasing abundance of rabbits is likely to have invited ready transmission of Rabbit Haemorrhagic Disease (RHD). Since it was introduced to the region in late 1995, RHD has generally re-occurred annually thereby continually retarding the growth of rabbit populations. The disease typically runs whenever there are sufficient susceptible young rabbits in the population to assist transmission – usually 2-3 months into the breeding season (Mutze *et al*. 2015). While sufficient rabbits survive RHD to maintain a reasonable population at times, the disease (probably assisted by myxomatosis) is likely to now prevent widespread plagues from occurring. However, the spread of RHD can be patchy which might explain some of the observed variability between treatments. Sporadic peaks in rabbit activity were observed in the Baited treatment area on Quinyambie following the 2009 drought year.

Kangaroo activity remained at relatively low levels at all sites for the duration of the study despite the period of above average rainfall in 2010/2011. Activity levels increased marginally in some treatment areas but in others there was no obvious difference. In contrast to these findings, kangaroo abundance in northern South Australia has previously been observed to fluctuate extensively according to rainfall, especially when kangaroo abundance is initially low (Cairns & Grigg 1993, McCarthy 1996). Moreover, other research has shown that the distribution and dispersion of red kangaroos across the landscape also varies in response to rainfall-induced changes in food availability. Pople *et al.* (2007) found that aggregations of red kangaroos were more likely to occur in periods of low rainfall, and that red kangaroo populations are always more evenly dispersed following periods of widespread high rainfall. Thus, it is likely that such dispersal of red kangaroos occurred following the high rainfall period of 2010/11 which may explain why kangaroo PTI did not increase as much as might have been expected during this period. Predation of red kangaroos by wild dogs may also have limited the rate of increase of kangaroo populations following the high rainfall period (Choquenot et al. 2013).

No consistent influence of baiting on subordinate predator populations (i.e. cats or foxes) was identified. Foxes and wild dogs were frequently recorded together on sandplots and no evidence of foxes avoiding areas occupied by wild dogs was identified. The main factor influencing fox distribution appeared to be the presence of rabbits which are likely to be important prey for foxes in the study area. Feral cats were infrequently recorded on sand plots, suggesting their abundance was very low across the study area. Cat activity appears to be greatest on dune crests or sandy creeklines (Mahon et al. 1998; Read and Eldridge 2010). Thus, the placement of sandplots solely along roads in this study may have resulted in an underestimate of cat activity. The absence of a response in cat activity to seasonal changes in prey availability seems unlikely and suggests that techniques employed in this study to assess the activity of cats were sub-optimal. We suggest that broad-scale assessment of cat activity/relative abundance in the arid zone requires enhancement, perhaps integrating additional techniques with sand plot monitoring to improve detection.

Wild dogs inhabiting the study area were found to consume a wide range of prey items which varied considerably over time and was strongly dependent on prey availability. The study demonstrated the importance of rabbits, rodents and red kangaroos to wild dogs at difference times and places, and identified the capacity of wild dogs to subsist on less preferred food items such as invertebrates, vegetation and reptiles when necessary.

Wild dog scats commonly contained cattle remains, indicating the significance of cattle as a prey item for wild dogs across the study area. However, the relative importance of cattle in wild dog diet varied substantially during the study at all sites and was related mostly to the availability of small mammalian prey. In analysing scats, the proportion of consumption attributable to calf predation was unable to be distinguished from that attributable to scavenging carrion. However, it is likely that the ratio of scavenged material to hunted material would have varied considerably over time at all study sites (and also between study sites) depending on the availability of carrion, the susceptibility of calves to wild dog attack and the availability of alternative prey.

The study found that individual wild dogs display different water point usage patterns but all tend to visit water points more frequently in summer. In the arid zone, poisoned baits are often distributed around remote water points in spring and/or autumn to protect calves. The choice to target water points is based on the notion that wild dogs visit water points daily, or at least regularly. One of the hindrances to effectively targeting all wild dogs in a population with a bait is the consumption of multiple baits by only a few individuals (Bird 1994). The results of the current study indicate that wild dogs at the study site visit water points more frequently in summer, regardless of local rainfall events, suggesting that more individual animals may be targeted by baiting programs if conducted during the hotter months. Because this typically coincides with the emergence of juvenile wild dogs (Fleming *et al.* 2001; Allen 2014), a bait-replacement strategy may produce more substantial results.

Although not statistically significant, a consistent overall trend for foetal/calf losses to be higher in summer in baited treatment areas is worth noting. Previous research in the Australian rangelands has found that calf mortality increases during summer months, attributed to heat stress and dehydration (McGowan *et al.* 2013, Fordyce *et al*. 2015). However, producers involved in this study assert that these findings do not apply in northern South Australia provided that stock receive appropriate husbandry. However, in hot weather, cattle frequently leave groups of calves at water points while they venture out to forage (J. Brook, Cordillo Downs Station, pers. com.). The increased susceptibility of these calves to wild dog attack could have contributed to the apparent trend of increased calf losses during summer months observed in this study.

No significant relationship was identified between calving success and seasonal conditions (as measured by “greenness” (NDVI) and all monitored cows retained a condition score of at least 2 (out of 6). This is indicative of the relatively good seasonal conditions that prevailed during parts of the study, but also reflects the proactive husbandry employed by the respective property owners to maintain the health and condition of their herd, including providing nutritional supplementation to assist lactation during dry periods, adjusting stocking rates according to pasture availability and rotating cattle between paddocks to avoid overgrazing. Managers of Quinyambie Station went to the extent of de-stocking completely in 2009, before serious drought conditions took hold.

5.1 Implications for Management

Arguably the greatest knowledge gap in the field of rangeland wild dog management is the lack of suitable gauging mechanisms to indicate periods when wild dog baiting is likely to confer significant production benefits and to differentiate these periods from when wild dog baiting may have negligible or even negative effects. A major focus of this project was to identify potential indicators of predation risk (or "triggers") that will enable pastoral land managers to apply lethal wild dog control optimally according to risk and the likelihood of significant calf loss.

Unfortunately the study did not yield the decisive conclusions that would enable these gauging mechanisms to be clearly defined. However, it did contribute significantly to the knowledge and understanding of wild dog predation in northern South Australia. Following are the key management outcomes arising from the project.

1. The disappearance of cattle from wild dog diet when alternative prey availability was high indicates that the risk of calf predation by wild dogs during flush climatic periods is quite low.
2. The finding that poison baiting (using conventional techniques) never completely removed wild dogs.
3. Satellite tracking found that wild dogs tended to visit water points more frequently in summer. This suggests that a greater number of wild dogs will be exposed to baits if they are laid around water points in the hotter months, particularly as this period also coincides with the emergence of juvenile wild dogs from their dens.
4. The observed variation in wild dog diet between properties suggests that the drivers for calf predation differ from property to property. Thus, a "one-size-fits-all" approach to wild dog management is not likely to be successful. The study has shown that calf production in the study area is likely to be affected by a range of many property-level variables, suggesting that strategies for wild dog management need to be tailored to individual properties.
5. There are still many unknowns around the predation dynamics of wild dogs in northern South Australia. This calls for a "learn by doing" approach to wild dog management, where careful monitoring and evaluation of management practices is used in conjunction with other new information as it comes to hand to continually improve the effectiveness of wild dog management. The current SAALNRM Wild Dog Management Plan fits well with this approach. It provides for landholders to have access to baits if and when they need them, while promoting the responsible use of baits and acknowledging the benefits of maintaining a certain number of wild dogs in the system. It endeavours to work with pastoralists and other stakeholders equitably and provides them with a level of ownership of wild dog management on their own property. Maintaining communication between stakeholders, and between landholders and government agencies will be key in ensuring wild dog impacts continue to be managed optimally across all land tenures.

5.2 Recommendations for Future Research

Although large-scale, long-term replicated trials such as this South Australian arid lands trial are required to determine trigger points and relative efficacy and impacts of wild dog baiting, they are by nature expensive, logistically challenging to conduct and open to different analytical and policy outcomes (Hayward *et al* 2015, Nimmo *et al*. 2015). Here we provide a list of general recommendations, learned from our study, to assist in the design and analyses of future trials.

5.2.1 Study design and implementation

Large scale, long term field experiments in remote regions on properties undertaking adaptive management to maximise production under variable conditions will by their very nature face considerable challenges to experimental design and execution. The degree to which compromises need to be applied to the optimum experimental design will be a function of the resourcing and management of the project, along with stochastic or changeable environmental, social and business factors.

Stakeholders including funding and management agencies, scientists, landowners and project staff need to reach consensus on non-negotiable requirements, acceptable trade-offs and individual responsibilities prior the finalisation of the experimental plan (Box 2). All potentially confounding variables including: landscape type; vegetation condition; herd size; demographics and disease status; recent and contemporary wild dog control; and availability of main alternate wild dog prey should strongly influence selection of study sites. The ability to conduct comprehensive six-monthly musters and to monitor wildlife activity before and after all baiting episodes should also determine suitable site selection. Our study has also shown the benefit of collecting additional information such as taking blood samples to test for abortive diseases from all pregnant cows, compiling carrion availability and vegetation condition indices, and regular recording of observations from study participants on a regular basis (Box 3)

5.2.2 Activity indices

In the same way that incomplete musters, irregular sampling dates, imprecise determination of calving date and inability to always determine pregnancy outcomes compromised the ability of this study to assess treatment effects on calving success, our ability to monitor responses of wildlife were limited by our dependence upon track activity plots for all species.

Hayward and Marlow (2014) summarised concerns about the sensitivity and appropriateness of using passive track indices to monitor changes in mesopredator and other wildlife activity and suggested that camera traps should be used in future studies. Short track plots such as we used have proven to be valuable monitoring tools for assessing changes in wild dog activity (Engeman and Allen 2000) and concurred with observation of wild dogs sighted during our monitoring program. However, longer or continuous transects are required to better detect cats that are less inclined to walk on roads (Read and Eldridge 2010). Camera traps are likely to provide greater precision for detecting cats and other more cryptic species (Moseby and Read 2014). Camera traps also improve the ability to identify individuals (Ballard *et al*. 2014; McGregor *et al* 2015), calculate densities (Bengsen *et al*. 2011), evaluate change in occupancy (Robley *et al*. 2014) and evaluate spatial and temporal changes in relative activity of predator species (Read *et al*. in press) compared to track plots. Camera traps are also conducive to the longer sampling periods necessary to improve occupancy or activity estimates (Ballard *et al*. 2014). For future studies of the effects of wild dog management on mesopredator and other wildlife populations, these benefits of camera traps need to be weighed up against the large numbers, hence cost, of cameras needed for robust monitoring, particularly recognising that detection rates vary for different species depending on the positioning and settings used (Robley *et al*. 2014).

Box 3 Suggested improvements for consideration in future predator manipulation experiments

Study design:

1. Allow 3-6 months to prepare the project plan and ensure participation and agreed responsibilities and obligations of participating landholders, biometrician and steering committee
2. Establish whether management to maximise stock condition (eg relocation or provision of supplements in dry times) takes precedence over experimental outcomes
3. To improve robustness of data, only select properties willing to undertake regular biannual (twice-yearly) mustering
4. Ideally use all cattle, with unique permanent tags, in each paddock rather than a sample
5. Optimise consistency across treatments with respect to demographics (cows preferable to heifers), breed, stocking intensity, land types, historic management, and use of vaccinations, supplements etc.
6. Plan for at least three activity surveys prior to implementation of the treatment (eg. baiting) and then conduct activity surveys a minimum of 4 weeks before **and after** each treatment event.
7. Ensure that data collection techniques use are optimal for key response variables (i.e. consider Landsat or aerial photography to monitor resource availability, camera traps for activity measurements of some key wildlife species, aerial kangaroo counts and electronic tag counters in cattle yards)

Data collection

1. Set up a minimum of five vegetation condition photo points for each treatment and control paddock, and photograph quarterly or during all activity surveys
2. Take blood samples from every pregnant cow to test for abortive diseases every muster during pregnancy testing
3. Develop a list of questions to ask landholders each activity survey and muster, eg. rainfall, land condition, cattle condition, kangaroo/rabbit movements and numbers, wild dog activity, observed calf/wild dog interactions
4. Name the locations for scat collection, record presence of water in permanent water sources
5. Develop a carrion availability index – rank cattle and other carrion availability separately (how much and how old)
6. Record the presence of fly larvae (maggots) in scat analysis as an indicator of carrion ingestion.
7. Where track plots are used, ensure consistency for plot length and width. Activity survey record sheets should include information on plot trackability (eg. wind, rain, shadow, substrate type, time of day (eg. Moseby *et al*. 2011), along with dog and wildlife sightings.

Analyses and Outcomes

1. Compare calves branded to calves weaned along with pregnancy outcomes
2. Take care not to draw conclusions from response variables with insufficient or ambiguous data

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APPENDIX A. Publications arising from this project to date.

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Allen B. L. (2010c) Skin and bone: observations of dingo scavenging during a chronic food shortage. *Australian Mammalogy* 32, 1-2.

Allen B. L. (2011) *'Efficacy of para-aminopropiophenone (PAPP) to control dingoes (Canis lupus spp.) in the Strzelecki Desert of South Australia: Quinyambie field trial*.' (Animal Control Technologies Australia: Melbourne)

Allen B. L. (2012a) *'Activity trends of dingoes and other wildlife on Quinyambie Station, April 2008 to May 2012.*' (Pest Animal and Wildlife Sciences: Toowoomba)

Allen B. L. (2012b) *'The diet of dingoes in northern South Australia: interim report inclusive of data until May 2012*.' (Pest Animal and Wildlife Sciences: Toowoomba)

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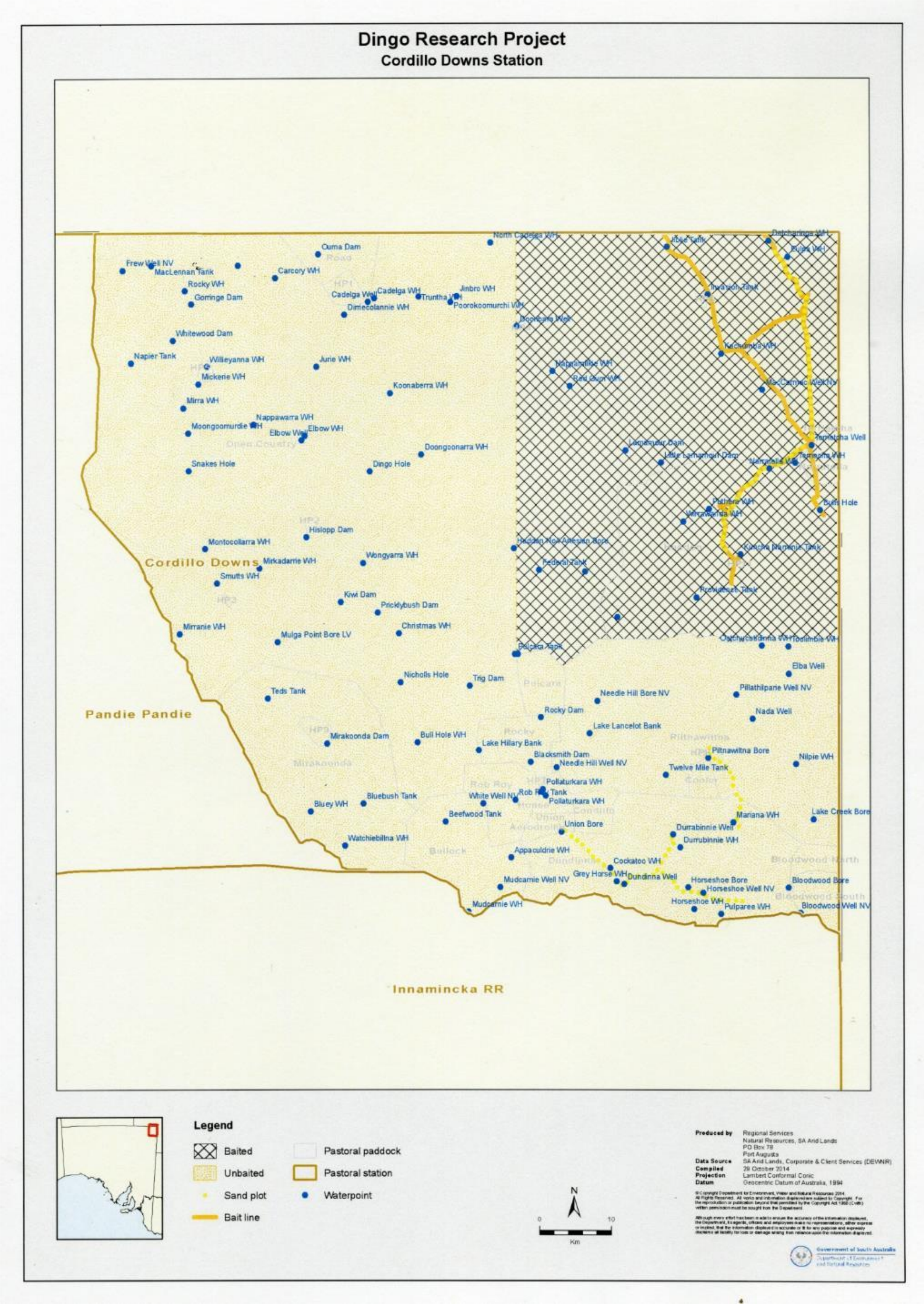
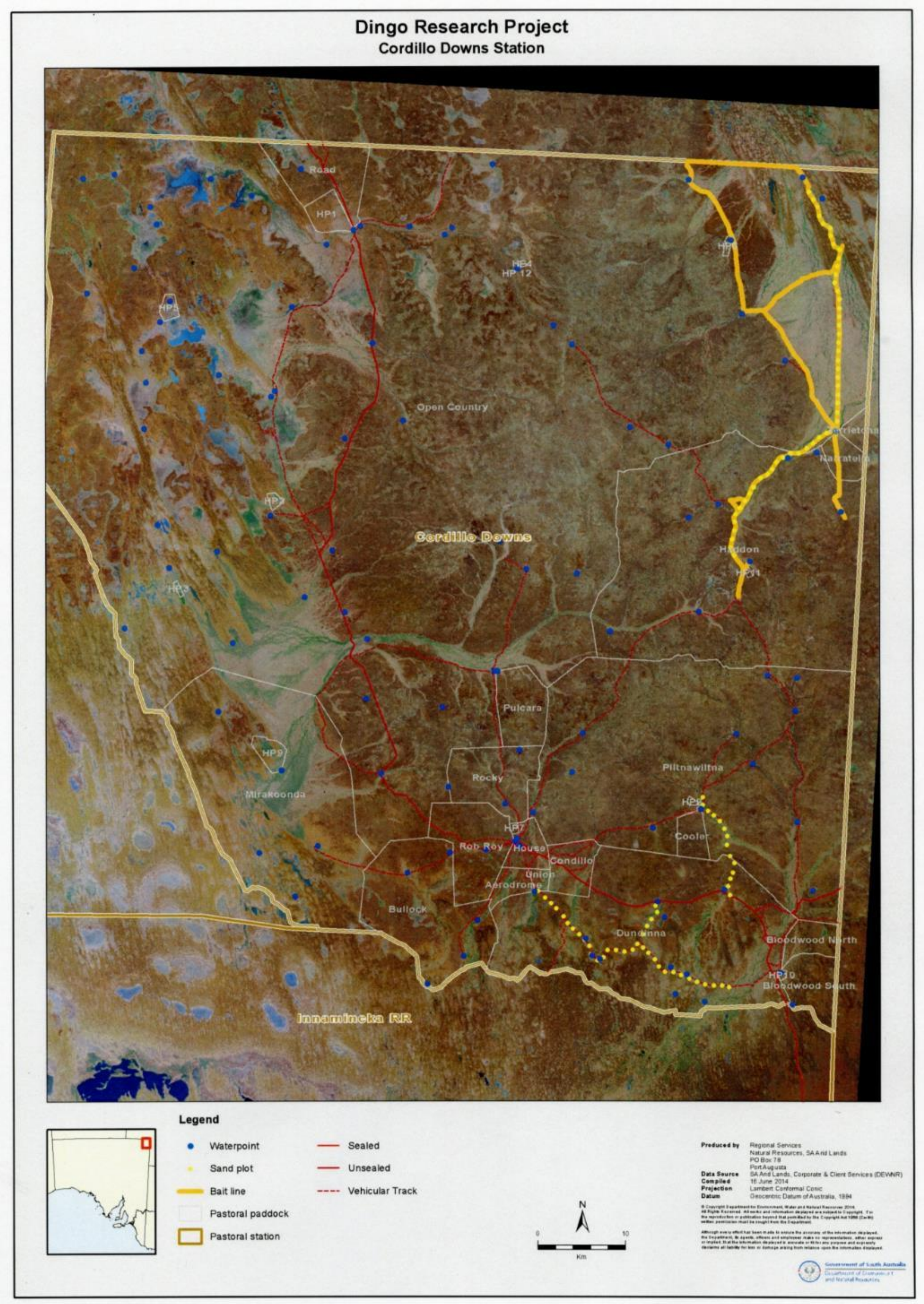
APPENDIX B. Site Maps

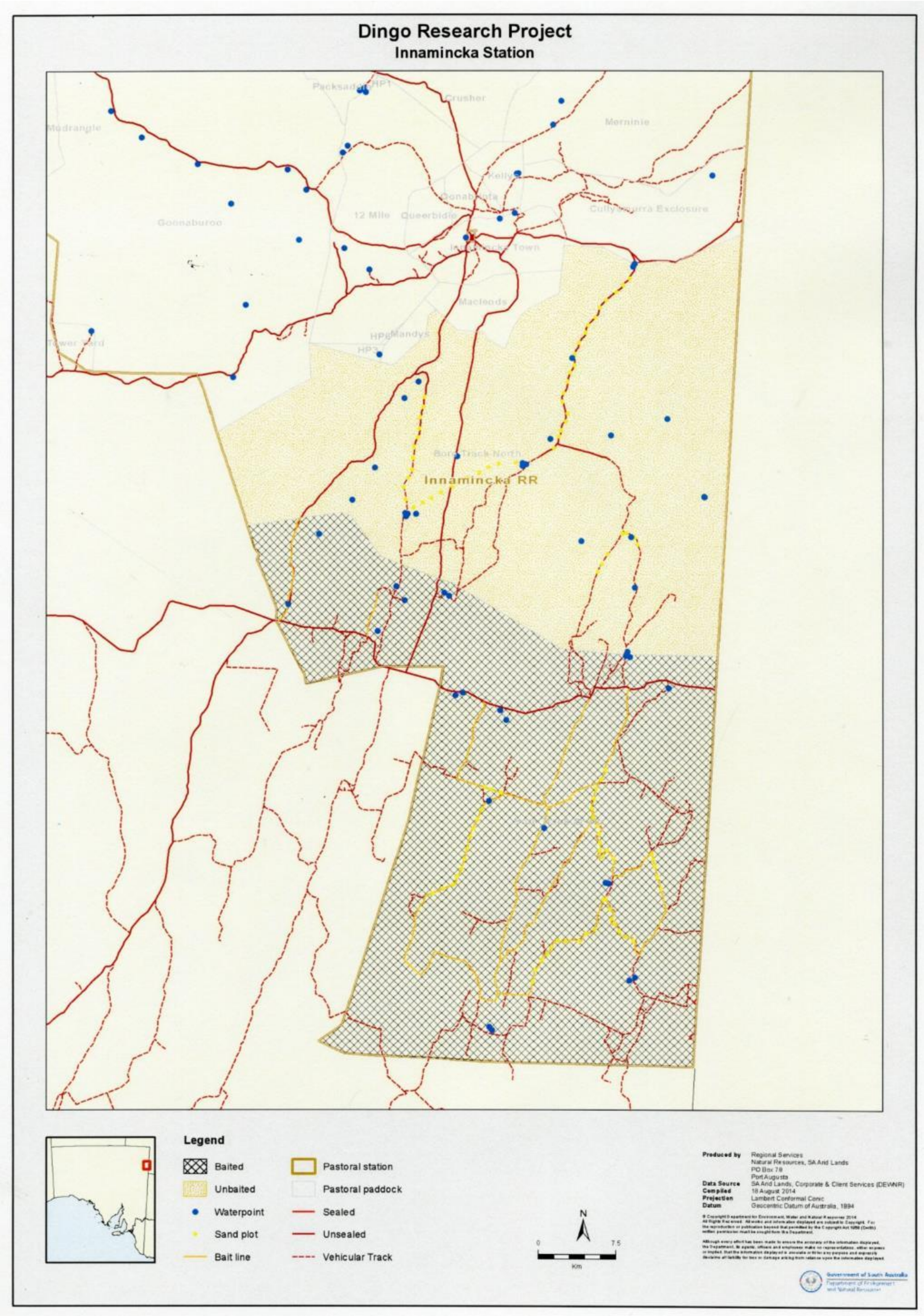
B.1 Cordillo Downs treatment areas and sand plot transects



B.2 Satellite Image of Cordillo Downs Station

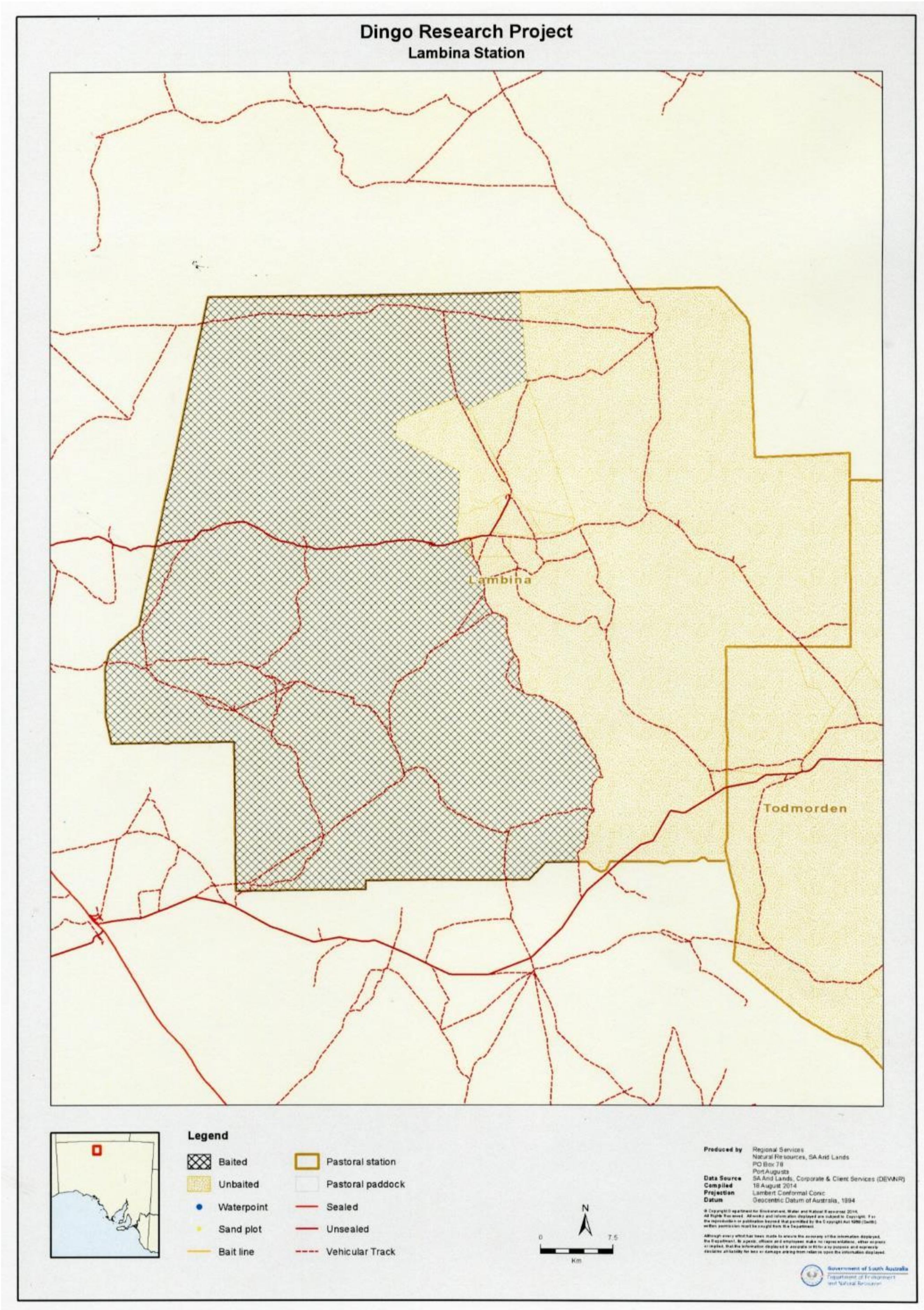


B.3 Innamincka treatment areas and sand plot transects

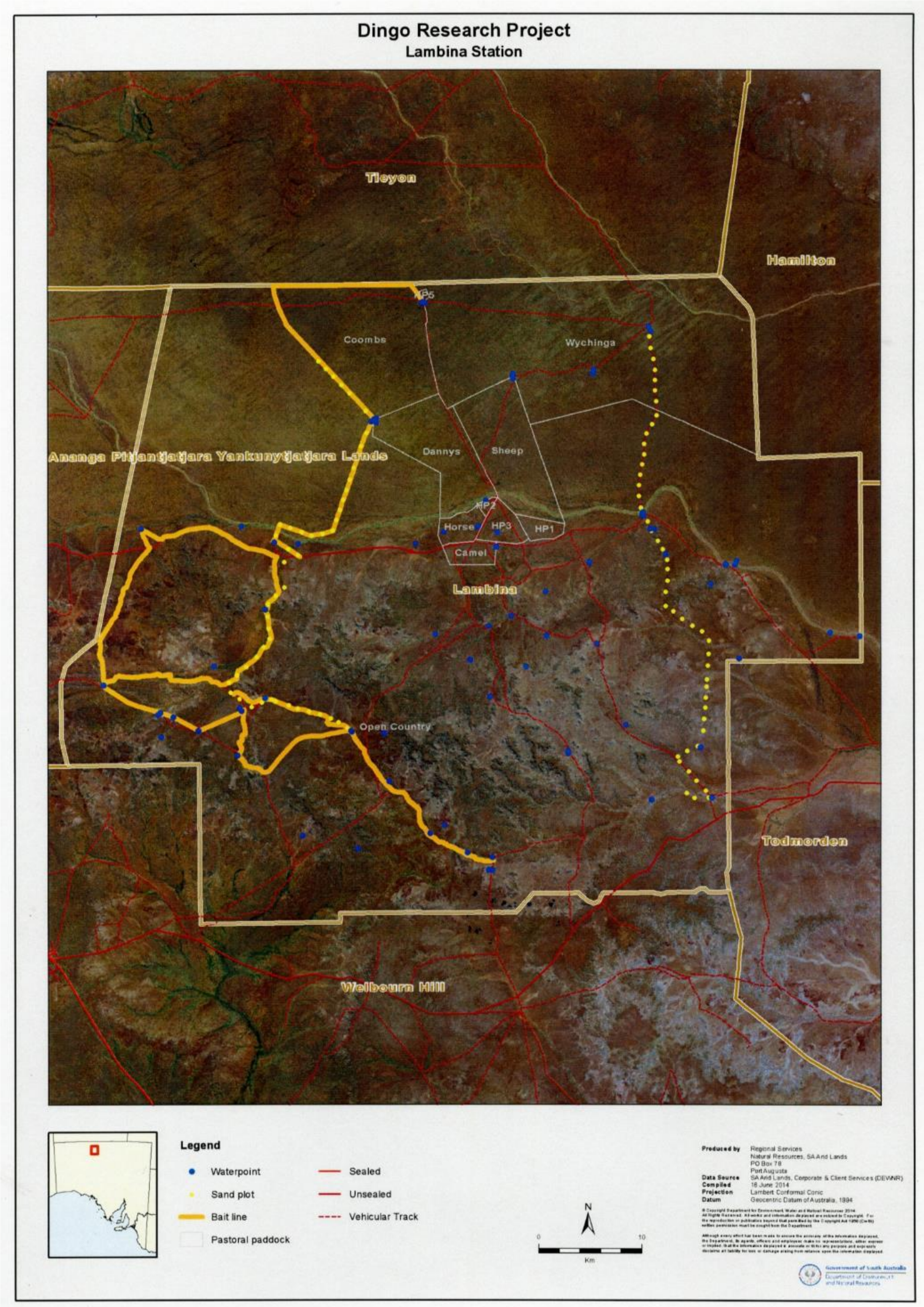


B.4 Satellite Image of Innamincka Station

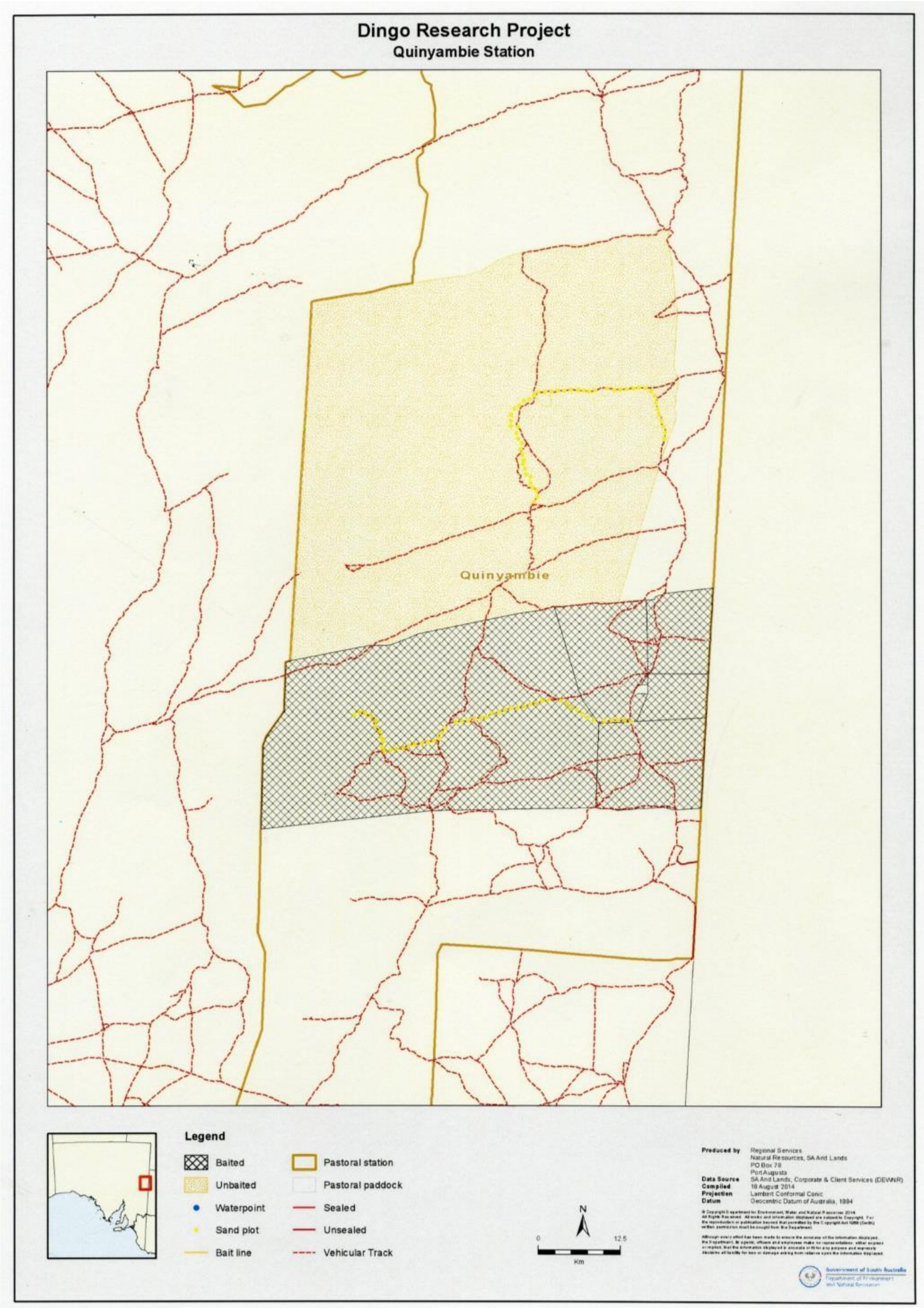
B.5 Lambina treatment areas and sand plot transects



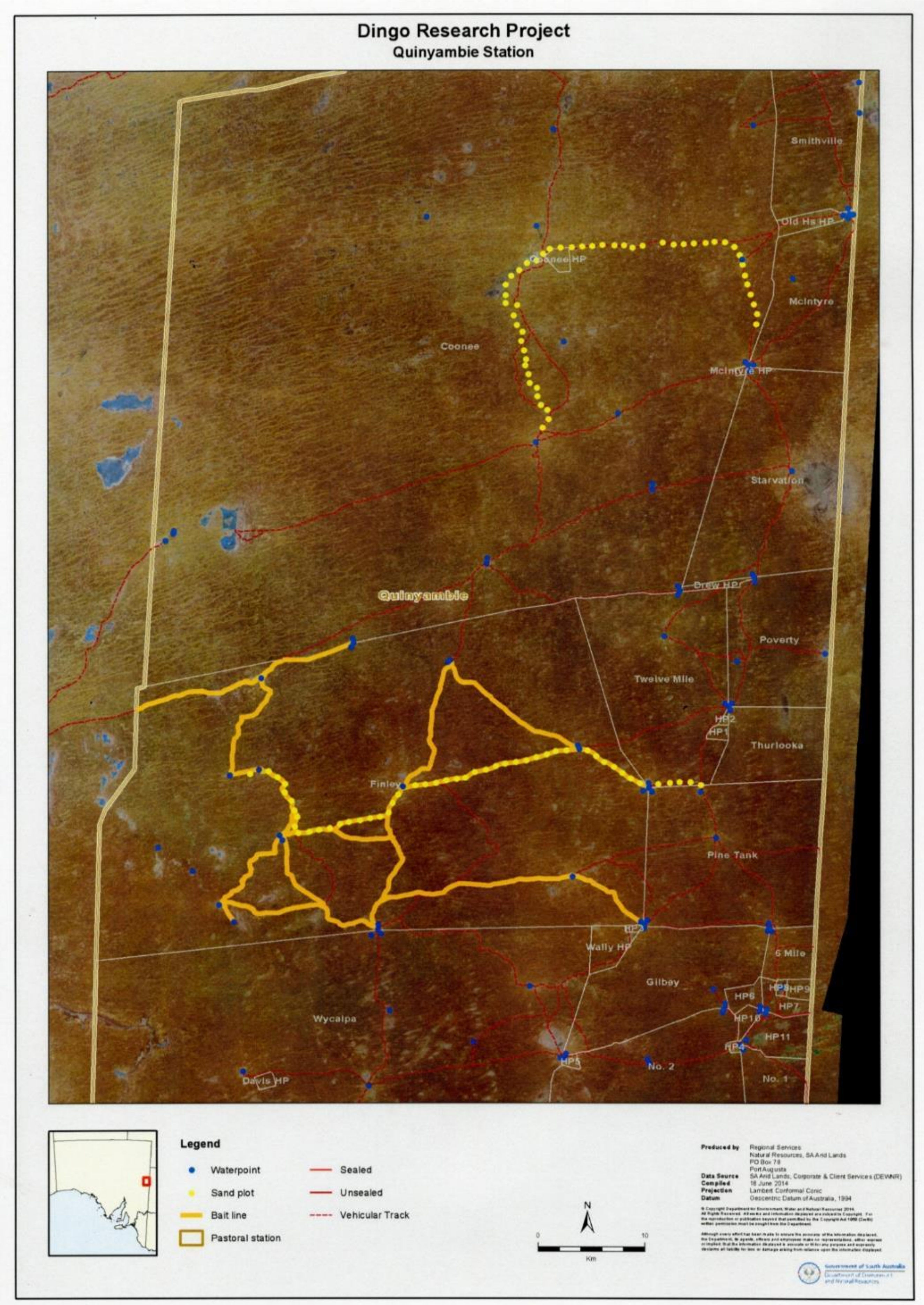
B.6 Satellite Image of Lambina Station



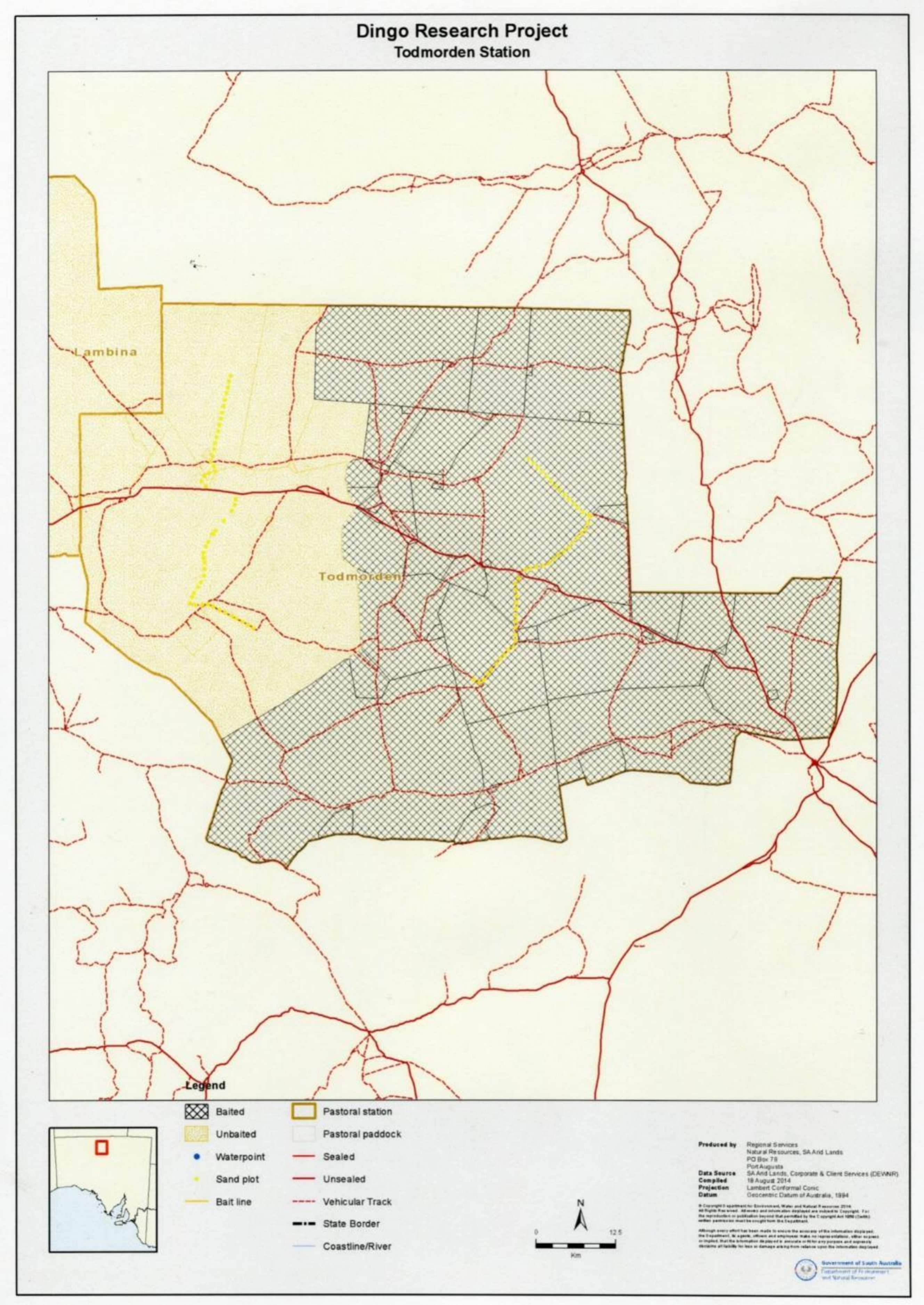
B.7 Quinyambie treatment areas and sand plot transects



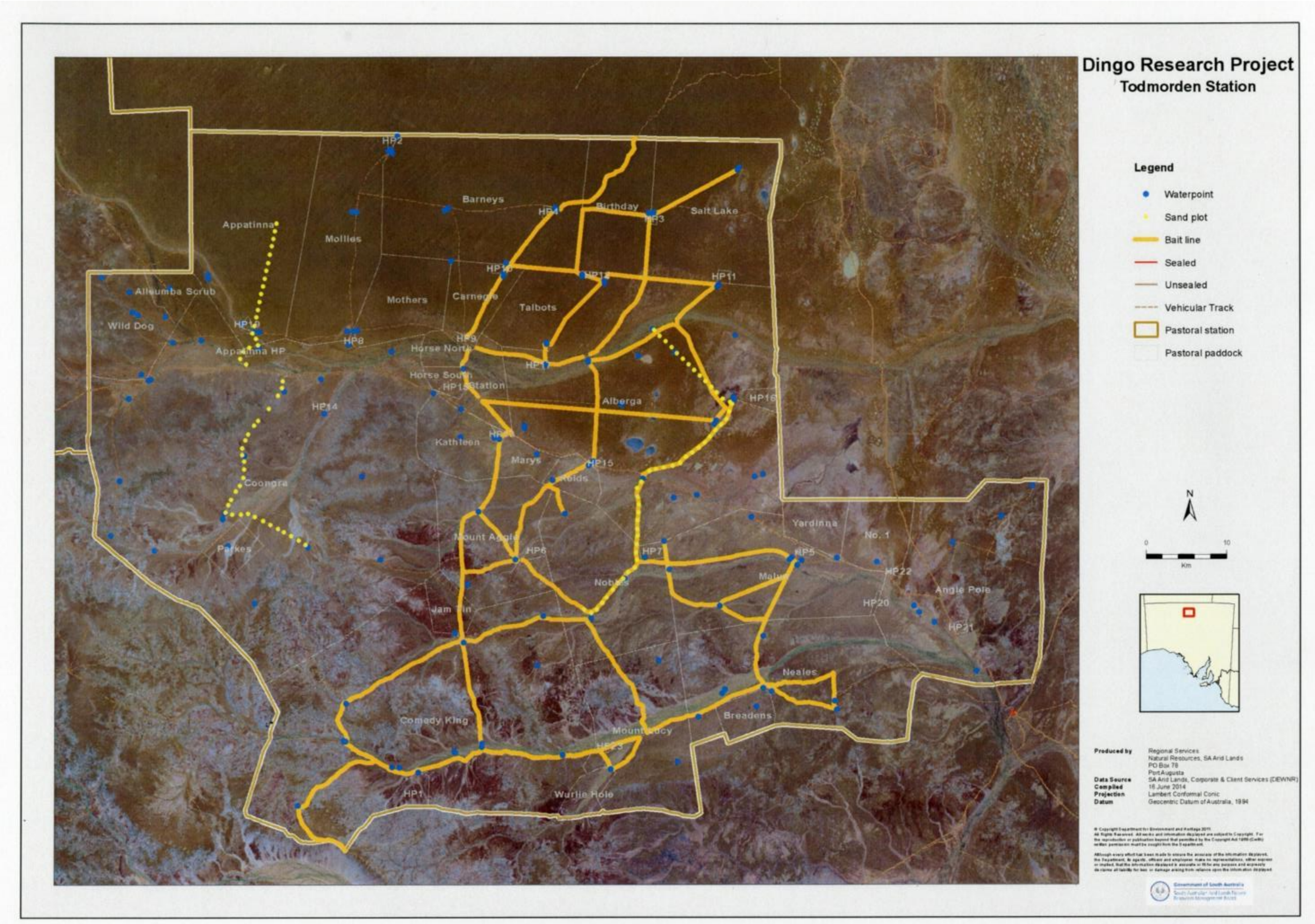
A.8 Satellite Image of Quinyambie Station



B.9 Todmorden treatment areas and sand plot transects



B.10 Satellite Image of Todmorden Station



APPENDIX C. Data Collection and Baiting Logs

C.1. Cordillo Downs

SURVEYS	SURVEY RECORDER	BAIT	BAIT TYPE	SCATS	PREG TEST	
					BAITED	CONTROL
2/08/2008	BA					
2/10/2008	BA	3/10/2008	MANUFCTD	3/10/2008		
2/04/2009	BA	3/04/2009	MANUFCTD	2/04/2009	3/04/2009	1/05/2009
24/07/2009	BA			24/07/2009		
6/11/2009	BA	6/11/2009	MANUFCTD	6/11/2009		
22/01/2010	BA	4/06/2010	MANUFCTD	22/01/2010	20/04/2010	5/05/2010
5/11/2010	SE	6/11/2010	MANUFCTD	06/11/201		1/06/2010
1/02/2011	SE	1/06/2011	MANUFCTD	1/02/2011	1/05/2011	23/03/2011
2/06/2011	SE			1/05/2011	11/05/2011	28/03/2011
3/10/2011	SE	5/10/2011	MANUFCTD	5/10/2011		7/04/2011 9/04/2011
13/01/2012	SE			13/01/2012		
8/05/2012	SE	8/05/2012	MANUFCTD	8/05/2012	18/03/2012	2/04/2012
3/08/2012	SE			3/08/2012	23/03/2012	5/04/2012
2/11/2012	SE			2/11/2012		
28/01/2013	HM			28/01/2013		
6/04/2013	SE			6/04/2012	29/04/2013	27/03/2013
27/07/2013	SE			27/07/2012		
17/10/2013	HM			17/10/2013		
7/02/2014	SE			7/02/2014		
13/06/2014	SE			1/06/2014		

C.2 Innamincka

SURVEYS	SURVEY RECORD	BAIT	BAIT TYPE	SCATS	PREG TEST	
					BAITED	CONTROL
7/08/2012	SE & HM	1/06/2012	MANUFCTD		15/06/2012	22/06/2012
6/11/2012	SE	6/11/2012	MANUFCTD		11/10/2012	15/10/2012
31/01/2013	HM					
10/04/2013	SE	10/04/2013	MANUFCTD		19/04/2013	4/03/2013
30/07/2013	SE					
23/10/2013	HM	23/10/2013	MANUFCTD		10/10/2013	18/10/2013
2/02/2014	SE	18/04/2014	MANUFCTD		27/03/2014	4/04/2014

C.3 Lambina

SURVEYS	SURVEY RECORD	BAIT	BAIT TYPE	SCATS	PREG TEST	
					BAITED	CONTROL
26/06/2009	HM	26/06/2009	MANUFCTD	26/6/2009 baited only		27/6/2009 W/D only
2/09/2009	HM			2/09/2009		
10/02/2010	HM	1/01/2010	WET MEAT			
25/04/2010	SE	26/04/2010	MANUFCTD	25/04/2010	19/04/2010	30/09/2010
1/09/2010	SE					
4/12/2010	SE	4/12/2010	MANUFCTD			
1/03/2011	SE			1/03/2011		
26/05/2011	SE	26/05/2011	MANUFCTD		26/05/2011	26/05/2011

C.4 Quinyambie

SURVEYS	SURVEY RECORD	BAIT	BAIT TYPE	SCATS	PREG TEST	
					BAITED	CONTROL
25/04/2008	BA					
27/05/2008	BA	28/05/2008	WM	25/05/2008		
10/07/2008	BA					
4/09/2008	BA			3/09/2008	27/11/2008	11/12/2008
6/03/2009	BA	13/02/2009	MANUFCTD	6/03/2009		
2/06/2009	BA			4/06/2009	22/05/2009	
2/10/2009	BA	2/09/2009	MANUFCTD	2/10/2009		
18/12/2009	BA			18/12/2009		
24/06/2010	BA			24/06/2010		
30/09/2010	BA	1/10/2010	MANUFCTD	30/09/2010		
26/04/2011	BA			6/01/2011		
1/06/2011	BA	13/06/2011	MANUFCTD	8/02/2011		
29/06/2011	BA			26/04/2011		
3/08/2011	BA	16/12/2011		3/08/2011		
15/02/2012	BA		MANUFCTD	15/02/2012		
15/05/2012	BA	17/05/2012	MANUFCTD	15/05/2012		
5/09/2012	HM	7/09/2012	MANUFCTD	16/09/2012		
19/12/2012	HM			19/12/2012		
19/03/2013	HM	20/03/2013	WM	20/03/2013		
20/07/2013	HM			19/07/2013		
11/09/2013	HM	12/09/2013	MANUFCTD	11/09/2013		

C.5 Todmorden

SURVEYS	SURVEY RECORD	BAIT	BAIT TYPE	SCATS	PREGNANCY TEST	
					BAITED	CONTROL
28/08/2008	HM	23/10/2008	WET MEAT	2/10/2008		
17/01/2009	HM			16/01/2009		
28/02/2009	HM					
23/04/2009	HM	23/03/2009	MANFCTD		24/04/2009	6/05/2009
24/05/2009	HM			24/05/2009		
28/08/2009	HM			28/08/2009		
5/12/2009	HM	16/12/2009	WET MEAT	5/12/2009 control only		
6/02/2010	HM			6/02/2010		
21/04/2010	SE	21/04/2010	MANFCTD	21/04/2010	27/04/2010	28/07/2010
3/09/2010	SE			1/08/2010		
30/11/2010	SE	1/12/2010	MANFCTD			
17/03/2011	SE	17/03/2011	MANFCTD	17/03/2011	21/1/2011 W/D only	15/06/2011
26/06/2011	SE			26/06/2011	12/05/2011	18/7/20011
30/09/2011	HM			30/09/2011	7/06/2011	19/07/2011
2/11/2011	HM	2/12/2011	WET MEAT	2/11/2011		
23/02/2012	HM			23/02/2012		
2/04/2012	SE	2/04/2012	MANFCTD	2/04/2012	3/04/2012	3/05/2012
20/08/2012	HM			20/08/2012		4/05/2012
13/11/2012	HM	13/11/2012	WET MEAT	13/11/2012 Baited only		
8/03/2012	HM			8/03/2012		
27/05/2013	HM	27/05/2013	MANFCTD	27/05/2013	28/04/2013	22/05/2013
30/08/2013	SE			30/08/2013		
2/11/2013	HM	2/12/2013	WET MEAT	2/11/2013		
30/01/2014	HM			30/01/2014		
13/06/2014	HM			13/06/2014c ontrol only	4/06/2014 26/06/2014 W/D only	15/02/2014 21/02/2014 28/05/2014 3/06/2014 W/D only

APPENDIX D. Results of abortifacient disease testing in cows sampled at Innamincka

Innamincka Disease Profiles (Baited)

Cow ID	Birth Year	Jun-12	Oct-12	Apr-13	Comment	Pestivirus	Neospora	*L. hardjo*	*L. pomona*	*L. tarassovi*
773148	2010	Wet/Empty	Wet/Empty	Dry/P4	Weaned first calf	3+	POSITIVE	0	0	1600
896119	2010	-	-	Dry/P7	First Pregnancy	2+	POSITIVE	0	0	0
777559	2010	-	Dry/Full	Wet/Empty	Had first calf	>3+	Negative	0	0	100
173506	2003	-	Dry/Full	Wet/Empty	Had Calf	2+	POSITIVE	50	0	50
896584	2009	Dry/P9	Wet/Empty	Dry/P6	Weaned Calf	>3+	Negative	0	0	0
897563	2010	-	-	Wet/P4	Had first calf	2+	Negative	0	0	100
897275	2010	Dry/P7	Wet/Empty	Dry/P3	Weaned first calf	2+	POSITIVE	200	0	100
587873	2005	Dry/P7	-	Dry/P6	Ambiguous	>3+	Negative	0	0	0
846585	2010	Dry/Empty	-	Dry/P8	First Pregnancy	3+	Negative	0	0	400
896640	2010	Dry/P9	Wet/Empty	Wet/P7	Had first calf	2+	Negative	200	0	50
643107	2003	Dry/P9	Wet/Empty	Wet/Empty	Had calf	3+	Negative	0	0	0
314501	2009	Dry/P9	Wet/Empty	Wet/P6	Had calf	Negative	Negative	0	0	100
773010	2010	-	Wet/Empty	Wet/P6	Had first calf	3+	Negative	0	0	100
809735	2005	Dry/P7	Wet/Empty	Wet/P5	Had calf	3+	Negative	0	0	0
896616	2010	-	Dry/Full	Wet/Empty	Had first calf	2+	POSITIVE	400	0	0
262274	2004	Dry/P6	Wet/Empty	Wet/P6	Had calf	3+	POSITIVE	200	0	0
575473	2010	Dry/P3	-	Dry/P7	Lost first pregnancy/calf	>3+	Negative	0	0	1600
767844	2010	Dry/Empty	-	Dry/P7	First Pregnancy	2+	POSITIVE	0	0	0
833711	2004	Wet/Empty	Dry/Full	Wet/Empty	Had calf	2+	Negative	0	0	0
942518	2010	Dry/P5	-	Wet/Empty	Had first calf	3+	Negative	0	50	400

Innamincka Disease Profiles (Unbaited)

Animal ID	Birth Year	Jun-12	Oct-12	Mar-13	Comment	Pestivirus	*Neospora*	*L. hardjo*	*L. pomona*	*L. tarassovi*
5110950	2009	Wet/Empty	Wet/Empty	Wet/Empty	Weaned first calf	2+	Negative	0	50	0
1896511	2009	Wet/Empty	Wet/P3	Wet/Empty	Had calf	2+	Negative	0	200	0
36774253	2007	Dry/Full	Dry/P8	Wet/Empty	Had Calf	3+	Negative	100	0	0
1897596	2010	Dry/P6	Wet/Empty	Dry/P4	Weaned first calf	> 3+	Negative	100	0	0
7147516	2003	-	-	Wet/Empty	Had Calf	2+	Negative	400	0	0
2990089	2007	Wet/Empty	Wet/P6	Wet/Empty	Had Calf	3+	Negative	0	0	400
2964750	2007	Dry/Full	Wet/Empty	Wet/Empty	Had Calf	2+	Negative	200	0	0
4641485	2004	Dry/Full	Wet/Empty	Wet/P2	Had Calf	2+	POSITIVE	0	0	0
298335	2006	Dry/Full	Wet/Empty	Wet/P2	Had Calf	2+	Negative	800	0	0
3858975	2007	Wet/Empty	Wet/P2	Dry/P5	Weaned Calf	> 3+	Negative	200	50	50
1897306	2010	Dry/Full	Dry/P7	Dry/Empty	Lost first pregnancy/calf	2+	Negative	0	0	800
762264	2010	Wet/Empty	Dry/P3	Dry/Empty	Lost second pregnancy/calf	> 3+	Negative	0	0	800
1896356	2010	Dry/P5	Wet/Empty	Wet/Empty	Weaned first calf	2+	Negative	200	0	0
761896	2010	Dry/P4	Dry/P7	Wet/Empty	Had first calf	2+	Negative	0	50	0
773776	2010	Dry/Full	Wet/Empty	Wet/Empty	Weaned first calf	2+	Negative	1600	0	0
3016271	2011	-	-	Dry/P7	First Pregnancy	3+	Negative	0	0	0
773203	2010	Dry/Empty	Dry/P4	Dry/P4	Ambiguous	3+	Negative	0	50	0
1809715	2010	Dry/P6	Wet/Empty	Dry/P4	Had first calf	3+	Negative	0	0	200
1896151	2010	Dry/Empty	Dry/P2	Dry/P7	First Pregnancy	3+	POSITIVE	0	50	400
2657901	2010	Dry/Full	Wet/Empty	Wet/P7	Weaned first calf	3+	POSITIVE	0	0	800