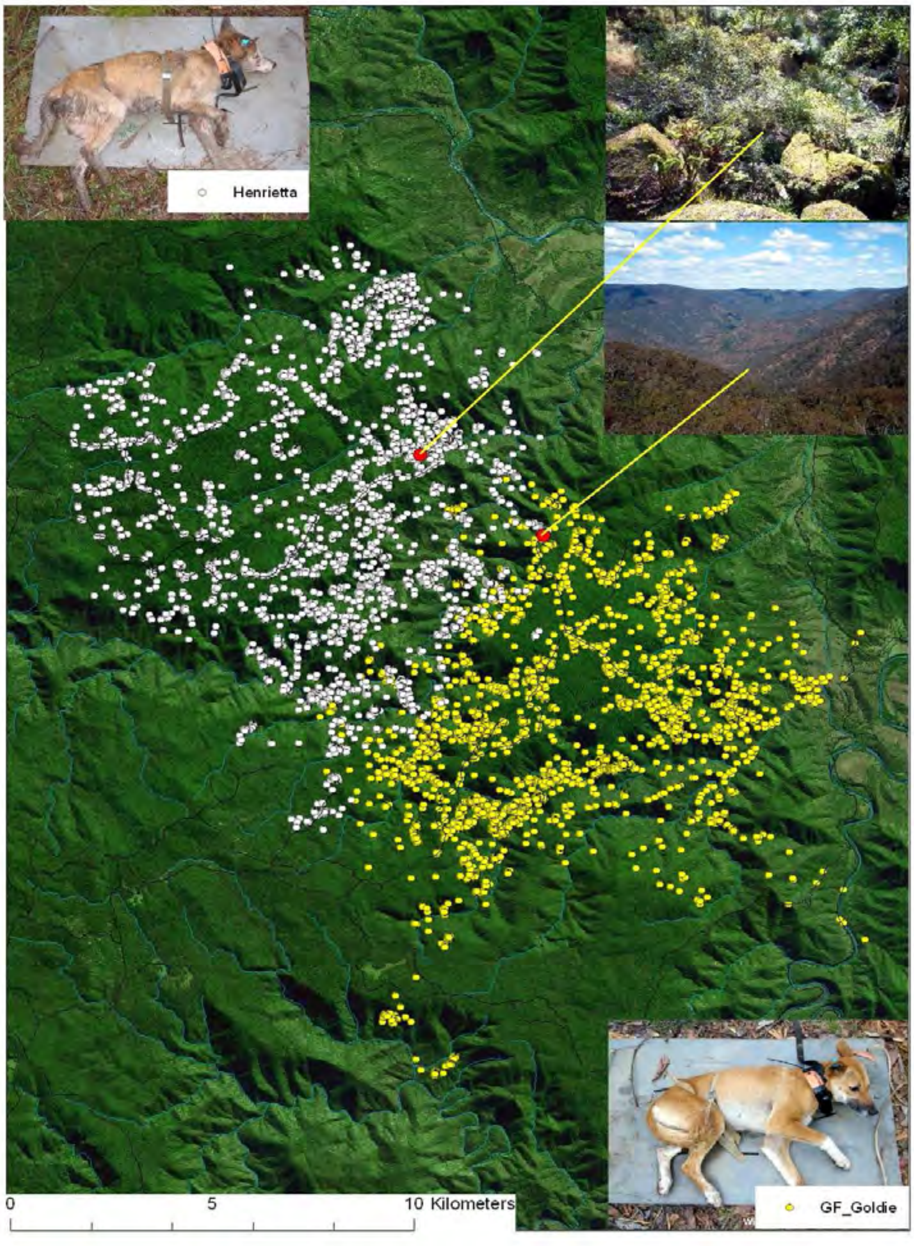
An investigation of aerial baiting rates for strategic control of wild dogs:

Final Report to Biosecurity NSW, Local Land Services and the Australian Pesticides and Veterinary Medicines Authority.



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[Cover image: GPS movement data for two collared wild dogs, indicating their point of death after aerial baiting and the terrain in which they lived: map and photos Guy Ballard]

Executive summary

This report details the outcomes of a series of trials to determine the efficacy of aerial baiting for wild dogs at two bait distribution rates, 10 baits per kilometre of flown transect and 40 baits km^{-1} and to determine if either rate achieved a minimum efficacy of 70%.

- Wild dogs cause losses to producers of livestock, particularly sheep, goats and calves.
- Aerial baiting is undertaken for strategic control of wild dog numbers in some parts of the Eastern Division of NSW.
- Two aerial bait distribution rates, 10 baits km^{-1} and 40 baits km^{-1}, are currently allowed there under permit.
- To test the mortality rate (efficacy) of both rates, 132 wild dogs were trapped prior to the annual aerial distribution of baits during 2007–2013, and fitted with tracking collars. These were later retrieved to download stored GPS movement data. Of the dogs, 117 were included in the trials, 102 were in locations where aerial baiting transects were flown and 15 in areas where aerial baiting did not occur.
- 90.6% of collared wild dogs exposed to 40 baits km^{-1} died, whereas only 55.3% of those exposed to 10 baits km^{-1} died. No unexposed dogs died during the same period.

Conclusion

Aerial baiting from helicopters to achieve strategic control of wild dogs in the Eastern Division of NSW and similar regions should be undertaken at rates approaching 40 baits km^{-1}.

Background

Where wild dogs co-occur with livestock they cause losses to agricultural production, particularly to sheep, goats and calves. Therefore, the control of wild dogs on all lands in NSW is mandated under the *Local Land Services Act 2013* (previously under the *Rural Lands Protection Act 1998*). Control is enabled through a number of technologies including aerial baiting. In eastern NSW, aerial baiting for strategic control of wild dogs involves the distribution of meat baits in inaccessible wild dog-inhabited terrain, from helicopters flown slowly at low altitudes along pre-approved transects. The objective is to place the baits as accurately as possible in locations that are chosen to maximise the opportunity for wild dogs to find and consume them. A concurrent aim is to minimise uptake by non- target animals, which otherwise reduces efficiency. While ostensibly expensive, aerial baiting is seen by proponents as a cost-efficient means of effectively reducing wild dog attacks on livestock.

Aerial baiting for control of wild dogs in north eastern NSW was first trialled in 1957-8 by the Barnard River Dingo Destruction Association, with CSIRO assistance (Barnard River Wild Dog Control Association records; B. Moore [Secretary] pers. comm. 2010). A fixed wing aircraft was used to distribute small baits containing strychnine and the results were inconclusive (F. Fenner 1958, unpublished internal report to CSIRO). Aerial baiting using matchbox-sized meat baits rolled in a solution of sodium fluoroacetate (compound 1080) (Korn and Livanos 1986) commenced across wild dog affected areas of north eastern NSW between 1964 and 1967. An average rate of 31.1 baits km^{-1} over 241 km of transect was reported for 1964 in the Yarrowitch Dingo Destruction Association (C. Young 1984, unpublished records of Yarrowitch Wild Dog Control Association).

No formal testing of different aerial baiting rates was undertaken at that time but measurements taken at two 1984 aerial drops by David Robinson and Peter Fleming of the then Department of Agriculture showed baiting rates of between 12 and 120 baits km^{-1}, with average rate of 35 baits km^{-1} over 145 km of transect on one site. The average bait densities were 20 and 35 baits km^{2} for the two sites. Following review in 1985 (Saunders *et al.* 1985, unpublished report), only helicopters were permitted for aerial baiting of wild dogs in the Eastern Division of NSW and the maximum permitted rate was 40 baits km^{-1}. The only previous test of efficacy was undertaken by Fleming *et al.* (1996) at the nominal rate of 40 baits km^{-1} (average bait rate applied in the efficacy study was 37 baits km^{-1}).

Following the release of the APVMA's 1080 Review (2008) the maximum allowable linear baiting rate for aerial application of 1080-injected meat baits for wild dog control was reduced to 10 baits km^{-1} of transect. However, the effectiveness of 10 baits km^{-1} in reducing abundance of the target species, wild dogs, and associated non-targets, red foxes (*Vulpes vulpes*), has never been tested.

Data from the Armidale Rural lands Protection Board (Harden 2005, unpublished report; Harden, Fleming, Ballard and Moore, unpublished data) shows that there is a negative relationship between the level of control (as expressed by amount of 1080 used annually for controlling wild dogs) and reported livestock attacks by wild dogs (Fig. 1).

Previous research (Fleming *et al.* 1996) showed that indices of wild dog abundance were lowered by between 69 and 85% when aerial baiting at a nominal 40 baits km^{-1} was applied in north eastern NSW sites that were typical of those baited annually. Other research (Claridge and Mills 2007; Kortner 2007) has shown that populations of non-target animals (spotted-tailed quolls, *Dasyurus maculatus maculatus*) were not adversely affected by aerial baiting at rates of 40 (or 10) baits km^{-1}.

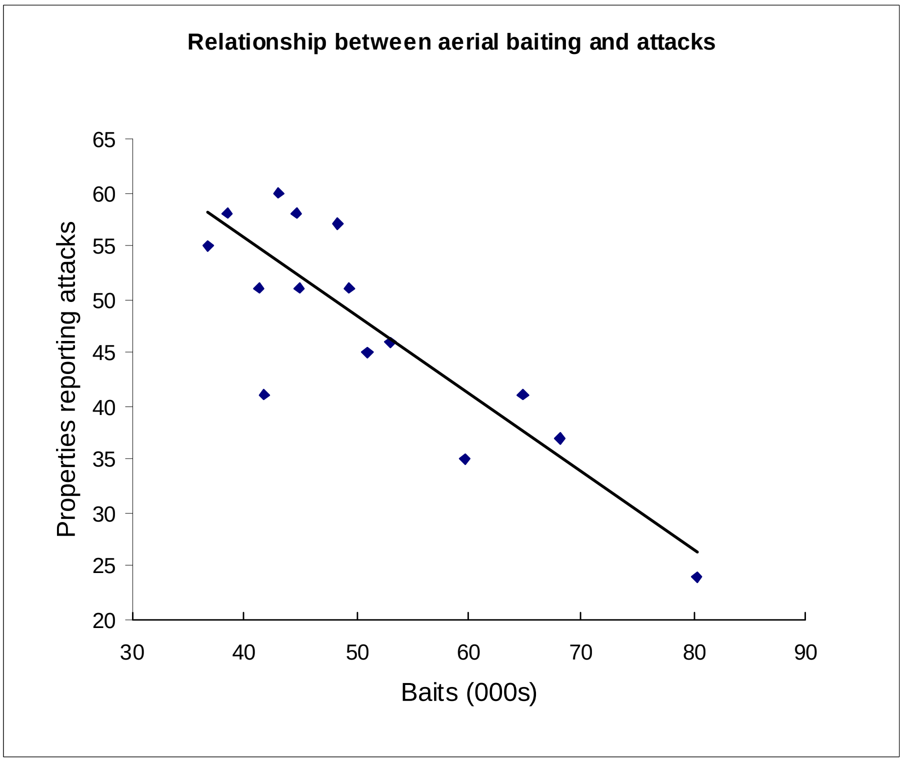

Fig.1. Relationship between quantity of aerially-distributed baits for wild dog control and the number of properties reporting attacks of livestock by wild dogs in the Armidale region between 1990 and 2005 (Data from R Harden, Brian Ferris and New England LHPA)The equation is highly significant and a good fit to the data ($y = -0.7281x + 84.863$, $P<0.001$, $r^2=0.72$).

Approaches by farmer groups to APVMA indicated that, on the basis of research and farmer experience since 1965, the higher rate of 40 baits per linear kilometre was still required and supported research to investigate the most appropriate rates. The APVMA agreed to the conduct of this research and issued an interim permit (Permit 12088) that allowed the continuation of bait rates up to and including 40 baits km^{-1}, in those Livestock Health and Pest Authority districts in New South Wales that had previously used higher rates than 10 baits per kilometre.

As a condition of AVPMA Permit 12088, research into the efficacy of bait rates was required. The Vertebrate Pest Research Unit of NSW Department of Primary Industries, after review by NSW DPI biometricians and external reviewers, proposed a wide ranging research program to determine the efficacy of a range of bait rates (10, 20, 30, 40 and 50 baits per kilometre). However, after review by AVPMA, it was agreed that the original proposal be split such that the determination the efficacy of the two aerial baiting rates approved either under the AVPMA guidelines or the special permit 12088, i.e., 10 and 40 baits per kilometre, should be undertaken as first priority, subject to funding availability. The project received funding from Australian Wool Innovation (AWI) and is the subject of this report.

Aims

The primary aim of this work was to investigate the mortality of wild dogs exposed to zero, 10 and 40 standard 1080 meat baits per kilometre of flown transect. Registration of new and existing 1080 products with APVMA has required the demonstration of ~70% reduction in known numbers of target animals, population estimates or population indices. Therefore, the second aim was to determine whether either or both of these rates achieved 70% field mortality as required by APVMA.

General Methods

Efficacy of currently permitted aerial baiting rates for wild dog control

Objective: Determine the mortality rates (efficacy) among wild dogs exposed to aerial baiting using ~250g, 1080-injected, boneless red meat baits distributed from helicopters at rates of 10 and 40 baits per kilometre of flown baiting transect. Mortality rates were to be contrasted with those of wild dogs that were not exposed to aerial baiting during the same period.

Pilot trials

Previous work in north eastern NSW (Fleming *et al.* 1996) relied on changes in indices to determine efficacy of aerial baiting. However, the relationship of the indices to real wild dog numbers was unknown so better methods were required to estimate proportional mortality.

Pilot trials undertaken between 2007 and 2010 tested the technical feasibility of using GPS/satellite/ VHF radio collars fitted to wild dogs to assess natural mortality and that caused by aerial baiting and other control methods. This technology was successful, with the fates of the majority of wild dogs being known over the period of collaring. The collar technology was therefore used as the primary aerial bait rate assessment method for the full program.

Alternative means of estimating proportional reductions in population indices, camera traps (Meek *et al.* 2012) and sandpads (e.g., Engeman 2005), were also tested for suitability in the local environments. Although well established as a means of estimating changes in abundance over short time frames, sand plots were found to be unreliable in the district because wet weather often occurred either immediately before and/or after aerial baiting, precluding their use. Camera trapping was initially proposed as an alternative indexing method, but subsequent testing with known events (Ballard *et al.* in press) showed that the detection probability of camera traps is variable and requires definition before it can be used for population estimation (this is subject of ongoing work).

The pilot trials also informed the spatial design by providing preliminary descriptions of wild dog home range size and range use, which assisted with determining the scale and locations of suitably sized sites. Importantly, the initial trials showed that the exposure of individual dogs to aerial bait lines could not be predicted by their point of capture because dog movements through their home range was not uniform and changed over time.

Experimental design elements and limitations

Total randomisation could not be achieved because of: the legal obligations of landholders to control dogs if they occur on their lands; ethical considerations about livestock welfare and the understandable reluctance of landholders to expose their sheep to attack by wild dogs; permit and policy constraints on where 40 baits per kilometre can be applied; and landscape differences within the zone where aerial baiting occurs in NSW. Therefore, a quasi-experimental design (see Hone 2007), where the treatments (0, 10 and 40 baits km^{-1}) were imposed non-randomly, but the movements of wild dogs in relation to the treatments was not pre-allocated or known. Such a design provides strong inference and is the best possible given the constraints. The limitation in interpretation is that the results can only be generalised from the study region to similar areas in south eastern Australia.

Technology required for efficacy determination

The primary source of data was GPS-logging collars affixed to free-ranging dogs that were trapped, collared and released back into their home range prior to aerial baiting. Wild dogs were captured with soft-jawed foothold traps (Orange Animal Ethics approval ORA 09/006; Fig. 2) and each one fitted with a GPS/ satellite/ VHF radiocollar manufactured to specification by SIRTRACK. The collars had release mechanisms timed to activate several months after aerial baiting and the VHF signal changed when the collar was stationary for >24 hours, indicating death of the animal or drop-off of collar.

Fig. 2. Guy Ballard photographs a wild dog, fitted with a GPS/ VHF/ ARGOS collar is held on a restraint board for handling, prior to release. Paul Meek holds a hessian sack that was used to cover the dog's head to reduce its stress during handling.

Collars regularly logged and stored GPS locations on board (either hourly or at 30 min intervals when satellite positions were optimal) and uploaded snapshot data to Argos satellites on a pre-programmed schedule (usually weekly). The VHF radio signal was used to indicate whether they were dead or alive and then to locate dogs and collars on the ground for retrieval. Argos data enabled likely dead dogs or dropped collars to be identified (from lack of movement between uploads) and the most recent points were used to direct searches for VHF signals, which are line-of sight in nature and require closer proximity (<1 km) for detection.

The individual dog provided the experimental unit and efficacy was binary, measured as the proportion of collared dogs that was exposed to baiting and subsequently died. Exposure was defined as the individual dog crossing or moving along one or more baiting transects in the two weeks immediately following the aerial baiting program. This allowed a direct comparison of mortality rate for exposed animals at the two rates, independent of overall bait density. Individual dogs were considered to be unexposed if they did not cross or walk along a baited transect during that time or, for those purposely collared where aerial baiting did not occur, for the period from the date of the first aerial baiting until two weeks after the last baiting at the sites with collared dogs. This was unavoidable but meant that the dogs that were purposely unexposed had potentially longer in which to succumb to other causes; however, none of these dogs died during that test period.

Replication was achieved by collaring more dogs. Simulations by NSW DPI biometricians using movement data and mortalities from the pilot program and reductions in index or abundance achieved in previous research (Thomson 1986; Fleming *et al.* 1996; Fleming *et al.* 2001), that is, when expected mortality rates are 50% or higher, indicated a minimum sample size of 90 collared dogs over three years (including ~15 nil-treatment animals).

Aerial baiting procedures

The treatments were applied in approved aerial baiting programs in north eastern NSW from 2007 to 2013, with major effort being invested in 2011, 2012 and 2013. Aerial baiting occurs on predetermined transects that have been mapped and approved by delegates for the Minister of Primary Industries and the Office of Environment and Heritage. Baits are prepared by cutting boneless red meat into fist-sized chunks ~250 g in size and injecting them with 6mg of 1080 in 0.2 mL of standard solution, according to the Pest Control Order for control of wild dogs and relevant permits. Baits are loaded into a helicopter and distributed along the transects with GPS direction and buffering to prevent misdistribution. Baitings monitored during these trials were conducted by local Wild Dog Control Associations, National Parks and Wildlife Service and Livestock Health and Pest Authorities. Aerial baiting transects varied between years according to management needs (the 2013 distribution is shown in Fig. 3, which also shows the location of study sites that year).

After aerial baiting, at either 10 baits km^{-1} flown or 40 baits km^{-1} flown transect, weekly data from ARGOS satellites were consulted and dogs were tracked on the ground using the VHF signal. Where GPS locations did not move between weekly updates or where the VHF collar emitting dead signals, searches for collars were made as soon as possible to retrieve collars and, when dogs were recently dead, their stomach and intestines were examined for baits or signs of the blue dye injected with the toxin, which confirmed ingestion of one or more baits. On collection of the collars, positional data were downloaded and the data mapped, as were the track logs of the baiting helicopters. The GPS data from retrieved collars were overlaid on the aerial baiting route track logs from the helicopters in GIS and those that crossed or walked along a transect within two weeks of the aerial baiting time and date were deemed to be exposed.

The proportion of dogs that were potentially exposed to baits at each rate and those that weren't exposed was determined from the maps. The mortality (and survival) of dogs exposed to the two baiting rates and unexposed dogs were then calculated.

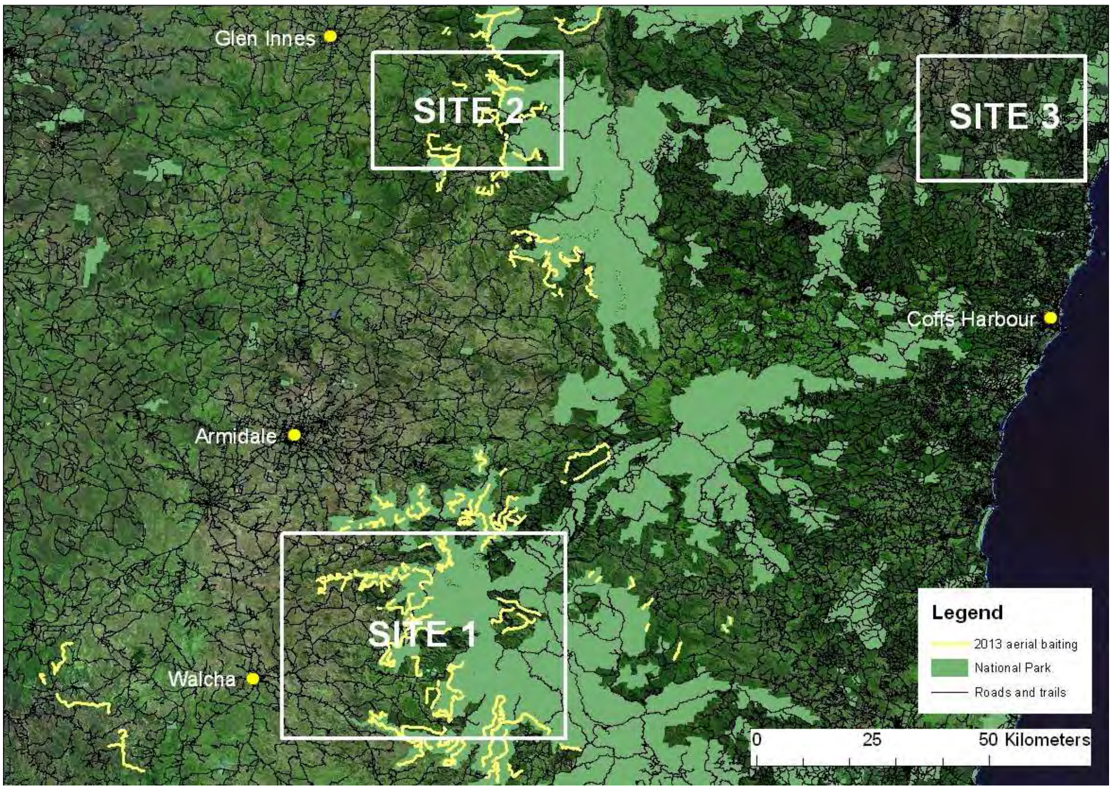

Fig. 3. Field sites where the fates of wild dogs were tracked during 2013. Aerial baiting transects undertaken by land managers are shown by the yellow lines. National Parks and Wildlife Service tenure (pale green shading) was baited at 10 baits km^{-1} and elsewhere at 40 baits km^{-1}. (Site 3 was chosen because it was well away from aerial baiting programs and assured that dogs would not be exposed).

Statistical Methods

The differences in mortality of wild dogs exposed to each rate and the nil-treatment animals were contrasted. Because the variance across samples was likely heterogeneous, Welch's t-tests (Welch 1947), which uses unpooled variance and degrees of freedom calculated with the Welch-Satterthwaite equation, were used to contrast mortality differences between the two aerial bait rates and the unbaited control. It was logical to expect a greater mortality from the higher aerial baiting rate, implying one-tailed tests were appropriate, but both treatments were expected to kill dogs so the direction of potential difference from the nil-treatment was negative for both. The baiting rate of 10 baits km^{-1} could also have been equally as efficacious as 40 baits km^{-1}, which was one possible outcome, and so two-tailed tests were used.

Results

Trapping and sample sizes

Trapping to obtain sufficient wild dogs prior to annual aerial baiting programs was time consuming and subject to weather interruptions. For example, for assessment of aerial baiting in

2011, trapping commenced in November 2010 and for 2012 it commenced in January 2012 and in December 2012 for assessment of the 2013 aerial baiting. After perusal of GPS data for wild dogs and aerial baiting transects from 2007–2010, we included additional wild dogs to maximise replication (Tables 1 and 2).

Table 1. Sample sizes of wild dogs treated in north eastern NSW with aerial baiting at two currently permitted rates, 10 and 40 baits km^{-1}. “Lost” represents collars that were active at the time of baiting program but could not be retrieved because of VHF signal failure, ARGOS signal failure or inaccessibility of terrain.

Nil-treatment (0 baits)	**10 baits km^{-1}**	**40 baits km^{-1}**	**Lost**	**Total wild dogs**
36	38	32	11	117

Over the duration of the pilot trials and full trials, 132 wild dogs were trapped and fitted with GPS collars. Of these, some (*n* = 15) were not available for inclusion in the aerial bait rate trials because tracking did not coincide with baiting periods or because they died prior to the aerial baiting programs. These latter dogs died from natural causes or were killed by shooting trapping or ground baiting by public and private land managers. . Some collars were not recovered (Table 1), either due to equipment malfunctions or harsh environmental conditions, e.g., flash flooding in rugged gorge country. Subsequently, the minimum required sample was exceeded, with 117 wild dogs available for inclusion in the trials and all bait rates had >30 representative dogs. Individual identification of wild dogs from camera trap images at one of the sites (Site 2, Fig. 1), indicated that 90% of dogs photographed were trapped and fitted with collars in 2012. This substantial proportion led us to assume that our captured sample was representative of the populations of wild dogs in the study sites.

Aerial baiting rate efficacy

In the main trials of 2011–2013, fifteen dogs were trapped and released where they would not be exposed to aerial baiting and 102 wild dogs were trapped and released into areas where they would potentially be exposed to the aerial baiting programs in April-May. As a consequence, some wild dogs were potentially exposed to both baiting rates and some were unexposed because they were not in a baited area while viable baits were available (e.g., one moved 90 km away). However, examination of GIS data revealed that only wild dogs that were exposed to aerial baiting transects died during the assessment periods (Table 2).

Although aided by ARGOS positions and VHF signals, collar recovery took many months and required reconnaissance flights with helicopters for the remaining few each year. Every effort was made to recover collars, including the donning of a wetsuit to retrieve two collars from deep streams. Even so, 11 collars could not be recovered because of release failure, VHF signal failure, ARGOS upload failure, flash flooding (one collar was tracked from ARGOS data and aircraft to a gully, but a flash flood through the gully occurred before the collar could be retrieved) or inaccessibility of terrain.

Table 2. Mortality of collared wild dogs in north eastern NSW exposed to aerial baiting at two currently permitted rates, 10 and 40 baits km^{-1}, by cohort. “Lost” represents collars were active at the time of baiting program but could not be retrieved because of equipment failure or inaccessibility of terrain.

Cohort	n (dogs)	Nil-treatment		$10km^{-1}$		$40km^{-1}$		Lost
		exposed	died	exposed	died	exposed	died	
Pre-2010	23	5	0	7	3	4	4	7
2010	16	4	0	12	8	0	0	0
2011	32	11	0	6	2	12	11	3
2012	26	9	0	4	2	12	11	1
2013	20	7	0	9	6	4	3	0
Total	117	36	0	38	21	32	29	11

The mortality of wild dogs (Table 2) did not differ between time periods for either those wild dogs exposed to 10 baits km^{-1} (χ^2= 2.75, dof= 4, not significant) or those exposed to 40 baits km^{-1}(χ^2= 1.59, dof= 3, not significant).

Table 3. Overall mortality rates and mean difference in proportional mortality from nil-treatment (*D*) for collared wild dogs in north eastern NSW exposed to aerial baiting at two currently permitted rates, 10 and 40 baits km^{-1}, during 2007-2013.

	Nil-treatment (0 baits)	$10km^{-1}$	$40km^{-1}$	Welsh's *t*	*P*, v
Overall mortality (%)	0	55.3	90.6	–	–
Mean *D* (95% CI)	–	0.52 (0.18)	0.90 (0.17)	4.478	0.004, 6.95

Overall, aerial baiting at 10 baits km^{-1} did not achieve the APVMA requisite 70% mortality, and the highest annual mortality recorded was 2/3 of the collared dogs. However, ~90% of wild dogs fitted with collars and exposed to 40 baits km^{-1} were killed (Tables 2 and 3).

The efficacy of aerial baiting conducted at 40 baits km^{-1} was highly significantly greater than that achieved with 10 baits km^{-1} (Table 3).

Discussion

With the exception of 2011, when only 4 dogs were exposed to aerial baiting at 40 baits km^{-1} (Table 2), neither aerial bait rate killed all collared wild dogs that were exposed to aerially baited transects. Baiting at 40 baits km^{-1} was most reliable and efficacious, always achieving a proportional mortality of > 0.7 and achieving overall efficacy >0.9. This was better than baiting at 10 baits km^{-1}, which never achieved a proportional mortality of 0.7, instead killing just over half of the dogs exposed to it. Overall, the efficacy of the 10km^{-1} rate was unacceptably low for a strategic technique and cannot be considered as "control".

There are a number of likely reasons for lower efficacy of aerial baiting at 10 baits km^{-1}. There is considerable competition for baits in the region from conspecifics, red foxes and feral pigs, and to some degree feral cats and this must be accounted for when deciding on bait quantities, transect routes and baiting rates. Some dogs, both from 10 and 40 baits km^{-1} sites, were recovered with multiple (2–11) baits in their stomach Some contemporaneous studies (Ballard and Fleming, unpublished data) indicate that foxes and birds, particularly corvids, can consume up to 100% of baits intended for dogs. Despite birds being unaffected (McIlroy 1986), this has obvious and significant implications on effectiveness for aerial baiting programs for wild dogs. To maximise the efficacy of control programs, baiting rates, overall bait quantity and transect routes must account for baits that will be consumed by target animals, by other affected vertebrate pests and by unaffected corvids and feral pigs

Fleming *et al.* (1996) showed that wild dog population indices returned to parity between baitings and that repopulation was observed to be both by recruitment and immigration. In the current trials, we observed both pups and new animals on camera following baiting each year, indicating that populations were not extirpated from the region. Populations of wild dogs at treatment sites have been exposed to aerial baiting rates and on-ground control for >45 years but current and past control has not eradicated wild dogs. As well as immigration from adjacent unbaited areas, or otherwise relatively under-controlled areas, survivors at treated sites ensure wild dog populations persist. In fact, consistent social patterns observed in some groups of dogs, via camera traps, suggested that some individuals would always be at relatively low risk of exposure from annual baiting events, because they consistently walked behind their conspecifics along trails. The lower mortality achieved at the 10 baits km^{-1} rate has resulted in a patchwork of treatment efficacies and remaining wild dog population sizes in the controlled region. It is likely that current livestock predation problems (New England Livestock Health and Pests Authority, unpublished predation records 2011–2013) are in part caused by changes in land tenure and policy application since 1987, as well as reduced aerial baiting efficacy in lands where a maximum of 10 baits km^{-1} has been mandated. Other factors such as enterprise substitution and change in agricultural land use have also likely affected control efficiency and distribution, in turn increasing the likelihood of wild dog predation, particularly to small livestock.

Spotted tailed quolls persist in the study area (24 individuals were captured and released at one of the wild dog study sites in autumn and winter of 2013 in a concurrent project) and it is likely that the population benefited from reductions in wild dog, red fox and feral cat numbers from the aerial baiting

Conclusions and recommendations

To achieve efficacious control of wild dogs, aerial baiting from helicopters in the Eastern Division of NSW and similar regions elsewhere should be undertaken at a rate up to and including 40 baits km^{-1}.

In eastern NSW, aerial baiting of wild dogs on public lands had been restricted by policy to 10 baits km^{-1} since about 1987, but, except for the expressed desire to minimise potential risks to non-target species, the justification for this arbitrary rate has not been articulated. Our series of trials has shown that aerial baiting at 10 baits km^{-1} is insufficient to achieve an efficacy of 70%. At an overall proportional mortality of 0.55, the 10 baits km^{-1} rate would be insufficient for the registration of a new pesticide and is unlikely to substantially reduce the risk of incursion of wild dogs into neighbouring livestock production areas.

These findings, coupled with extensive research on baiting effects on spotted tailed quoll populations by NSW National Parks and Wildlife Service researchers (Claridge and Mills 2007; Körtner 2007), indicate that using a rate of 10 baits km^{-1} for strategic wild dog control is unsupportable given the evidence and that the policy should be updated to allow baiting at 40 baits km^{-1} .

Aerial baiting programs in eastern NSW are designed to prevent or minimise incursions of wild dogs into livestock production areas from forested and wooded lands. Because the cost of wild dog predation cannot be predicted from wild dog abundance (Fleming *et al.* In press), the objective of wild dog control must be to reduce populations adjacent to livestock production areas to as low as possible so that the probability of incursion is similarly reduced. Therefore, it is not justifiable to purposefully engage in control programs that cannot achieve desired efficacy because wild dogs will die with limited benefit. Additionally, an increase to 40 baits km^{-1} would significantly improve efficacy with only slight increases in cost (Smith and Fleming 2010).

The results of our trials indicate that aerial baiting in the Eastern Division of NSW and in similar regions should be undertaken at rates above 10 baits km^{-1} to achieve efficacies above 0.7. However, our trials were constrained by the currently permitted rates, which restricts the conclusions to the efficacies of only those rates. Because we were not supported to measure efficacy at rates between $10km^{-1}$ and $40km^{-1}$, we cannot determine at what bait rate mortalities of 0.7 were achieved, nor the shape of a response curve describing efficacy. Therefore, we must pragmatically conclude that to obtain substantial reduction in wild dog numbers that will reduce the probability of wild dogs entering livestock production areas adjacent to treatment areas requires aerial baiting rates of about 40 baits km^{-1}.

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