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Wildlife Research, 2004, **31**, 639–644

Potential impact of aerial baiting for wild dogs on a population of spotted-tailed quolls (*Dasyurus maculatus*)

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Abstract. The spotted-tailed quoll (*Dasyurus maculatus*) is a threatened marsupial that inhabits forests in eastern Australia. In many of these forests the species is sympatric with populations of wild dogs (*Canis lupus dingo*, *Canis familiaris* and hybrids of the two), which are subject to poison-baiting programs. Many of these programs involve dropping meat baits injected with 6 mg of 1080 from helicopters. To date, the effect of this method on populations of spotted-tailed quolls has not been quantified. We carried out a simulated aerial baiting program using meat baits injected with a non-toxic baitmarker, Rhodamine B, which is laid down in the vibrissae of mammals ingesting baits. Of the 16 spotted-tailed quolls subsequently captured, 10 had Rhodamine B in their vibrissae. The potential impact that this level of bait uptake might have on a population of quolls is discussed.

Introduction

The spotted-tailed quoll (*Dasyurus maculatus*) is a threatened marsupial carnivore confined to forested habitats in south-eastern Australia and Tasmania (Mansergh 1984). It is the largest extant dasyurid in mainland Australia (Settle 1978) and the only surviving species of *Dasyurus* in south-eastern mainland Australia (Jones *et al*. 2003). The species has suffered a decline, both in distribution and abundance (Mansergh 1984). Several factors have been implicated in this decline, including loss and fragmentation of habitat (Mansergh 1984; Maxwell *et al*. 1996), competition with introduced predators (Fleay 1932; Mansergh 1984; Mansergh and Belcher 1992; Watt 1993), and the direct persecution of quolls (Fleay 1948; Rolls 1969). In addition, several authors (Wood-Jones 1923; Fleay 1932; Troughton 1962; Wakefield 1967; Caughley 1980) have discussed the possibility that during the first quarter of the 20th century an epidemic disease devastated populations of the larger marsupial carnivores.

With legal protection, a decline in the rural human population, improvements in the manner in which poultry is housed, and greater community sensitivity towards native wildlife, it is likely that the risk to quolls posed by intentional persecution has declined. However, quolls may still be at risk from baiting programs for feral predators that fail to take the risk posed to non-target species into account. Aspects of these baiting programs that could put quolls at risk include: the amount of poison (1080) contained within baits, the type of bait used, the method by which baits are deployed, the habitat in which baits are deployed, and the intensity of baiting.

Although spotted-tailed quolls are adept at hunting and killing prey (Fleay 1948; Troughton 1962; Settle 1978), like many carnivorous species they will also scavenge for food (Fleay 1948; Sharland 1963; Belcher 1995; Mansergh 1995). The suggestion that quolls could be attracted to large meat baits that are used to poison wild dogs (*Canis familiaris*) and dingoes (*Canis lupus dingo*) has been made by several authors (Rolls 1969; Breckwoldt 1984). In this paper we use the nomenclature used by Fleming *et al*. (2001) with reference to 'wild dogs', meaning all wild-living dogs, including dingoes and their hybrids.

Aerial baiting, in which poison meat baits are deployed from helicopters, is widely used for wild-dog control in the forested freehold areas encompassed by the Cooma, Bombala and the Braidwood Rural Lands Protection Boards (RLPBs) in south-eastern New South Wales. The method is considered an important component of wild-dog control in the areas encompassed by these boards. Many other RLPBs, in both the north-east of New South Wales (in areas inhabited by spotted-tailed quolls), as well as in more arid areas in the west of the State (which lack suitable forest to support populations of spotted-tailed quolls), also carry out similar aerial baiting programs.

There has been little research into the effects of aerial baiting on rare or cryptic non-target species (McIlroy 1992). As McIlroy (1992) points out, one of the critical reasons that few field studies have investigated the impact of 1080-poisoning program on animal populations is the difficulty in obtaining sufficient data to evaluate the effects of such programs due to the low population density of many potentially affected native species. The few field studies in mountain forest areas of south-eastern Australia that have been published suggest that poisoning campaigns carried out to control dingoes with unburied baits had no significant effect on populations of reasonably common small mammals and birds (McIlroy 1982, 1992; McIlroy *et al*. 1986).

10.1071/WR03067 1035-3712/04/060639

The impact of aerial baiting on two other species of *Dasyurus* has been investigated in Western Australia. King (1989) attempted to determine the hazard posed to the northern quoll (*D. hallucatus*), by aerial baiting. Approximately 1000 air-dried meat baits (average weight of 26.2 ± 9.2 g) injected with 6 mg of 1080 were dropped at a variable rate along the dry creek bed of the Fortescue River and its tributaries, for a total flight length of ~54 km. Eight quolls that had been radio-collared before baiting were still alive for at least 12 days after baits had been laid. *D. hallucatus* is most abundant in broken rocky country and in open eucalypt forest (Braithwaite and Begg 1995). Oakwood (2000) found that of the *D. hallucatus* deaths that could be attributed to predators (dogs and cats), most occurred in open areas where there was little vegetative cover. It could therefore be assumed that the baits were dropped into a habitat not frequently used by the quolls, thereby reducing the risk of poisoning.

In a study in forest in south-western Western Australia, Morris *et al*. (1995) captured and radio-tracked ten western quolls (*D. geoffroii*), for a period of 12 months, during which four baiting sessions took place. This study used 40–60-g dried meat baits injected with 4.5 mg of 1080. None of the radio-tracked quolls died as a result of 1080 poisoning during the 12 months study.

An important first step in determining the risk that this baiting method poses to *D. maculatus* was to investigate what percentage of a population of quolls was capable of locating and consuming aerially deployed meat baits, using a non-lethal method.

Methods

Study site

The project was carried out in the southern part of Tallaganda State Forest (State Forest No. 577), and the northern section of the Badja State Forest (State Forest No. 567), in south-eastern New South Wales. The southern end of the study site (36°05′S, 149°35′E) is ~45 km north-east of the township of Cooma. The northern end of the study site (35°40′S, 149°33′E) is ~60 km south-east of Canberra. The study site was chosen because it was known to support a locally abundant population of spotted-tailed quolls (Belcher 2003; Belcher and Darrant 2004).

Tallaganda State Forest lies on the Great Dividing Range, and is a band of forest, ~60 km long in a north–south direction and no more than 10 km wide (and often much narrower) from east to west. It is bounded by cleared land to the west, north and east. To the south, Tallaganda State Forest is connected to Badja State Forest, and to Deua and Wadbilliga National Parks, which cover 80000 ha and 76400 ha, respectively.

The vegetation on the study site is tableland forest, growing at elevations of 900–1300 m above sea level. White ash (*Eucalyptus fraxinoides*) and brown barrel (*E. fastigata*) are the more common tree species occurring in the area. The understorey tends to be shrubby on the lower slopes, but can be relatively open on the upper slopes. The riparian gullies tend to have an overstorey of brown barrel or manna gums (*E. viminalis*) with an understorey of tree and ground ferns.

The area receives an annual rainfall of 900–1100 mm. Winters are cool to cold, with regular winter rain and occasional snow falls. Summers are mild to hot, and fogs and rainfall occur regularly during this season as a result of the uplift of moist coastal air (Anon. 1995).

Baiting methodology

Baits containing a non-toxic dye were used to determine what percentage of a population of spotted-tailed quolls had located and consumed aerially deployed baits. The dye, Rhodamine B, mixed in solution, was injected into meat baits. When ingested, Rhodamine B results in systemic marking in animal hair (Fisher 1999). When the hair of an animal that has ingested Rhodamine B is examined under ultraviolet light, the dye usually appears as a band of extremely bright orange fluorescence, but may also have a yellowish or reddish appearance (Fisher 1998). The fluorescence is seen most easily and consistently in vibrissae. Unmarked vibrissae appear as an outline or a shadow against the background, whereas the bright fluorescence of a Rhodamine B band may be so bright that it produces a ‘white-hot’ or ‘halo’ appearance (Fisher 1998).

Rhodamine B was obtained in powder form, and mixed with water to create a solution. A dosage rate of 10 mg per kilogram of animal weight was used, which was regarded as sufficient to mark vibrissae. In order to ensure that spotted-tailed quolls weighing up to 5 kg were marked, 50 mg of Rhodamine B powder was dissolved into 1 mL of water. This solution was injected into fresh kangaroo meat baits weighing 200–250 g which were allowed to air-dry for two days

Following the period of air-drying, the baits were dropped from a helicopter on 20 July 1999, along a 30-km transect (Fig. 1), from near Pikes Saddle in the south (36°00′S, 149°33′E) to near Round Mount in the north (35°40′S, 149°31′E). Approximately 40 baits were dropped per kilometre. This baiting intensity replicated that of a routine aerial baiting program undertaken by the Braidwood, Bombala and Cooma RLPBs. The transect chosen mirrored closely the flight path used for annual aerial baiting programs undertaken in Tallaganda State Forest by

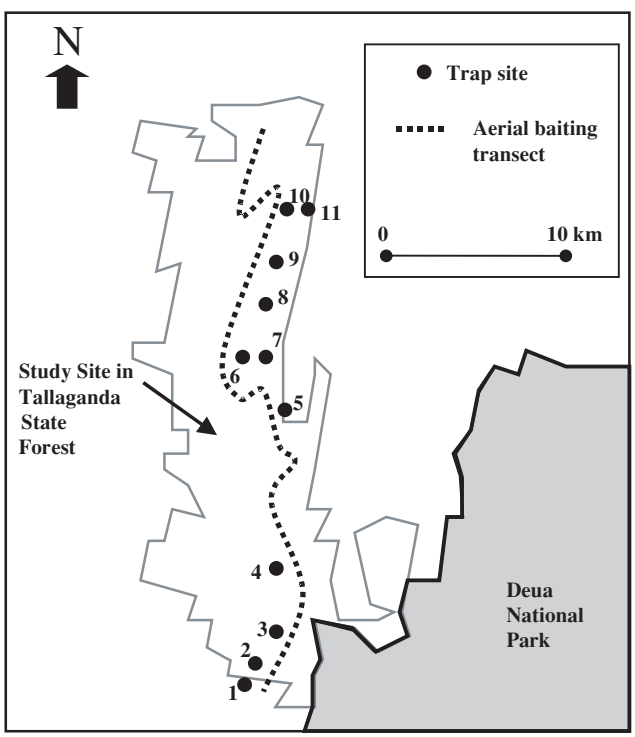

Fig. 1. The study site in Tallaganda State Forest, indicating the flight path of the aerial baiting transect, and the location of spotted-tailed quoll trap sites.

the Braidwood RLPB between 1982 and 1996. The program was carried out during winter, which is when most baiting programs are routinely undertaken.

Post-baiting trapping

Trapping for spotted-tailed quolls commenced three weeks after the aerial baiting program was carried out. Trapping was carried out each night for 11 nights (11–22 August 1999). All traps were closed on 14 August 1999 owing to an impending snowstorm but were reopened the following morning once the weather conditions had improved.

Twenty-eight wire cage traps baited with raw chicken were used at 11 sites (Fig. 1). Most traps were placed in gullies and along creek lines. The only exception was Trapsite 8, which comprised two traps set on a rocky outcrop.

All spotted-tailed quolls captured were weighed, their sexual status determined, and the pouches of females were inspected for the presence of young. Upon first capture each quoll was sedated with Zoletil (dose rate of 5 mg per kilogram of bodyweight). Under sedation each quoll was microchipped (Trovan ID-100 passive integrated transponder microchips) to allow subsequent identification, and eight mystacial or genal vibrissae were plucked with tweezers, following the guidelines of Fisher (1998). Following the removal of the whiskers, each quoll was returned to the cage in which it was captured, along with more chicken, and left for at least 2 h to recover. When fully recovered, each individual was released at the point of capture. Once plucked, the eight whiskers from each animal sampled were stored in an individual resealable plastic bag. All quolls were scanned with a multireader scanner upon capture, and those quolls that had previously been captured and processed were weighed and immediately released.

Analysis of the vibrissae

Each of the vibrissae collected were permanently mounted on standard laboratory slides and were inspected for the presence of Rhodamine B fluorescence, as described in Fisher (1998).

Results

Post-baiting trapping results

Sixteen spotted-tailed quolls – seven females (four with pouch young) and nine males – were captured on 40 occasions during the 11 nights of trapping (Table 1).

Results of the vibrissae analysis

The analysis of the vibrissae indicated that 10 of the 16 captured spotted-tailed quolls had consumed one or more baits injected with Rhodamine B (Table 1). There was no significant difference in the proportion of male and female quolls marked, with six of nine males and four of seven females being marked ($\chi^2 = 0.04$, d.f. = 1, $P = 0.851$).

Analysis of the vibrissae indicated that three quolls appeared to have consumed several baits (because multiple bands of Rhodamine B were seen). Of the three quolls captured during this study that exhibited multiple banding in their vibrissae, one appeared to have consumed two baits, a second appeared to have eaten three baits, and a third had eaten 3–5 baits.

Three of the four females captured that had young had consumed Rhodamine B-injected baits.

Discussion

Exposure to bait

The results of this study provide the first quantifiable evidence that spotted-tailed quolls are capable of locating and consuming meat baits deployed from aircraft as part of a wild-dog control program. Analysis of the vibrissae found that 62.5% of the quoll population we sampled had eaten Rhodamine B-injected baits. The high proportion (75%) of female quolls carrying pouch young that were found to have eaten Rhodamine B baits was a significant result, given that this component of the population is critical in the ongoing survival of the species at a local level.

The high percentage of spotted-tailed quolls that had located and consumed Rhodamine B-injected baits during this study is not surprising given the diet of the species. Spotted-tailed quolls appear to be dependent upon their olfactory sense to locate food (Green and Scarborough

Table 1. Details concerning individual *Dasyurus maculatus* captured during the 11 nights of trapping in the Tallaganda State Forest study site

Sex	Weight (kg)	Capture date	Trap site	Marking of vibrissae	Notes
Female	1.9	11.viii.1999	1	Not marked	6 pouch young
Female	1.0	12.viii.1999	10	Not marked	
Male	2	13.viii.1999	1	Single band, indicating one uptake	
Female	2	13.viii.1999	4	Single band, indicating one uptake	6 pouch young
Female	0.95	13.viii.1999	7	Not marked	
Female	1.6	13.viii.1999	10	Two uptakes close together	
Male	3.3	13.viii.1999	10	Not marked	
Male	3	14.viii.1999	6	Single band, indicating one uptake	
Female	1.5	16.viii.1999	8	Single band, indicating one uptake	5 pouch young
Female	1.1	18.viii.1999	8	Multiple uptakes, possibly up to five	4 pouch young
Male	3	19.viii.1999	8	Single band, indicating one uptake	
Male	2.9	20.viii.1999	3	Single band, indicating one uptake	
Male	2	20.viii.1999	6	Not marked	
Male	2.5	20.viii.1999	10	Single band, indicating one uptake	
Male	2.7	21.viii.1999	8	Three uptakes indicated	
Male	1.4	22.viii.1999	7	Not marked	

1990), which is how they are most likely able to locate the meat baits. Like many carnivorous mammals, *D. maculatus* will readily consume carrion (Belcher 1995).

While our results unequivocally demonstrate that quolls are 'exposed' to baits during routine aerial baiting programs, they do not provide an indication of the impact that this method of baiting would have on the quoll population. The LD_{50} (the amount of poison required in each bait to kill 50% of the population) for spotted-tailed quolls to 1080 is ~1.85 mg kg^{-1} (McIlroy 1981, 1986). Baits used to poison wild dogs in New South Wales are routinely injected with 6 mg of 1080, which would theoretically be enough to kill quolls weighing up to 3.2 kg. During this study, all of the 10 quolls that had ingested marked baits weighed less than 3 kg, with all of the female quolls weighing 2 kg or less. It is theoretically possible, therefore, that, of the quolls that had eaten marked baits during this study, over 50% of the animals would have died had the baits been injected with 1080, assuming that they had consumed the entire bait

One factor that may reduce the impact that baiting may have on the quoll population is the possibility of quolls ingesting a sublethal dose of 1080 as a result of consuming baits within which the 1080 has leached out or deteriorated. McIlroy *et al*. (1988) investigated the effect of rainfall and blowfly larvae on the toxicity of 1080 meat baits. They determined that in winter deployed baits would still retain an LD_{50} for an 'average' (2.8 kg) quoll for 4–15 days. Fleming and Parker (1991) also found that fresh meat baits (mean weight of 245.3 g) injected with 5.3 mg of 1080 and placed in the field for 20 days still retained a mean amount of 1080 of 3.4 mg (n = 10, range = 1.5–6.5 mg). Theoretically, this is enough 1080 to kill 50% of quolls weighing up to 1.84 kg. In the current study, this would have included five of the seven females captured. While leaching and deterioration of 1080 do occur in baits once they have been deployed, it is unlikely that, had this been a baiting program using baits injected with 1080, that quolls would have received a sublethal dose. This conclusion is made given the relatively short interval between bait deployment and trapping in this study (22 days), which included enough time for Rhodamine to have been laid down and become visible in vibrissae.

History of baiting in Tallaganda/Badja

Aerial baiting methods vary between agencies, especially in regard to the number of baits deployed per kilometre of flight transect. The New South Wales National Parks and Wildlife Service, for example, employs a relatively low baiting intensity of 4 baits dropped per kilometre, often using horsemeat or beef (J. McIlroy, Wildlife Consultant, Akaroa, New Zealand, personal communication). For the purposes of this project, it was considered appropriate to adopt the methods preferred by the Braidwood RLPB (40 baits per kilometre) to bait the study site, as it was likely to present a 'worst case' scenario for the quoll population.

The Braidwood RLPB has carried out aerial baiting programs annually in Tallaganda State Forest for at least 16 years (Phil McGrath, Braidwood RLPB, personal communication) until 1996. In 1997 and 1998 the aerial baiting effort was confined to the freehold land bordering the eastern side of the State Forest, while within the State Forest feral predators were poisoned using baits buried in mounds of soil (Phil McGrath, Braidwood RLPB, personal communication). Given the results of this study, it may appear contradictory that such a relatively large and trappable spotted-tailed quoll population exists in an area that has been systematically aerially baited for at least the last 15 years. While it is possible that a significant proportion of the quoll population has been poisoned in each year that the area was baited, the results of this study suggest that some resident quolls may not encounter baits, or that they may not consume such baits when they are encountered. Deua and Wadbilliga National Parks border the study area, and collectively comprise 150 000 ha of forest. These National Parks are known to support spotted-tailed quolls (Atlas of New South Wales Wildlife). Neither park is aerially baited; however, strategic ground-based wild-dog control programs have been carried out in both parks for several years, primarily in areas of park adjoining private land (Preston Copes, National Parks and Wildlife Service, Narooma, personal communication). Given the high level of connectivity between these areas and Tallaganda State Forest, it is possible that young quolls disperse into Tallaganda State Forest from the adjoining National Parks during summer to supplement the quoll population that survived the poisoning campaign carried out the previous winter. The post-weaning dispersal behaviour of young spotted-tailed quolls is not well known. However, it is likely that suitable vacant habitat (brought about by the aerial baiting program) would be reoccupied by young quolls looking to establish their own territory.

The impact of aerial baiting on a population of spotted-tailed quolls in the longer term probably depends on several factors. The size of the quoll population will be important, as it could be assumed that a larger population is more likely to recover from a baiting event than a smaller population. The size of the inhabited area that is aerially baited will also be important. If a significant area of unbaited forest that supports quolls lies adjacent to the area that is baited it seems reasonable that the baited area is more likely to be reoccupied by dispersing juvenile quolls compared with an isolated area of forest that is baited in its entirety.

The interval between baiting sessions will also influence the potential for a quoll population to recover. In many areas, an annual baiting program may be sufficient to produce localised extinctions of quolls, and prevent reoccupation by dispersing young. Finally, the impact of an aerial baiting program may exacerbate other threatening processes operating upon a quoll population (habitat fragmentation, inappropriate or high-intensity fire regimes and competition with

introduced predators), thereby preventing or inhibiting the recovery of the species.

Canid control in forested habitats

Canid control in forested habitats will continue to be an important activity for both the protection of domestic stock and for wildlife conservation. While baiting programs are the most effective and efficient method of controlling both red foxes (*Vulpes vulpes*) (Saunders *et al*. 1995) and wild dogs (Fleming *et al*. 2001), techniques that minimise the risk to non-target species such as the spotted-tailed quolls should be adopted. In eastern Australia, burying baits successfully targets canids while minimising the risk to non-target species (Saunders *et al*. 1995; Fleming *et al*. 2001). The existence of a population of quolls in an area should not be seen as a reason or excuse to not undertake baiting programs, particularly those that target foxes. It is possible that quolls suffer from direct predation and competitive killing by canids, as well as competition for prey (Edgar and Belcher 1995; Dickman 1996; Maxwell *et al*. 1996), so it is likely, therefore, that quolls would benefit from the reduction in fox numbers.

Conclusions

Aerial baiting at the intensity undertaken in this study in south-eastern New South Wales created a situation whereby a substantial percentage (62.5%) of the resident spotted-tailed quolls consumed marked baits. In our study, animals of both sexes consumed baits, with high rates of bait consumption by reproductive females. The results of this study suggest that aerial baiting has the potential to seriously impact on populations of spotted-tailed quolls in south-eastern Australia.

Acknowledgments

David Fairbridge (Vertebrate Pest Research Department, Victorian Institute of Animal Science) provided the Rhodamine B in a powder form to be injected into the meat baits. Frank Busana (Vertebrate Pest Research Department, Victorian Institute of Animal Science) provided additional information concerning the application of Rhodamine B. Chris Belcher was involved in the trapping program, and Jim Darrant navigated the helicopter during the simulated aerial baiting run. Craig Mills assisted in the aerial baiting program. David Fairbridge carried out analysis of the whiskers. David Choquenot, Nick Dexter, Andrew Claridge, John McIlroy, Stephen Henry, David Fairbridge and Mike Crowley all made useful contributions to earlier drafts of this paper, as did two anonymous referees. This research was carried out under the authority of National Parks and Wildlife Service Scientific Licence No. A1571, with the authority granted under the State Forests Special Purposes Permit No. 05378, and was carried out under State Forests Ethics Committee approval. The Australian Alps Liaison Committee, the Victorian Department of Natural Resources and Environment, and the New South Wales National Parks and Wildlife Service provided funding for the study.

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Manuscript received 24 July 2003, accepted 9 July 2004