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The immediate impact of 1080 aerial baiting to control wild dogs on a spotted-tailed quoll population

Gerhard Körtner[A,B] *and Peter Watson*[A]

[A]Biodiversity, Conservation and Science Section, NSW Department of Environment and Conservation, c/- Zoology, University of New England, Armidale, NSW 2351, Australia.
[B]Corresponding author. Email: gerhard.koertner@environment.nsw.gov.au

Abstract. In eastern Australia, the spotted-tailed quoll (*Dasyurus maculatus*) is the species thought to be most likely at risk from aerial baiting with compound 1080 to control wild dogs (*Canis lupus familiaris* and *C. l. dingo*). Although it is known that quolls occasionally die of 1080 poisoning, the broader impact on populations remains unresolved. We therefore assessed the impact of a regular aerial baiting campaign on a population of spotted-tailed quolls. Baiting with 1080 meat baits was conducted by the local Wild Dog Control Association and followed the same procedure as in previous years with the exception that the biomarker, rhodamine B, was added to the baits. Prior to the baiting, 36 quolls were trapped and fitted with mortality radio-collars; 31 of these collars were still functional at the time of baiting. Quolls were monitored from a helicopter and on the ground until retrapped 5–9 weeks after baiting. Transmitters were then removed and a sample of vibrissae was taken for rhodamine B analysis. Carcasses found were analysed for 1080. Predator numbers were assessed before and after baiting using track pads across trails. Among the initial 36 radio-collared quolls, nine mortalities were recorded during the course of the study (seven after baiting). Only one of the nine deaths could be directly attributed to 1080 poisoning. In addition, vibrissae from five of the 35 individuals sampled after baiting were marked with rhodamine B, indicating that these individuals had consumed bait, and survived. Consequently, mortality attributable to this particular aerial baiting campaign was low, apparently because few quolls ate bait and most of those that did survived. Track counts for predators indicated a significant decrease in dog and fox numbers after baiting. Cat activity remained unchanged and the number of quoll tracks increased.

Introduction

Wild dogs are controlled because they can cause severe damage to the livestock industry, particularly to sheep-grazing operations. Since the 1960s, aerial distribution of baits containing sodium monofluoroacetate (compound 1080) has become an integral part of strategic wild dog (*Canis lupus familiaris* and *C. l. dingo*) control over large parts of Australia (Fleming *et al*. 2001). Procedural standardisation now restricts aerial baiting in eastern New South Wales (NSW) to the use of helicopters to improve accuracy of bait placement (Thompson *et al*. 1990). Baits are dropped at a rate of up to 40 km^{-1}. Only fresh, large boneless meat baits, weighing ~250 g are now legally permitted (EPA 2002). The intent is to protect small carnivorous vertebrates, which are not able to eat the whole bait in one meal. In NSW, 6 mg of 1080 in solution is injected per bait. Injection gives more consistent results than tumble-mixing and concentrates the toxin within the meat rather than on the bait surface, which reduces leaching and protects small animals that are likely to eat from the surface (Korn and Livanos 1986). Although these refinements may reduce the potential impact on small non-target species, they are less likely to offer protection to larger species such as the spotted-tailed quoll (*Dasyurus maculatus*), the largest marsupial carnivore on mainland Australia. To protect this threatened species the supposedly safer method of burying baits (mound baiting) is preferred practice in conservation reserves (Belcher 1998; Glen and Dickman 2003). However, this approach is not feasible in inaccessible areas. As a consequence, aerial baiting is used not only on private properties but also still on some Crown land where the ruggedness of the terrain precludes ground baiting. Thus, the debate continues regarding the potential impact of aerial baiting on quolls (Belcher 1998, 2003, 2004; Murray and Poore 2004).

Spotted-tailed quolls are medium-sized carnivores/scavengers; the average body mass of adult males is 3.0 kg and of females 1.7 kg (Belcher 1995, 2003; Edgar and Belcher 1995; Körtner *et al*. 2004). Although they are more tolerant to 1080 (LD_{50} = 1.85 mg kg^{-1}: McIlroy 1981) than canids, the nominal 6-mg dose of 1080 in fresh dog baits and 3 mg in fox baits is potentially fatal, particularly for smaller individuals such as females and juveniles. In two quoll populations in southern NSW about half the spotted-tailed quolls consumed aerially deployed non-toxic fresh meat baits laced

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with the biomarker rhodamine B (Murray and Poore 2004; A. Claridge, personal communication), whereas dried meat baits appeared to be less attractive and were consumed by 33% of the quolls (Belcher 2004). Following wild dog baiting campaigns the collection of at least three quoll carcasses with 1080 residues has been reported (Belcher 2003; P. Cremasco, personal communication). Nevertheless, quoll populations are known to persist in areas with long baiting histories (Fleming 1996), including aerial baiting (Dawson *et al*. 2003; Körtner *et al*. 2004; Murray and Poore 2004). It also appears that the closely related but more 1080-tolerant northern (*D. hallucatus*) and western (*D. geoffroii*) quolls are not susceptible to aerial baiting: following aerial baiting no mortalities among radio-collared individuals were detected for either species (King 1989; King *et al*. 1989; Morris *et al*. 1995). Moreover, regurgitating parts of the bait in response to the ingestion of 1080 is common in carnivorous mammals (McIlroy 1981) and innate or developed 1080 bait avoidance, as for example observed in the small dasyurid *Sminthopsis crassicaudata*, can also occur (Sinclair and Bird 1984). Such a demonstrated ability of some species to detect and avoid 1080 baits thus cautions against extrapolating results derived from simulated (i.e. non-toxic) baiting trials to the use of toxic baits.

The aim of this study was to assess the immediate impact of aerial baiting with 1080 to control wild dogs on a spotted-tailed quoll population. Because of the potential for the absence of poison to affect the outcome of simulation trials, it was necessary to study a quoll population subjected to actual toxic baiting. However, to prevent any unnecessary additional quoll mortalities, the experiment was carried out in conjunction with a routine annual baiting campaign conducted by the Wild Dog Control Associations and Rural Land Protection Boards and no additional bait was dropped.

Material and methods

Study area

The study was conducted on the southern New England Tablelands of NSW (31°30′S, 151°30′E) (Fig. 1) and encompassed parts of Tuggolo State Forest (SF), Nowendoc National Park (NP) and several adjoining private properties. The core area comprised two north–south ridges running either side of Stockyard Creek. This and the adjoining creeks have incised steep-sided gullies and at the southern end of the study

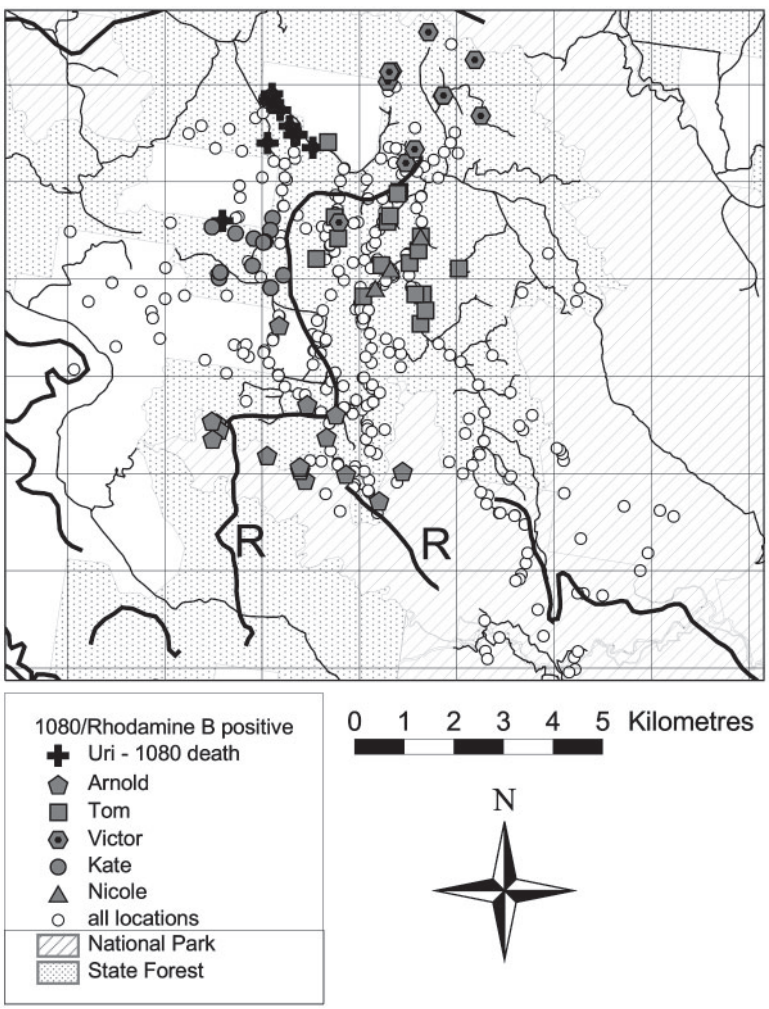

Fig. 1. Map of the study area, Tuggolo SF and Nowendoc NP, north-eastern NSW (2-km grid). Bait runs (solid lines) marked with an 'R' were those where rhodamine B was added to the baits. Quoll location records for quolls are illustrated as circles and animals that had consumed bait (1080- or rhodamine B-positive) are shown with individual symbols. Tracks are depicted as thin lines.

area the vertical relief exceeds 400 m. Vegetation ranges from rainforest in the steep south-eastern gullies to wet and dry sclerophyll forest to cleared or semi-cleared areas on private properties and recently logged compartments. Similarly, the understorey ranges from dense vine thickets and shrubs to open grassland.

Trapping and radio-tracking

Extensive trapping for spotted-tailed quolls was conducted for five weeks before and from Weeks 5–9 after the baiting with an effort of 1511 and 1585 trap-nights respectively. Up to 100 cage traps (60 × 30 × 30 cm; Mascot Wireworks) were set at 300-m intervals along existing tracks, hidden in the adjacent vegetation. Trapping was conducted for no more than four consecutive nights followed by at least two days without trapping. Traps were covered with plastic rain covers and were baited with fresh chicken wings. Canned cat food was smeared onto nearby vegetation as a lure. Traps were checked once daily shortly after sunrise. Because the bait in the trap was insufficient to cover a quoll's daily energy requirements and because some individuals were trapped frequently, extra chicken meat was routinely provided to the trapped quolls 1–3 h before they were processed and released.

All captured quolls were permanently marked with identification transponders (PIT tags, Destron Fearing Corp.). Sex, body mass, apparent health and reproductive status were determined. Animals trapped before baiting were fitted with mortality radio-collars (Sirtrack/Faunatech, ~30 g, 150–152 MHz). These transmitters emit short-pulsed radio-signals at a constant rate. The pulse rate doubles when the transmitter has been stationary for a predetermined period. Two types of transmitters with different electronics were used. One type turned to mortality mode after 24 h and the other had a 12-h mortality switch and, in addition, featured a timer function that regularly transmitted the number of hours elapsed since mortality or collar loss.

The mortality status of the deployed radio-collars was monitored regularly (daily after baiting) from a vehicle (mounted dipole antenna) and on foot (three-element Yagi antenna). In addition, starting on the day before baiting, quolls were monitored and tracked from a helicopter every second day (weather permitting) for 15 days. The helicopter radio-tracking system, which used three fitted Yagi antennas integrated into a direction-finding system, allowed the animal to be located as the signal strength increased with proximity to a transmitter and then passed through a 'null' (weak distorted signal) as the helicopter flew directly over the animal. Collared quolls were occasionally tracked on foot to their den sites to supplement location records obtained from trapping and helicopter tracking. Triangulation to locate quolls was too unreliable in the rugged terrain (Körtner *et al*. 2004).

Although for most individuals the number of locations obtained was not sufficient for a home-range analysis *per se*, a 'home range' polygon was calculated (Animal Movement 2.04) and the distance from its boundary to the closest bait line was measured to the nearest 100 m.

Carcasses or lost collars were retrieved as soon as possible after the detection of a mortality signal. Carcasses were subjected to an initial post-mortem. For those carcasses retrieved after the baiting, the stomach and liver were removed for 1080 analysis and the carcasses and tissue samples stored in a deep freezer until assayed. Full autopsies were later performed by two qualified veterinarians.

Baiting

Aerial baiting in the study area on 24 May 2004 was part of the annual wild dog control program coordinated by the NSW Department of Primary Industries and conducted by the Niangala and Barnard River Wild Dog Control Associations and the Armidale Rural Lands Protection Board. Baiting followed standard operating procedures using fresh boneless meat baits (~250 g, injected with 6 mg of 1080) deployed from a helicopter at an average rate of 40 km^{-1}. The approved, predetermined flight path was programmed into the navigation system of the helicopter. A navigator from the Niangala Wild Dog Control Association assisted the pilot and instructed the bait dropper as to when and at what frequency to drop baits. The actual elapsed flight path was logged by a differential global positioning system.

The only variation to the standard baiting procedure was the addition of the biomarker rhodamine B (50 mg $bait^{-1}$) to the baits (~200 kg or ~800 baits) used for the two major bait runs across the study area (Fig. 1). Usually the 6 mg of 1080 is injected dissolved in 0.2 mL of water. However, 1.2 mL of warm water was needed to dissolve the 6 mg of 1080 plus the 50 mg of rhodamine B. To compensate for the extra injection volume, baits were air-dried for 1.5 days rather than just overnight before injection. Very little seepage was observed during injection or bait deployment.

Rhodamine B temporarily stains the mouth and gut of an animal that eats the bait so any pink stain serves as a first indication that 1080 may have been involved in its death. In animals that survive bait ingestion, rhodamine B is incorporated into growing hair and after some weeks can be detected microscopically under UV illumination as a fluorescent band (Fisher 1998). To test for rhodamine B, samples of eight vibrissae were taken from carcasses found and from all quolls trapped following baiting. Three quolls trapped in Week 5 after the baiting and again re-trapped in Week 9 were sampled twice. Samples were prepared according to Fisher (1998) and examined by the Victorian Department of Primary Industries, Frankston.

To model the deterioration of 1080 in the deployed meat baits, 110 baits were randomly selected on the day of deployment. Of these, 10 were bagged separately and frozen a few hours after injection (Day 0) and the remaining baits were placed in 10 wire cages scattered throughout the study area. A sample was then collected at random from each cage on Days 2, 4, 8, 14, 22, 29 and 43, bagged separately and frozen until analysed for 1080 (Alan Fletcher Research Station, Sherwood, Qld). Upon conclusion of sampling, all surplus baits from the decay trial were destroyed. A series of curves were fitted to the data using SigmaPlot 5 (SPSS Inc.). Three models ('Exponential decay', 'Hyperbolic decay' and 'Power function') were tested.

Rain and temperature may affect the breakdown and leaching of 1080 and hence rainfall (standard rain gauge, daily) and ambient temperature (iButtons, Dallas Semiconductors; 30-min interval) were recorded at two locations, one each on the two main ridges on either side of Stockyard Creek.

Track pads

Predator numbers were monitored both before and 2–3 weeks after baiting using 36 sand pads (Newsome and Catling 1979; Körtner *et al*. 2003) spaced at 1-km intervals across some of the existing trails. Sand pads were generally at least 1 m wide and both ends were blocked with branches to prevent animals bypassing them. The exceptions were the pads along the main road on the ridge east of Stockyard Creek, where the sand pads had to be established across some side trails or parallel to the gutter of the road, because of vehicular traffic associated with an ongoing logging operation. Tracks of dogs, foxes, cats and quolls were counted over four rainless nights before and after baiting. As it is difficult to assign multiple tracks to individual animals and double counting is possible, both the presence and absence of tracks on a pad and the overall number of crossings were analysed using adjusted *G*-statistics. 'Abundance ratings' for carnivores were calculated according to Catling and Burt (1994).

Results

Trapping and radio-tracking

A total of 43 spotted-tailed quolls was trapped over the entire experimental period. Prior to baiting, 36 individuals (24 males, 12 females) were trapped and radio-collared. Of

these, six males and five females were less than one year old. Following two quoll mortalities (see below) and the loss of three collars, 31 collared quolls could be tracked at the time of baiting.

Of the initial 36 quolls collared, 23 were retrapped after the baiting. Of the remaining quolls, one could not be relocated even from the helicopter, either because the transmitter failed or the animal moved out of range. Three collars had detached from the animal, and nine animals had died (see below). All but one transmitter was therefore retrieved.

In addition, seven quolls (3 males, 4 females) not trapped before baiting, were captured after baiting. With the exception of one adult female, all were young animals about one year old. Overall, 30 individuals were trapped after baiting.

For 34 quolls (23 males, 11 females) more than three location records were obtained, allowing calculation of a 'home range' polygon. For 17 males and 6 females this polygon was intercepted by a bait line (68%). For the remaining individuals, including the adult male, which tested positive for 1080 (distance 700 m), the distance from polygon to bait line varied from 100 m to 1300 m. Overall, the average distance from 'home range' to a bait line was 200 m.

Mortalities

During the course of the experiment, nine mortalities were recorded (Fig. 2). Two of these, a subadult female and an adult male, died before the baiting. The female was probably killed and partly eaten by a bird of prey. It was decapitated but consumption had caused little damage to the skull and other bones. The male had fractured and lost the frontal part of half its lower jaw at the level of the right canine, which appeared to be consistent with the breakage of canines commonly observed in other individuals (see also Jones *et al*. 2001). No other injuries were found on the carcass, but the jaw injury was infected and flyblown.

All seven mortalities recorded after the baiting occurred 20 or more days after baiting, with the exception of one adult male (<Day 2 after baiting). Only five carcasses could be retrieved because two individuals, one adult male (<Day 2 after baiting) and one subadult male (Day 20 after baiting), were consumed almost entirely, little being left but scraps of fur and bone fragments. Not enough tissue was available for a 1080 assay and it was impossible to determine whether these two carcasses were scavenged or had been killed by predators. It also remained unclear whether the male found dead two days after baiting died shortly before or after the bait drop. The transmitter he carried lacked a timer and the animal could not be found during the prebaiting helicopter survey.

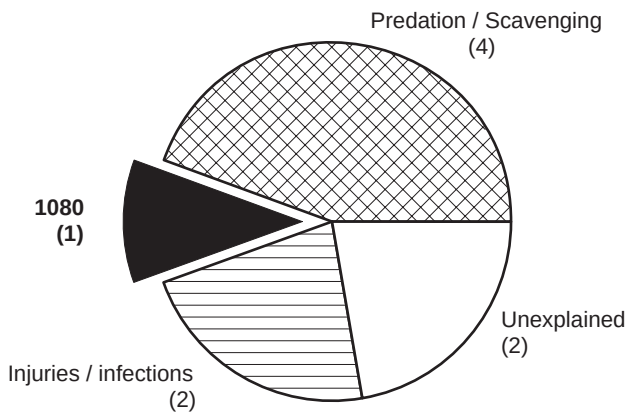

Fig. 2. Proportion of likely causes of mortality of radio-collared spotted-tailed quolls (number of individuals shown in parentheses).

Of the remaining five carcasses (two adult males [Days 23, 24], one adult female [Day 27] and two subadult females [Days 22, 24 after baiting]), none showed obvious traces of rhodamine B in mouth or stomach to indicate recent bait consumption. However, 1080 residues were found in the stomach and its content (0.85 μg g^{-1}) and the liver (0.28 μg g^{-1}) of the carcass of the adult male that died 23 days after baiting.

Both adult males found dead had been very large, with a body mass of >4 kg when initially captured. Both carcases had localised injuries to the head or neck, but apparently in neither case had the injuries been instantly fatal. One of them had a small puncture wound in the back of the neck and its head and neck were extensively swollen. The other male had small flyblown lesions in its chest and a large lesion on the right side of the face. It had also lost over 1 kg since it was last trapped. Skinning revealed heavy bruising to its head. This and the size of the maggots indicated that the injuries occurred before death. This male, which was retrieved 26 h after death, was the only quoll in the study to test positive for 1080. One subadult female was killed by a large predator with a bite to the thorax, puncturing the lung. The carcass was otherwise left intact. The deaths of the two remaining females remain unexplained. There were no external or internal injuries evident or found. Both had some subcutaneous fat, indicating that they were not starving. Both carcasses tested negative to 1080. These two carcasses were retrieved 25 h and less than 84 h after death, respectively, and showed little signs of decomposition. Hence complete deterioration of 1080 following poisoning is implausible.

Vibrissae analysis

Overall, 38 vibrissae samples from 35 quolls were collected after the baiting. These included the five carcasses retrieved during Week 4 after baiting and samples from 30 individuals trapped between Weeks 5 and 9 after baiting (three individuals were sampled twice).

Five quolls (1 subadult female [not reproductive], 1 adult female [6 pouch young after baiting], 3 adult males) trapped after the baiting showed rhodamine B bands in their vibrissae. One of the males was sampled twice and both samples contained rhodamine B bands. All positive vibrissae contained only a single band and all markings were weak, sug-

gesting that only a small amount of rhodamine B had been ingested.

None of the vibrissae samples obtained from carcasses were positive for rhodamine B. Bearing in mind the delay between rhodamine ingestion and its deposit into growing hair, these quolls had apparently not ingested baits in the weeks before death.

1080 deterioration in baits

During the trial some moderate rainfall occurred. This included the night following bait delivery. There were some mild frosts although ambient temperatures stayed above freezing most of the time (Fig. 3).

The exponential decay model best described the loss of 1080 from meat baits (Fig. 3):

$$y = 5.011(\pm 0.334)e^{-0.059(\pm 0.010)x}$$

where y gives the content of 1080 in milligrams after x days (adjusted $R^2 = 0.54$, $P < 0.0001$; numbers in parentheses represent the standard errors of the constants).

The large variance for each sampling period reflects not only differences in the actual 1080 content of baits due, for example, to variable rates of bait deterioration and inconsistencies during injection, but methodological errors in the recovery of 1080 during the assay as well. The lower than expected recovered 1080 levels (nominal 6 mg injected) for the first two sample periods has been observed in previous experiments and might be explained by 1080 initially binding to the meat and thence being released later into solution with the decomposition of the bait (Fleming and Parker 1991).

When the 1080-positive adult male died (Day 23), the baits contained an average of 1.3 mg of 1080, far below the 6.3 mg of 1080 that would constitute a LD_{50} for a population of quolls with a body mass similar to the one recorded for this animal (3.4 kg).

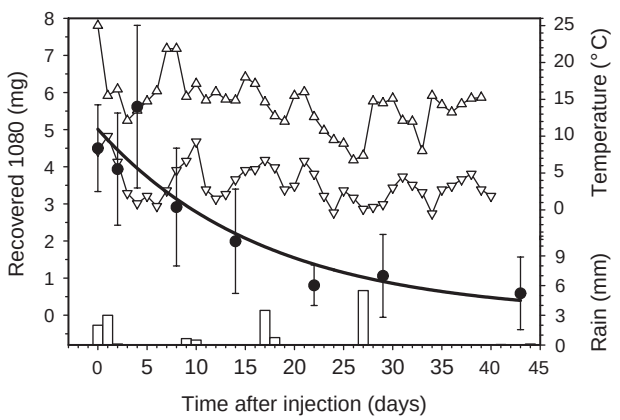

Fig. 3. Deterioration of 1080 in meat baits is depicted by the large black dots and solid line. The error bars (s.d.) illustrate not only variations in the 1080 content of baits but also metholodogical errors during the recovery of 1080 for the assay. The triangles show the daily minimum and maximum ambient temperature (°C) and the bars the daily rainfall (mm).

Track counts

Both the number of crossings and the number of track pads with tracks indicated a significant decrease in fox and dog numbers 2–3 weeks after baiting (Fig. 4). Both dogs and foxes did, however, persist in detectable numbers. For both canids, calculated 'Abundance Ratings' went from medium to scarce. Cat numbers were apparently not affected by the baiting and the 'Abundance Rating' for them remained medium. The number of quoll tracks increased significantly from low to high 'Abundance Rating'.

Discussion

Despite the study area being subjected to annual aerial baiting for over 30 years, the number of individual quolls captured before the baiting indicated a sizeable quoll population, comparable to those found at other locations on the New England Tablelands (Körtner *et al*. 2004). Nevertheless, the possibility remained that a substantial number of quolls would be killed by the planned baiting or had been killed in

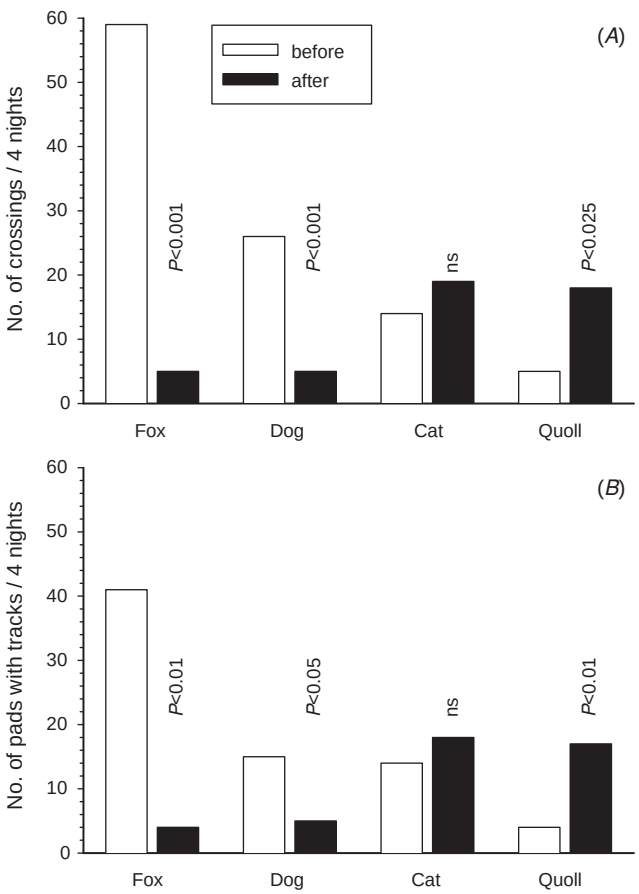

Fig. 4. Counts of crossings (*A*) and number of positive track pads (*B*) for mammalian predators measured over four days before and after baiting.

the past by previous baiting campaigns. Survival of this and other quoll populations that are subjected to baiting might be facilitated by the fact that aerial baits are generally delivered along transects so that parts of the targeted area may be unaffected. Consequently, it is possible that not all animals in a population are actually exposed to baits. Also, in this case, the study area is bordered to the east by large tracts of Tuggolo SF and Nowendoc NP where there has been no aerial baiting since 2001. On a local level, therefore, immigration from unbaited areas could have played some role historically in maintaining the quoll population at the site.

Following aerial baiting, which, according to track counts, appeared to have had a significant impact on the dog and fox populations, only one quoll mortality, that of an injured adult male, might have been caused by 1080. This single mortality did not occur until more than three weeks after bait delivery. At that stage, on average, baits should have posed little risk for a healthy quoll of that size owing to bait deterioration (McIlroy *et al*. 1988; Fleming and Parker 1991; present study). Even when this animal is counted and an assumption is made that the two dead quolls whose carcasses were not retrieved died of poisoning, 1080-related mortality rates were low in comparison to projected rates based on non-toxic trials. Such a low rate of poisoning following aerial baiting is corroborated by baiting trials with northern and western quolls (King 1989; Morris *et al*. 1995). However, in these two trials the apparent absence of 1080-related mortalities could have been explained by a lack of bait exposure, because bait exposure and/or consumption could not be measured. In contrast, the location records derived from radio-tracking and trapping for the present trial on spotted-tailed quolls (Fig. 1) suggest that the activity area of most collared quolls came close to, or overlapped with, the baiting transects. Therefore, many quolls could have encountered either marked or, towards the periphery of the study area, unmarked baits. However, only six quolls (one dead plus five survivors) out of 35 sampled (17%) had ingested bait and multiple bait takes by individuals were not detected. Even allowing for a slightly higher rate of non-fatal bait take from nearby baits runs with unmarked baits (Fig. 1), it is highly likely that bait consumption would have been substantially lower than that observed during simulation trials in southern NSW (Murray and Poore 2004; A. Claridge, personal communication). During three trials using non-toxic bait at least 50% of the sampled animals consumed bait, often more than one. The results were consistent although bait density, presumably affecting bait availability, differed between 10 and 40 baits km^{-1} between these trials. Hence during simulation trials substantially higher bait-consumption figures were observed even at bait densities only one-quarter of that used in the present study (A. Claridge, personal communication). It appears unlikely, therefore, that variables affecting bait availability along baiting transects, such as rate of bait delivery and probably also bait removal by other species, contributed significantly to the observed bait consumption by quolls. Hence two major questions arise. Why did bait consumption differ substantially between the present toxic and previous non-toxic baiting trials? Does this difference reflect bait avoidance?

It could be speculated that the availability of alternative food sources was much higher during the present study, and hence fewer quolls consumed meat baits, assuming that quolls favour freshly hunted prey over scavenging. Measuring food availability for animals such as quolls with a wide dietary range is logistically difficult and was therefore neither attempted during this nor previous studies. Nevertheless, it appears unlikely as an explanation. In traps even four-day-old chicken wings remained attractive to quolls and also the lean body conditions of captured quolls did not indicate that prey was superabundant or easily accessible.

Alternatively, the observed low rate of bait consumption in the present trial could reflect bait avoidance. This, however, could not have been based on general neophobia as, again, it did not extend to cage traps and chicken wings. Any bait avoidance would have had to be fairly specific to dog baits and then probably based on 1080 itself. At least for some species 1080 is not tasteless and odourless, as is often stated (Eason and Wickstrom 2001). For example, learned 1080 bait aversion has been demonstrated, and is now widespread in New Zealand's brushtail possum (*Trichosurus vulpecula*) populations (Morgan 1982; Morgan *et al*. 1996; Moss *et al*. 1998). Learning usually requires the consumption of a sublethal dose of toxin. It would therefore be expected that bait consumption and mortality is more common among young and naïve individuals. Bearing in mind that aerial baiting campaigns are usually conducted at a time of year when quolls have become independent from their mothers, the present data do not match this prediction: five adults but only one subadult had consumed bait.

Bait avoidance in response to regular baiting could also develop over time by selecting for bait-shy individuals, without the requirement of individuals learning. Such a mechanism would need to rely on a baseline level of innate, genetically propagated bait-shyness amongst quolls. When baiting is introduced or abandoned, changes in the level of bait-shyness large enough to explain the marked differences in bait consumption between the present toxic and previous simulation trials, should take several generations to develop. In this regard, all study sites have had an established history of aerial baiting, but in contrast to the present study area, in Tallaganda SF aerial baiting had been substituted with mound baiting three years before the simulation trial. This was after at least 16 years of annual aerial baiting (Murray and Poore 2004). Similarly, in the Byadbo Wilderness, two non-toxic trials produced similar results to that conducted in Tallaganda SF (A. Claridge, personal communication) and were conducted six and seven years after aerial baiting had been replaced by mound baiting and trapping (P. O'Brien,

personal communication). Differences in baiting history therefore exist. However, particularly for the Tallaganda trial, the three years without baiting would appear too short a time to explain the considerable difference in bait uptake between that quoll population and this one. Nevertheless, due to the apparently high mortality and turnover rates in quoll populations (Jones *et al*. 2001; Körtner *et al*. 2004; present data), it cannot be ruled out that bait avoidance in quolls can develop in response to baiting and possibly be lost within a few years.

Another, arguably more likely, explanation for the difference in bait uptake between non-toxic and toxic baits would be an innate high level of 1080 avoidance in quolls. Innate and developed behaviours need not be mutually exclusive. One relevant example would be the fat-tailed dunnart (*Sminthosis crassicaudata*), a dasyurid related to quolls, which regurgitates, reduces food intake or even refuses to eat when 1080 is added to its laboratory diet (Sinclair and Bird 1984). In such a case, learning or selection can still occur, but even without them the risk of poisoning would be reduced. It is therefore conceivable that the quolls in this study survived bait consumption, because they ate only part of a bait or regurgitated some of it as a response to ingesting 1080. Such a scenario would also explain the weak fluorescence of the rhodamine B bands. However, at least in dunnarts, this mechanism does not provide 100% protection. Some of the dosed individuals still died (Sinclair and Bird 1984), as apparently do some quolls (Belcher 2003; P. Cremasco, personal communication; present data).

Conclusion

It has been postulated (Belcher 1998, 2003, 2004; Murray and Poore 2004) that 1080 baiting to control canids is a major threat to quoll populations and has contributed to their decline. However, it has been shown recently that fox baiting can be conducted relatively safely with Foxoff® baits because this type of bait is most often rejected by quolls when encountered (Körtner *et al*. 2002, 2003). During the present aerial baiting trial the consumption of toxic fresh meat baits was lower than that of non-toxic baits used during simulation trials, a first indication that quolls might avoid 1080. Perhaps, even more importantly, the results refute the assumption that dog baits are fatal for most quolls that may eat them (Belcher 1998, 2004; Murray and Poore 2004). Quolls are probably only occasionally fatally poisoned. Given the high natural mortality rate (Jones *et al*. 2003; Körtner *et al*. 2003, 2004; present data), quoll populations as large as the one studied can apparently compensate for occasional deaths caused by poisoning. Whether the same would apply to already ailing small populations where stochastic events can have a more dramatic effect remains uncertain.

Despite these encouraging results, from a single trial, the present data cannot be generalised either temporally or spatially and must be regarded as preliminary until confirmed by replication. It also appears that the potential for developed and/or innate avoidance of 1080 has to be investigated before any final conclusions can be drawn as to whether spotted-tailed quolls are threatened by aerial baiting to control wild dogs.

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