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Original Article

Target Specificity of the Felixer Grooming "Trap"

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ABSTRACT Felixer grooming "traps" provide a novel technique for controlling invasive red foxes (*Vulpes vulpes*) and feral cats (*Felis catus*) by ejecting a dose of poison onto the fur of a target animal, which is subsequently ingested through grooming. The Felixer achieves target specificity through a discriminatory sensor arrangement and algorithm as well as a dosing pathway and toxin, which together make feral cats and foxes more vulnerable than humans and nontarget wildlife. The toxin 1080 used in many pest control projects in Australia is derived from native plants, which renders Australian wildlife, including potential scavengers of poisoned carcasses, that have co-evolved with these toxic plants less sensitive than their nonnative counterparts to 1080 poisoning. We investigated the success of the Felixer sensor system in discriminating target cats and red foxes from nontargets under field conditions. All foxes and 82% of feral cats were correctly identified as targets. No people or medium-sized marsupials—including brush-tailed possums (*Trichosurus vulpecula*), bettongs (*Bettongia* spp.), bilbies (*Macrotis lagotis*), and western quolls (*Dasyurus geoffroii*)—were incorrectly assigned as targets, suggesting Felixers could provide safe and specific feral-predator control at many conservation sites, albeit not at sites with threatened endemic small felids or canids. A low false-positive detection rate was recorded in larger macropods and poultry that will be addressed with more sophisticated sensor positioning and algorithms in optimized Felixers, along with more careful installation. The low sensitivity of macropods and malleefowl (*Leipoa ocellata*) to 1080, and their reduced grooming behavior relative to feral cats, suggests these species will not be affected by Felixer deployment. © 2019 The Wildlife Society.

KEY WORDS control tool, *Felis catus*, Felixer, feral cat, marsupial, oral grooming, predator, red fox, target specificity, 1080.

Feral cats (*Felis catus*) present a significant threat to wildlife on islands or continents, particularly where small native felines are not endemic (Woinarski et al. 2012, Nogales et al. 2013, Dickman and Newsome 2015, Moseby et al. 2015). Cat predation and disease transmission has contributed to the decline and extinction of numerous wildlife species (Burbidge and McKenzie 1989, Smith and Quin 1996, Woinarski et al. 2015). Feral cats have also thwarted many reintroduction attempts of vulnerable fauna worldwide (Short et al. 1992, Armstrong et al. 2006, Shier and Owings 2006, Moseby et al. 2011*b*). Although invasive red foxes (*Vulpes vulpes*) have proven easier to control than cats, foxes continue to represent a significant threat to Australian wildlife (Woinarski et al. 2015, Kinnear et al. 2017).

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The dominant form of broadscale pest-predator control in Australia is aerially distributed meat baits containing 1080 poison. The toxin 1080 used in many pest control projects in Australia is derived from native plants, which renders Australian wildlife, including potential scavengers of poisoned carcasses, that have co-evolved with these toxic plants less sensitive to 1080 poisoning than their nonnative counterparts (Twigg and King 1991). Toxic 1080 baits can temporarily reduce feral cat abundance and are a valuable tool in eradicating feral cats from confined areas (Algar et al. 2007, 2010; Moseby and Hill 2011). However, bait uptake by feral cats is typically lower than for foxes and varies considerably in relation to study area, seasonal conditions, and alternative prey availability, which limits the efficacy of baiting for sustained feral cat control (Moseby et al. 2011*a*, Christensen et al. 2012). Also, uptake of baits by nontarget species can be substantial, in some cases exceeding 95% (Dundas et al. 2014). Trapping and shooting can be effective for short-term control when target predator densities are

high but labor-intensive and logistically prohibitive for sustained control at remote sites (Short et al. 2002, Rich et al. 2014). Development and registration of new control devices with low labor costs and that do not rely on cats' hunger are needed, and a tool exploiting cats' unique grooming behavior is a very high priority of the Australian Threat Abatement Plan for Predation by Feral Cats (Denny and Dickman 2010, Read 2010, Commonwealth of Australia 2015). Such a tool could improve feral cat control in a range of settings including islands, restricted threatened species sites, and remote areas.

The Felixer feral cat grooming "traps" (hereafter, Felixer) uses an array of sensors controlled by a specially designed controller to automatically detect and distinguish target feral cats and foxes from similar-sized native animals and larger species, including kangaroos (*Macropus* spp.), livestock, and humans. Just as camera traps "capture" images of wildlife without restraining them, Felixers are stationary box-like devices equipped with sensors, camera, and a delivery mechanism that induce a grooming response without physically capturing targeted individuals. Once detected by the Felixer's sensors, and recognized as targets by the Felixer algorithm, feral cats and foxes are automatically squirted with a measured dose of toxin, which is subsequently ingested through instinctive oral grooming (Read et al. 2014). Unlike other contemporary control techniques for invasive predators, the Felixer does not require the target animal to change behavior, consume bait, or enter a trap. Proof-of-concept poisoning of feral cats through oral grooming has been demonstrated in pen trials but the ability to successfully differentiate target pests from nontarget wildlife has yet to be demonstrated (Read et al. 2014).

A key driver of the development of Felixers is to minimize animal welfare issues for invasive predators and nontarget wildlife or pets. 1080 becomes lethal when sufficient nontoxic fluoroacetate is metabolized to fluorocitrate, shutting down the production of energy (Eason et al. 2011). Fluorocitrate also inhibits nerve and brain function, decreasing the ability of poisoned animals to experience painful stimuli (Twigg and Parker 2010). Progressive lack of energy without apparent pain is consistent with the lethargic response of 24 fatally 1080-poisoned cats described by Eason and Frampton (1991). 1080 was selected as the toxin for initial Felixer trials because of its relative target specificity to invasive mammals and reports of the relatively benign animal welfare responses to poisoning in cats.

In addition to selecting safe doses of toxin for most nontargets, Felixer target specificity can also be achieved by restricting access by nontargets, arranging sensors in a pattern that prevents triggering by nontarget species, creating a sensor algorithm that selects targets based upon the timing and pattern that they intercept different sensor beams, and interspecific differences in grooming behavior (Read 2010). This study experimentally tested the efficacy of sensor arrays and algorithms to distinguish target from nontarget Felixer activations in the field to guide improvements in target specificity. We hypothesized that the discrimination capabilities of Felixers would result in a greater target specificity than is typically achieved with baiting or trapping of feral cats and foxes.

METHODS

Felixer Design

Prior to this field trial, we designed, tested, and improved Felixers during a 2-year period in the laboratory to maximize reliability, efficacy, and target specificity. We used infrared laser-based range-finding sensors to detect objects moving in front of the Felixer without the need for a backing reflector that could be knocked out of alignment or could frighten wary target animals away from the firing zone. We evaluated range data from Felixer sensors to determine sensor capacities to distinguish feral cats from other nontarget wildlife, domestic animals, or people over time and distance. We designed the 2 activation sensors and 2 blocking sensors to only trigger the Felixer when a target animal intercepted both activation sensor beams simultaneously while not intercepting blocking beams (Fig. 1). We defined targets by body height >230 mm but <460 mm, body length >250 mm, and with a ventral clearance of >60 mm based on pen trials of precursors to the Felixer (Read et al. 2014). Many Australian animals of similar size to a feral cat (koala [*Phascolarctos cinereus*]), wombat [*Vombatus ursinus*, *Lasiorhinus* spp.] and brush-tailed possum [*Trichosurus vulpecula*]) have shorter legs and lower ventral clearance than cats and, hence, the bottom blocking sensor has been incorporated to prevent them from triggering the Felixer (Fig. S1 available online in Supporting Information). For this trial, we distinguished feral cats from domestic pets by only deploying Felixers ≥ 5 km from any residence.

Rapid target qualification (150 ms), triggering (<40 ms), and gel ejection speed (60 m/s) ensured the toxin gel strikes a target cat moving at 5 km/hr at the maximum 4-m range. The fast and silent triggering was integral to delivering a dose to target animals moving at a typical pace through the environment. Each 12-mg sodium fluoroacetate (1080) Felixer dose was contained within a sealed cartridge to maximize consistency and longevity. Felixers also used a selection of intermittent programmable audio lures to attract feral cats and foxes, captured all sensor activation information, and photographed all triggered events to confirm target specificity.

A sensor algorithm selected targets based upon the timing and pattern that they intercepted different sensor beams at different distances. This algorithm included a minimum and maximum time that activation sensors were broken (including simultaneously) consistent with a feral cat's gait but not most nontargets. These gait data were derived from field Felixer deployments and, hence, likely represent the speed of target and nontarget animals in field conditions. Feral cats and foxes approaching from either direction intercepted the near activation sensor before they intercepted the bottom blocking sensor and typically intercepted the far activation sensor within 0.4 s (Figs. S2 and S3 available online in Supporting Information). The sensor algorithm also included a shutdown period (nominally set at 60 s) to

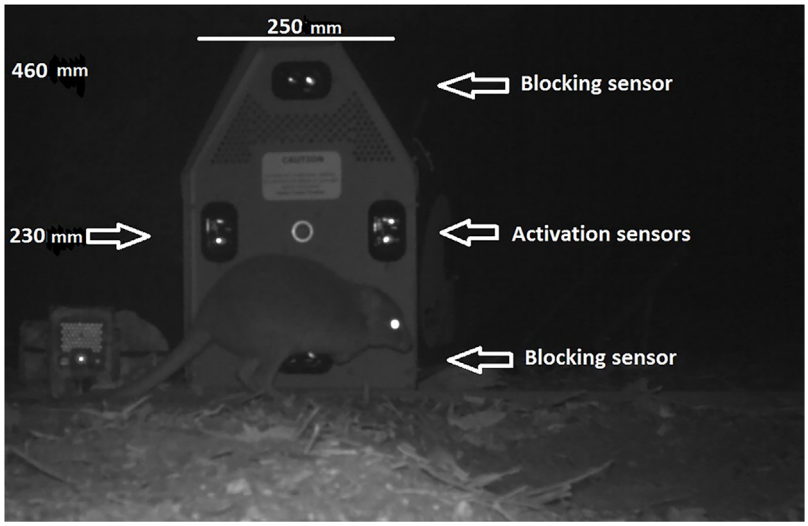

Figure 1. Brush-tailed bettong at Venus Bay Conservation Park, South Australia, passing underneath both activation sensors and hence not activating the Felixer.

prevent firing after the top blocking sensor was broken, in case an animal taller than a cat subsequently crouched below the top blocking sensor. Furthermore, to ensure that feral cats or foxes were only squirted when side-on and hence received a full dose of toxin, both activation beams must have been broken within 300 mm of the same perpendicular plane from the Felixer. An animal walking at an angle $>57^{\circ}$ to perpendicular to the line of fire will have intercepted one activation beam 300 mm closer than the second beam and will not have triggered the Felixer. Target discrimination was determined with the Felixer in either active deployment or "photo-only" mode, where the firing mechanism was disabled, but sensor information and images were still collected.

Field Trials

To test whether characteristics chosen for the Felixers would be effective in targeting invasive foxes and cats and not nontargets, we conducted 5 independent field experiments. Five diverse study sites were chosen across South Australia; Secret Rocks Nature Reserve in arid mallee vegetation, Venus Bay Conservation Park in coastal heath, Flinders Ranges National Park with open woodlands in rocky ranges, Arid Recovery Reserve in the sandy arid zone, and Kangaroo Island with mixed agricultural and high rainfall heath and forest (Fig. 2). We selected study locations based on established monitoring and management programs for feral cats and the presence of nontarget threatened fauna species of similar dimensions to feral cats. Trial locations, with the exception of Kangaroo Island, were all remote from public access and we sign-posted Felixers with warning signs as per safeguards required by Australian Pesticides and Veterinary Medicines Authority permit 80269 for use of 1080 toxin. At each site, we tested 4 Felixers independently and collectively for 50–120 days. We demonstrated Felixers and tested them in photo-only mode in a number of locations on Kangaroo Island where we deliberately tested chickens, turkeys, and pet dogs of a co-author (PH).

We established Felixers perpendicular to vehicle or animal tracks, along fence-lines, or on other pathways where feral cat activity was likely to be concentrated (Read et al. 2015). We operated Felixers in photo-only mode for $\geq$2 weeks prior to switching to active firing at all locations, except for Kangaroo Island, where we did not conduct lethal trials. We also included initial data from a pilot Felixer pen trial at Secret Rocks, where we placed 2 feral cats separately for 2 days in a pen equipped with video cameras and a Felixer.

We programmed Felixers to record images whenever sensors where intercepted, either by a feral cat or fox, or by a nontarget animal. We inspected all images recorded by Felixers, whether operating in photo-only or active mode, by downloading them from the Felixer's Universal Serial Bus

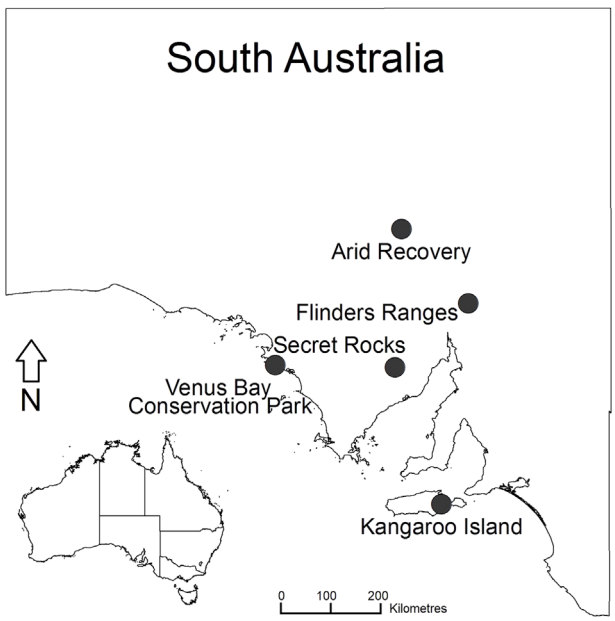

Figure 2. Map of Felixer field study sites within South Australia, 2017.

memory stick onto a computer. We investigated any incidents of incorrect target discrimination through analysis of data logs that recorded activation status of each sensor on a millisecond timeframe. We recorded the number of target and nontarget firings for each location and used them to determine the average number of correct assignments of target and nontarget passes for individual species.

We also used an array of ≥12 Reconyx cameras to independently measure activity of feral cats and nontarget species at each study site to determine whether distinctly patterned, sprayed feral cats were subsequently recorded alive (McGregor et al. 2015). We obtained additional cat-specific information from the Arid Recovery site from survivorship details of 7 feral cats fitted with very-high-frequency radiocollars monitored daily for an independent study. We also monitored the 2 feral cats in the pen trial for 1 day before we switched the Felixer to active mode.

To statistically compare the ability of Felixers to target feral cats and foxes and nontarget species in the field, we considered each data point as a detection from the Felixer camera, with a binary response of whether the Felixer determined the animal was a target or not. Our fixed effect was species category, where we clumped target species together (feral cats and foxes) and set them as the intercept, combined poultry and bush stone-curlews (*Burhinus grallarius*), red (*Macropus rufus*) and western gray kangaroos (*M. fuliginosus*), each of the mammals <3 kg (bilbies [*Macrotis lagotis*], bettongs, rabbits [*Oryctolagus cuniculus*], possums), and anthropogenic triggers: cars and humans. Random effects were each separate study location. We ran a mixed-effects generalized linear model with a binomial distribution using the Program R library "lme4" (Bates et al. 2015). Binomial models cannot converge for categories that only contain absence data; therefore, we created a single dummy data point with a trigger for the 3 categories with no activations. For statistical purposes, the probability of nontarget firing for this combined category of nontargets was exaggerated because of the addition of this false activation.

RESULTS

Target Specificity

We recorded 1,335 Felixer target and nontarget triggering events at the 5 study sites (Table S1 available online in Supporting Information). None of the 269 human, 226 vehicle, 95 brush-tailed possum, 64 corvid (*Corvus* spp. and *Strepera* spp.), 33 European rabbit, 15 bilby, 48 burrowing bettong (*Bettongia lesueur*), 5 bronzewing pigeon (*Phaps chalcoptera*), 5 bush stone-curlew, or 4 brush-tailed bettong (*Bettongia penicillata*) triggering events were identified as targets by the Felixer at any site (Fig. 3). In addition 2 echidna (*Tachyglossus aculeatus*) and 1 western quoll (*Dasyurus geoffroii*) were also correctly identified as nontargets, and numerous rodents and small birds that clearly failed to reach the height of the activation sensors were also photographed as nontargets when they broke the bottom blocking sensor.

Felixers correctly identified all 5 foxes and 82% of 66 feral cat detections as targets (Fig. 3). We used a mixed-effects binomial generalized linear model to measure target specificity, and a random effect of study site was necessary (variance = 14.4, SD = 3.8). With the random effect of study area considered, target species were the only category likely to trigger a Felixer (Table 1). Tammar wallabies (*Macropus eugenii*) and poultry–bush stone-curlews had a negative and lower probability of being targeted, followed by all other categories (Table 1).

Analyses of the sensor data logs indicated the time between feral cats and foxes intercepting the first and second activation sensors was typically 250 to 600 ms (Fig. S2 available online in Supporting Information), which equates to speeds of 0.6–1.0 m/s (2.5–3.6 km/hr). One of 9 feral cats detected by Felixers at Venus Bay, 5 of 16 feral cats at Arid Recovery, and 6 of 24 feral cats on Kangaroo Island were not correctly identified as targets. One of these cats was too small to intercept both activation sensors concurrently, 5 were detected at a location where the bottom blocking sensor intercepted sloping ground, and 6 feral cats were not designated as targets because they walked at an acute angle to the Felixer.

The sensor positioning and algorithm employed produced false-positive target identifications for 11 of 62 poultry, 21 of 218 tammar wallabies, and 8 of 189 kangaroos during photo-only trials (Fig. 3; Table S1 available online in Supporting Information). Inspection of the data logs revealed that most false-positive wallabies were misidentified as targets at a single deployment when the bottom sensor of the Felixer, which would have otherwise prevented triggering, was blocked by a rock that had not been cleared from the distant end of the sensor detection area. The other false-positive macropod misidentifications were caused either when stationary kangaroos, crouching and hence not intercepting the top blocking sensor, took >1 s (speed <0.25 m/s) to intercept both activation sensors (Fig. S3 available online in Supporting Information), or when a wallaby hopped past at speeds of >2 m/s. Most feral cats and foxes took 250–600 ms to intercept both activation beams, whereas nontarget macropods were typically slower or faster (Fig. 4). Two of 25 dogs were classified as targets in photo-only mode. One was a small pug of similar proportions to a feral cat, the other was a larger dog that failed to activate the 46-cm-high blocking sensor when it crouched in front of the Felixer, similar to the kangaroo false triggers recorded.

Efficacy

Although developing a tool for humane and targeted lethal control of feral cats and foxes was the driver for developing Felixers, this study concentrated upon testing the target discrimination capabilities in photo-only mode. However, we did collect evidence that 6–7 feral cats potentially died after being squirted by Felixers in either pen or field trials as described below. A 3.15-kg female and a 3.5-kg male feral cat squirted by the Felixer in the pen trial were both motionless within 6 hr and retrieved dead within 10 hr after being squirted. At no stage after ingesting the 1080 was

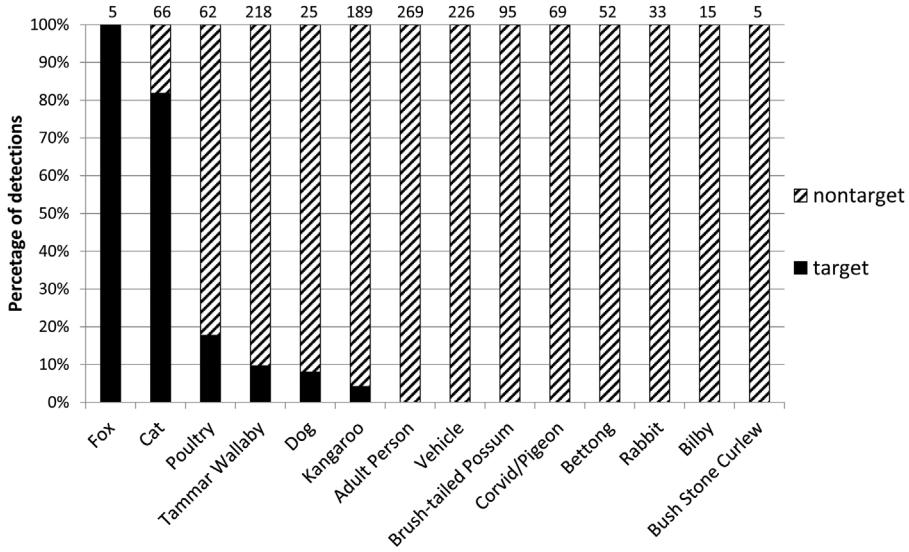

Figure 3. Summary of target specificity results showing whether an object was classified by the Felixer as a target (solid) or nontarget (hatched). Data combined for all study sites (2017 South Australia) with the sample size for each taxon listed above the columns.

hyperactivity or external evidence of distress recorded on the motion-activated cameras in the pen. One of the Arid Recovery collared feral cats was found dead in the open 310 m from the Felixer within 4 hr of being squirted. As a result of failure in the mortality signal, the other collared feral cat was not located until 3 days after activating the Felixer (1,180 m away), but its state of decomposition suggested it had died within 24 hr of being squirted. Two of the 3 feral cats inside Venus Bay Conservation Park enclosure were photographed numerous (>5) times on an array of 15 monitoring cameras before being squirted, but never afterward, suggesting they were likely killed by poisoning as a result of oral grooming. The third feral cat was squirted when only 4 cameras were active and, despite it not being recorded again, we can be less confident that it died.

DISCUSSION

High targeting rates of those feral cats (82%) and foxes (100%) that encountered a Felixer support our hypothesis that these new devices offer a more targeted control tool than is typically achieved through baiting where encountered bait uptake by feral cats is often <20% (Algar et al. 2007, Moseby et al. 2009). Although we were unable to find reported percentages of feral cats or foxes encountering cage or leg-hold traps that are captured, we are confident that Felixer activation rate would also exceed conventional trap-activation rates by feral cats and foxes.

Our field tests demonstrate the risk of nontarget triggering, especially by humans, from carefully set trial Felixer deployments at our study sites was minimal. When the lack of human triggering is combined with sign-posted deployment in remote locations, the risk of injury to humans is considered negligible. Furthermore, because 1080 is not readily absorbed dermally and 3 doses would have to be completely licked and ingested by an 18-kg child for a lethal dose (or 12.5 doses for a 75-kg adult; Table 2), inadvertent fatal human poisoning is extremely unlikely (Eason et al. 2011).

The main nontargets not reliably distinguished by the sensor array and algorithm were poultry, which are morphometrically similar to threatened malleefowl (*Leipoa ocellata*; also recognized as targets). These large walking birds

Table 1. Results from a mixed-effects generalized linear model on target specificity of Felixers for the main categories of objects detected from all field study sites (2017, South Australia) combined, showing that only cats and foxes yielded positive *z*-values or likelihood of being considered targets. Significant *P*-values indicate a low probability of being targeted.

Species category	Coefficient	Lower 95% CL	Upper 95% CL	*z*	*P*
Feral cats and foxes	4.33	0.93	7.72	2.50	0.013
Poultry–curlew	−5.42	−7.28	−3.57	−5.73	<0.001
Tammar wallaby	−6.08	−7.82	−4.35	−6.87	<0.001
Kangaroo	−8.17	−10.6	−5.73	−6.58	<0.001
Dog	−10.28	−13.36	−7.19	−6.53	<0.001
Corvid–pigeon[a]	−10.52	−13.88	−7.15	−6.12	<0.001
Small mammals[a]	−10.69	−14.64	−6.73	−5.29	<0.001
Humans and cars[a]	−13.91	−17.44	−10.37	−7.72	<0.001

[a] Values are minimum because there were no triggers for these categories.

Table 2. Approximate lethal dose for 50% of individuals (LD_{50}) and number of 12-mg 1080 Felixer cartridges required to deliver estimated lethal dose to target and nontarget animals (LD_{50} data provided by biosecurity SA [Glenside, South Australia] from King [1990] and McIlroy [1986]).

Species	Mass (∼kg)	LD_{50} (∼mg/kg)	No. cartridges
Fox	4.7	0.12	0.05
Cat	4.2	0.40	0.14
Dingo	16.0	0.11	0.29
Brush-tailed possum	2.6	0.67	0.29
Tammar wallaby	6.0	0.30	0.30
Australian raven	0.6	5.10	0.50
Stone-curlew	0.7	10.00	1.20
Child	18.0	2.00	3.00
Bilby	1.5	15.00	3.75
Red kangaroo	30.0	3.20	8.00
Adult person	75.0	2.00	12.50
Malleefowl	2.0	100.00	16.70
Brush-tailed bettong	1.3	100.00	22.00

intercept sensor beams in a pattern different from that of a walking feral cat or fox and, hence, will likely be more distinguishable with advanced algorithms that include the entire sensor log pattern rather than only concurrent beam intercepts. Despite potentially not being reliably distinguished by the Felixer, malleefowl are at very low risk of serious injury from Felixers because they are most unlikely to thoroughly preen (J. Benshemesh, La Trobe University, personal communication) and ingest a full dose, which in any case is only 3% of a 200-mg lethal dose as a result of their high tolerance of 1080 (King et al. 1996).

Confirmation that cat-sized dogs activate Felixers confirms that additional precautions are required where Felixers are deployed where small dogs, pet cats, endemic foxes or felines, or young dingoes may have access. Like conservative bait-laying, judicious Felixer placement is the simplest method of minimizing risk to pet cats or dogs, but the algorithm-based Felixer target-selectivity tool enables additional safeguards to be implemented. One such approach under development is the incorporation of a collar-borne Wireless Identification Device that can disable a nearby Felixer and hence permit feral cats to be controlled while shielding pet cats from the toxin. The false-positive wallaby detections along with false-negative cat detections highlight the importance of thoroughly clearing and leveling the specified detection range to maximize target specificity. Vegetation and rocks can also be used to guide animals into the direct path of the Felixer.

The 2 feral cats filmed in our pen trial after poisoning laid down and remained motionless until death, consistent with the 1080 poisoning observations of Eason and Frampton (1991) and the consequence of fatal para-aminopropiophenone poisoning reported by Read et al. (2014). Onset of symptoms and speed to death from 1080 poisoning are accelerated by larger doses, which is considered desirable from a welfare perspective (Weinstein and Davidson 2004, Sherley 2007). Hence, these initial field trials used a 12-mg 1080 dose to achieve rapid death, although <50% of this dose is required to deliver the LD_{50} for a 5-kg feral cat. The high target specificity reported here, along with low susceptibility of humans to such a dose, suggests that this high dose rate is optimal and appropriate where fast death is the preferred ethical outcome.

Any feral cat succumbing to 1080 poisoning must have ingested the majority of the toxin from its fur and, hence, the main risk of secondary poisoning from Felixers is presented to scavengers large enough to consume cat carcasses, namely dogs, foxes, or eagles. Feral cats have larger body size and lower typical population densities compared with poisoned rabbits or rodents; therefore, secondary poisoning associated with Felixer-sprayed nonnative invasive predators is less than the potential for secondary poisoning through established pest-control methods (Heyward and Norbury 1999, Alterio 2000). Given the greater tolerance of Australian predators and scavengers to 1080 than tolerance of invasive mammals,

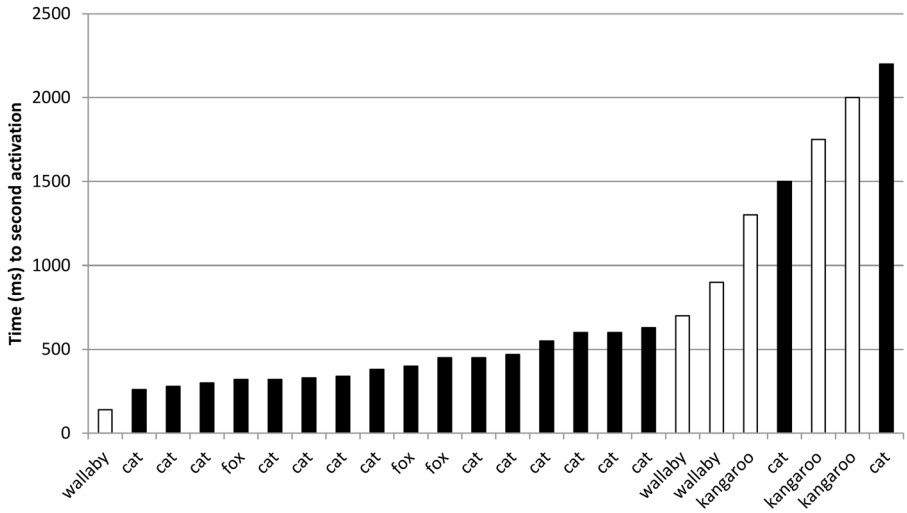

Figure 4. Time interval between intercepting first and second Felixer activation beams in target (black) and non-target (white) species, from data collected at all study sites (2017, South Australia).

and the more targeted and less abundant 1080 doses used in Felixer operations compared with baiting, we consider the risks of secondary poisoning from Felixer use to be low and acceptable.

Collectively, Felixer's nontarget isolating mechanisms of sign-posted installation in locations remote from young children, sensor pattern, sensor algorithm, grooming pathway, choice of toxin with low risk to humans and most wildlife, and careful installation will deliver a very high degree of target specificity and negligible risk to the nontarget species assessed to date. As a result of this trial, planned Felixer optimizations include a bottom sensor that can be adjusted up to 87 mm in height, which is expected to block most triggering events of large walking birds and wallabies. Optimization of algorithms to include the full sensor sequence will also minimize false-positive macropod detections by limiting the target speed to a window most typical of a walking feral cat or fox. Optimized Felixers will also collect greater resolution and signal strength data from sensors operating in a mode optimized in the 0–4-m range, compared with the initial trials documented in this study where sensors operated in a default setting that only collected basic distance data. Determination of acceptable false-positive triggering risk and potential nontarget species may ultimately determine the optimum bottom blocking sensor height and algorithms used for particular locations and continuously improved and even site-specific software can be readily uploaded to the Felixers following routine assessment of field results. Future efficacy studies evaluating optimal Felixer deployment strategies and cost-effectiveness of Felixers for eradication or control programs will utilize algorithms modified as a result of this initial study; hence, the target specificity data derived will not be directly comparable with these pilot data.

MANAGEMENT IMPLICATIONS

Our results suggest that Felixers offer a safe (relative to more indiscriminate baiting) and automated mechanism by which to expose feral cats and foxes to measured doses of 1080 toxin, with minimal exposures to nontarget wildlife. Inclusion of Felixers could provide a useful adjunct to conventional control techniques for feral cats in areas where threatened small felids or canids are absent and enable feral cat management in areas where shooting or less-discriminant toxic baiting are not desirable or authorized. Further trials with optimized Felixers and software are required to provide additional target-specificity data for a wider range of geographic, habitat, seasonal, and wildlife assemblages. The collated sensor-log data will be used to optimize the qualification and discrimination algorithms. Future trials will also be necessary to collect efficacy data through monitoring movements and survival of collared or clearly recognizable target individuals, which is integral to determining the value of this new technology to ethically, economically, and sustainably control invasive cats and foxes. Felixers are automated, powered by batteries with solar rechargers, and record all data of target and nontarget detections; therefore, Felixers may prove to be valuable for sustained feral cat control and wildlife monitoring at isolated locations and where logistical expenses and safety regulations limit or prohibit conventional control techniques. Inclusion of additional blocking systems to safeguard pets or working dogs wearing wireless identification devices will enhance the range of landowners who can safely conduct feral predator control. Use of Felixers on islands where feral cat effects can be great (Medina et al. 2014), threatened wildlife habitats in remote regions (Read et al. 2018), or even peri-urban or industrial areas where regular surveillance is required, will be assisted by incorporation of proposed telemetry interrogation capabilities.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article.

Table S1. Target and nontarget detections of different species at the individual study sites

Figure S1. Felixer photographs of nontargets: a) dog intercepting the Top Blocking Sensor (at 200-cm distance

from the Felixer on 5 Mar 2016), and b) bilby intercepting the Bottom Blocking Sensor (at 118-cm distance on 20 May 2017) without intercepting both Activation Sensors simultaneously. Neither were fired upon by the Felixer.

Figure S2. Image and sensor log of a fox moving from left to right that initially intercepted the left activation sensor at 240 cm from the Felixer before almost immediately intercepting the bottom blocking sensor with its nose and leg.

Figure S3. Sensor log of stationary kangaroo that was wrongly identified as a target when it extended its head across the left activation sensor and then 1.3 seconds later also intercepted the right activation sensor.