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Evaluation of five kill traps for effective capture and killing of Australian brushtail possums (*Trichosurus vulpecula*)

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Abstract Five types of kill trap for possible use by professional possum trappers in New Zealand were tested for their potential to kill possums quickly and for their capture efficiency. Traps were evaluated using the testing requirements outlined in a draft International Trap Standard. This involved sequential mechanical testing, pen testing with free-moving possums, and field testing. The Banya and Lokaasklem traps failed the mechanical evaluation because of insufficient impact momentum and clamping force; pen testing failed the Conibear 160 because insufficient possums were killed; and field testing failed the BMI 160 because insufficient possums were struck on the target location. The LDL 101 trap was the only one of the five traps to pass all three test stages. The ISO draft standard therefore provides a rigorous testing procedure that most kill traps currently available in New Zealand would not pass. However, because one trap did pass, it is clearly possible to develop kill traps to meet the standard and which also could compete realistically as capture-efficient alternatives to leg-hold traps.

Keywords humaneness; kill traps; possums; standards; trapping; *Trichosurus vulpecula*

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INTRODUCTION

Trapping of Australian brushtail possums (*Trichosurus vulpecula*) in New Zealand has relied on the use of leg-hold traps since the early 1920s. The currently permitted use of leg-hold traps, particularly the most commonly used Lanes-Ace gin trap, appears unlikely to continue given the rising opposition to such traps from animal welfare groups. Although some modified leg-hold traps such as the Victor Soft Catch may be permitted (Warburton 1992), there is a general preference for traps which supposedly kill the captured animal quickly, and therefore humanely, rather than hold the animal alive until the return of the trapper.

Kill traps first became available in New Zealand in the mid to late 1970s. Two models were designed in New Zealand specifically for possums, and two were imported from the United States. Field evaluation of these traps showed that none was capture-efficient or acceptably humane (Warburton 1982). Another new model of kill trap (Timms) was developed specifically for possums in the early 1980s. Its ease of use and apparent effectiveness at killing possums has led to its wide acceptance, especially for removing nuisance possums from gardens, orchards, and other easily accessible areas. This trap, however, has limitations for use by commercial trappers and pest control staff because of its size, weight, and low capture efficiency (Miller 1993). Consequently, there is still no kill trap available to them that could replace the leg-hold traps they normally use.

For a kill trap to be acceptable to commercial trappers and pest control staff, it must capture the target animals as efficiently as the traditional leg-hold traps. Kill traps must also kill the captured animal rapidly if they are to be acceptable to the general public. Some generally agreed criteria are needed to evaluate whether a trap has efficient capture and kill rates. To assist in the setting of criteria, an International Organisation for Standardisation (ISO) Technical Committee is currently developing protocols for evaluating traps for humaneness, capture efficiency, and other performance measures (Gilbert

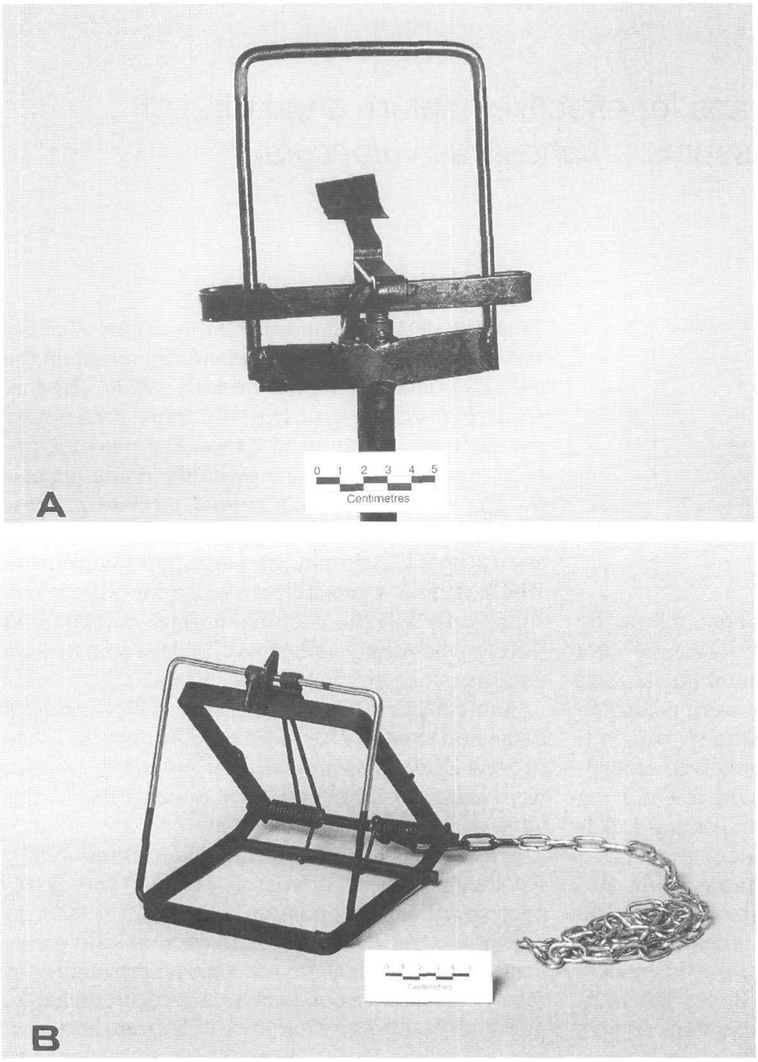


Fig. 1 Five kill trap types evaluated for their humane and capture performance. A, Banya; B, Lokaasklem; C, LDL 101; D, Conibear 160; E, BMI 160.

1991). The evaluations undertaken in this study were based on the draft protocols, which test kill traps in three progressive steps.

The availability of kill-threshold data (Warburton & Hall 1995) allows traps to be screened for their mechanical performance, ensuring that traps tested on animals at the pen stage have sufficient impact momentum and clamping force potentially to provide an acceptably rapid kill. The pen test then evaluates the ability of the trap to capture and strike free-moving target animals in the correct body region, and the field trials evaluate the traps' performance under operational conditions.

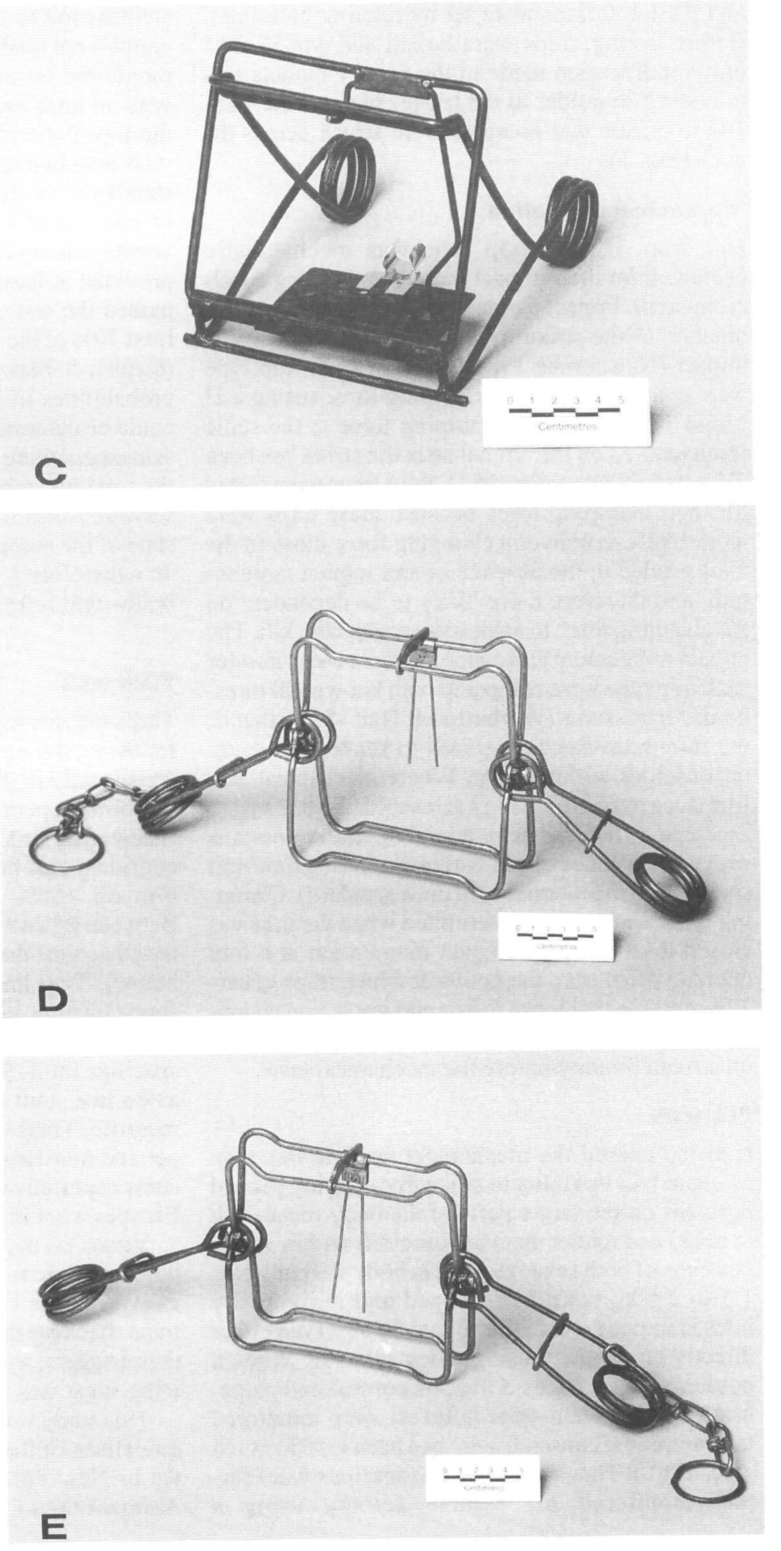
METHODS

Trap types

The trap models selected for evaluation in this trial were compact and light enough to be useful to commercial trappers and pest control staff.

Five trap types were selected (Fig. 1): the Banya from New Zealand, Lokaasklem from Belgium, LDL 101 from Canada, and the Conibear 160 and BMI 160 from the United States. The Banya trap had one striking bar that was designed to strike the animal ventrally, the Lokaasklem and LDL 101 trap were set by cocking a dorsal striking bar, and the Conibear

Fig. 1 *continued*



and BMI 160 traps were set by rotating both jaws. Before testing, traps were boiled and waxed. The only modification made to the factory models was to add a bait holder to the trigger plate of the LDL 101 to ensure that possums were struck across the neck (Fig. 1).

Mechanical evaluation

One trap of each trap type was mechanically evaluated for their impact momentum (using accelerometers). Impact momentum (kg m/s) is the combination of the striking bar mass and its velocity at impact (Newcombe 1981). Four of each trap type were evaluated for their clamping force (using a JJ Lloyd Tensile tester). Clamping force is the static force exerted on the animal after the strike has been delivered (Newcombe 1981). Four traps were tested for their clamping force because these traps were more likely to deliver a clamping force close to the total needed in the absence of any impact momentum, and therefore more likely to be dependent on the clamping force to achieve an acceptable kill. The impact momentum and clamping force measured for each trap type were compared with known kill thresholds for possums (Warburton & Hall 1995), that is, the minimum forces required to render a possum unconscious within 3 min. Where mechanical performance exceeded the kill threshold, the traps were accepted as having the potential to render possums irreversibly unconscious within 3 min (the time unit specified in the international draft standard). Clamping force values were determined when the trap was closed to 20 mm and impact momentum at a trap opening of 70 mm, the points at which traps generally exert the clamping forces and impact on an animal the size of a possum. Traps were fired 10 times on a foam dummy before the mechanical tests.

Pen tests

If a trap passed the mechanical tests, it was then evaluated for its ability to strike free-ranging penned possums on the target parts of the body (head and/or neck) and render them unconscious within 3 min. Possums of both sexes ranging in body weights from 1.5 to 3.5 kg were live-trapped and individually housed in pens where they could be observed either directly or remotely using video cameras. When a possum was struck by a trap, its corneal and palpebral reflexes (brain-stem reflexes) were monitored to determine if consciousness had been lost (Rowsell et al. 1981). Those rendered unconscious were further monitored for cardiac activity using a stethoscope to ensure that death followed. Those animals not rendered unconscious within 3 min were monitored for an additional 2 min then euthanased with an intra-cardiac injection of 200 mg/kg of sodium pentobarbitone.

A two-step sequential test developed for the draft standards was used, which required that at least 10 of 10 or 13 of 15 possums had to be rendered irreversibly unconscious within 3 min. This requirement provided at least a 90% probability that a trap that passed the test could achieve an acceptable kill at least 70% of the time. Kaplan Meier survival curves (Kaplan & Meier 1958) were generated so that the probabilities of possums surviving any given time could be determined. The minimum times to unconsciousness were truncated at about 30 s because of the time taken by the observer to get from the observation area to the trap and assess the conscious state of the animal. Observed times between 30 and 40 s therefore represent maximum times to loss of brain-stem reflexes.

Field tests

Traps that passed the pen tests were then evaluated for their capture efficiency and their ability to strike consistently in the required body region when used in normal operational conditions. For a trap to be accepted as striking consistently, we had to be 95% confident that the trap could strike the target location on >80% of the target animals captured. Between 25 and 30 traps of each model were field-tested against the same number of control traps (see below). Trap lines were set up in forest and along forest/pasture margins, with trap types randomly distributed between sites. Traps were set at c. 50 m spacings for 4–5 nights. Traps were then shifted to a new line, until c. 300 trap-nights per trap type were recorded. Traps were checked daily for captures (target and non-target). The strike location on all possums captured and any sprung traps were recorded. Escapes were identified where possible.

Victor 1½ unpadded traps, a commonly used leghold trap type for which capture-efficiency data exist (Warburton 1982, 1992), were used as the control traps. Because the kill traps required a solid bait for their triggers, a piece of apple coated with flour and icing sugar was used for all traps.

This study was conducted in accordance with the guidelines of the National Animal Ethics Committee of New Zealand and with Landcare Research Animal Ethics Committee approval.

RESULTS

Mechanical tests

All five trap types produced impact momentums well below the 7–8 kg m/s required to induce unconsciousness in the absence of a clamping force (Table 1, Fig. 2). Clamping forces varied considerably between trap types and within some trap types (e.g., Conibear 160).

The mechanical forces exerted by three of the trap models (LDL 101, Conibear 160, and BMI 160) exceeded the kill threshold for possums (Fig. 2). The Banya and Lokaasklem had insufficient clamping force and impact momentum to have any potential for killing effectively and were therefore not evaluated on possums in pen tests.

Pen tests

The LDL 101 and BMI 160 made enough successful strikes to pass the pen test, although both recorded some failures (Table 2). The Conibear 160 had two unsuccessful strikes before 10 possums had been tested and was therefore rejected from further testing. For the LDL 101 and BMI 160 traps, the mean time to loss of consciousness for the successful strikes was 71 and 65 s, respectively. Possums captured in LDL 101 traps had a 0.33 probability of surviving longer than 1 min but only a 0.07 probability of surviving longer than 2 min 25 s (Fig. 3). Possums caught in BMI 160 traps had a much lower probability of surviving longer than 30 s (0.33) than those captured in either the LDL 101 (0.54) or the Conibear 160 (0.86) (Fig. 3).

The LDL 101 struck the 15 test possums across the neck, although three also had one forelimb caught in the trap. The one strike that failed to render the possum unconscious within the approved time of 3 min (3 min 12 s) struck the animal correctly, but with only one corner of the trap. The strike locations of the BMI 160 trap were less consistent: three possums were struck by the dorsal bar anterior to the ears and by the ventral bar anterior to the angle of the jaw; one was struck on the base of the neck and shoulder; three were struck across the neck; and eight were struck by the dorsal bar anterior to the ears but

Table 1 Impact momentums and clamping forces of five kill traps.

Trap model	Impact momentum (kg m/s) @ 70 mm	Clamping force (N) @ 20 mm, mean (range)
Banya	0.50	67.0 (60–75)
Lokaasklem	1.10	59.3 (55–61)
LDL 101	0.71	150.8 (118–165)
Conibear 160	2.20	54.5 (0–125)
BMI 160	2.20	166.5 (115–305)

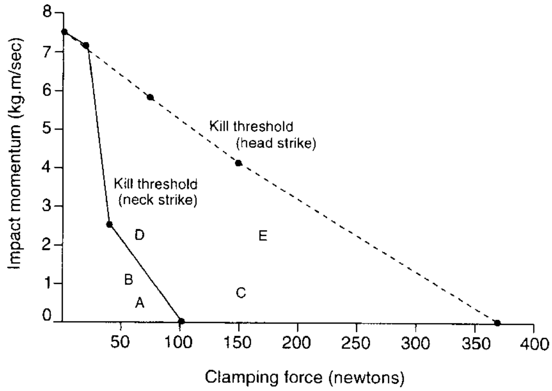


Fig. 2 Mechanical performance of test traps in relation to kill thresholds for possums struck on the neck and head. A, Banya; B, Lokaasklem; C, LDL 101; D, Conibear 160; E, BMI 160.

Table 2 Time to unconsciousness (UC) and cardiac arrest (CA) for possums caught in three kill trap types during pen trials. Statistically similar body weights are indicated by an ($_a$) as tested by Fisher's Least-Significant-Difference test.

Possum number	Conibear 160 UC	Conibear 160 CA	BMI 160 UC	BMI 160 CA	LDL 101 UC	LDL 101 CA
	Time to (min.s)					
1	1.05	3.41	2.50	7.02	0.32	7.05
2	1.46	3.52	2.35	6.41	0.38	5.07
3	1.06	4.31	0.55	4.50	0.51	7.24
4	>5.00	–	0.33	3.04	1.29	5.20
5	0.49	4.55	0.46	3.53	1.54	5.15
6	1.47	11.25	1.36	6.35	2.02	6.45
7	>5.00	–	>4.00*	–	2.09	8.10
8			0.31	7.20	2.25	9.34
9			0.40	8.42	3.12	9.00
10			0.47	6.10	0.31	8.06
11			0.37	4.56	0.34	5.33
12			0.54	6.45	0.39	9.47
13			0.45	4.04	0.45	7.30
14			0.35	6.45	1.01	11.28
15			>5.00	–	1.02	5.34
Mean wt (kg)	2.3_a		2.1_a		2.9	

*Possum euthanased at 4 min instead of 5 min.

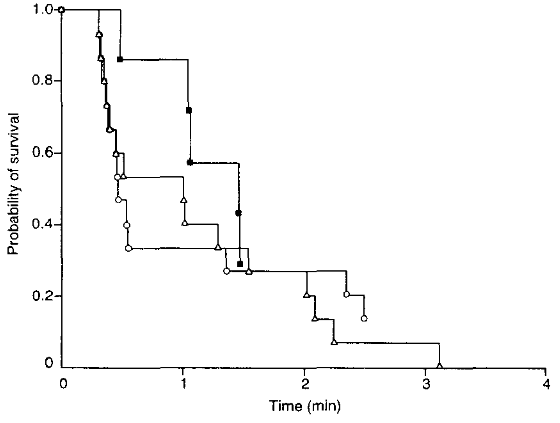


Fig. 3 Survival curves of possums captured in LDL 101 (△), BMI 160 (○), and Conibear 160 (■) traps. Only times less than 4 min are shown.

across the neck by the ventral bar. The seven Conibear 160 strikes were all across the neck, although two had dorsal bar strikes just anterior to the ears. These two animals were rendered unconscious within 3 min. The possums tested in the LDL 101 trap were significantly heavier than those tested in the BMI 160 and Conibear 160 traps, for which weights were similar (Table 2). Possum body weight did not appear to influence the times to unconsciousness, however (Table 3).

Field tests

Thirty LDL 101 and 30 BMI 160 traps were evaluated in separate field tests. In the LDL 101 trial, 270 trap-nights were recorded for the test and control traps, resulting in the capture of 207 possums (Table 4a). In the BMI 160 trial, 303 trap-nights were obtained for the BMI 160 traps and 310 trap-nights for the Victor control traps, with 260 possums caught (Table 4b). The LDL 101's capture efficiency (34%) was similar to that of the Victor (42%; $\chi^2 = 3.455$, $P = 0.065$), but the BMI 160's capture efficiency (34.3%) was significantly less than that of the Victor (50.3%; $\chi^2 = 16.059$, $P < 0.001$).

Both the BMI 160 and LDL 101 trap types allowed similar percentages of escapes (6.3 and 6.1%, respectively). A higher percentage of LDL101 traps were sprung without making a capture (6.6%) than the BMI 160 (0.7%; $\chi^2 = 15.292$, $P < 0.001$), mostly by possums interfering with the trap.

The LDL 101 struck 92.5 ± 5.4% of 93 possums on the target body region (neck), plus one possum (1%) caught across the shoulders and six (6%) across the thorax. All possums caught in the LDL 101 traps were killed. The BMI 160 struck the target location less consistently than the LDL 101 ($\chi^2 = 5.408$,

Table 3 ANOVA results of possum's weights and trap type on time to unconsciousness.

Source	*F*-ratio	Probability
Weight	0.123	0.729
Trap	1.130	0.297
Trap × weight	0.990	0.329

Table 4 Capture data from LDL 101 and BMI 160 field tests using Victor 1½ traps as controls.

Trap status & species caught	Number of captures	
	LDL 101	Victor 1½
a) LDL 101		
Escapes (fur in trap)	6	6
Sprung (no fur in trap)	18	3
Possum	93	114
Hedgehog (*Erinaceus europaeus*)	20	15
Ferret (*Mustela furo*)	2	4
Rat (*Rattus rattus*)	4	1
Cat (*Felis catus*)	0	1
	BMI 160	**Victor 1½**
b) BMI 160		
Escapes (fur in trap)	7	0
Sprung (no fur in trap)	2	3
Possum	104	156
Hedgehog	3	2
Sheep	0	1

Table 5 Species and mortality of all animals caught in the LDL 101 and BMI 160 traps during field trials.

	Number of captures (%)			
	LDL 101		BMI 160	
Species	Dead	Alive	Dead	Alive
Possum	93 (100)	0	101 (97)	3 (3)
Hedgehog	11 (55)	9 (45)	1 (33)	2 (66)
Ferret	1 (50)	1 (50)	–	–
Rat	1 (25)	3 (75)	–	–

$P = 0.02$), with 18 (17.3%) struck across the thorax, shoulders, head anterior to the eyes, and limbs (82.7 ± 3.5% correct strikes). Apart from three caught only by the limbs, all possums were killed.

Both test trap types captured non-target species, most commonly hedgehogs (Table 5). The LDL 101 trial was conducted in late summer when hedgehogs were plentiful, and setting the trap on the ground gave this species ready access to the trap. The LDL 101 killed 55% of hedgehogs captured and the BMI 160 killed 33% (Table 5).

DISCUSSION

Only one of the five traps tested (LDL 101) satisfied the requirements of the draft ISO standard. Two (Banya and Lokaasklem) had insufficient mechanical performance and would not have killed possums rapidly enough to be acceptable. One (Conibear 160) failed to kill enough possums during pen trials, and one (BMI 160) failed to achieve a sufficiently high number of correct strikes during the field trials. The ISO standard requirements therefore provide a rigorous testing procedure that most kill traps now used in New Zealand for trapping possums would not pass. However, the trial does indicate that it is possible to develop compact and relatively light-weight traps to kill possums humanely and efficiently.

Past evaluations of kill traps for possums have recorded capture efficiencies significantly lower than that achievable by leg-hold traps (Warburton 1982). The LDL 101, however, performed well and should be considered as a serious alternative to leg-hold traps. It is light (450 g, similar to that of commonly used leg-hold traps) and compact enough to be carried in sufficient numbers to make it a useful trap for use in inaccessible areas. Because this trap is not designed for capturing possums, the trigger plate must be modified to ensure that the possum is struck on the neck. Further minor development would therefore be required before the LDL 101 would be commercially available for trapping possums.

Although the BMI 160 had sufficient power to kill all possums caught across the head or neck, the trap proved difficult to set to achieve a consistent strike location. The survival curves show that these traps render possums unconscious more rapidly than the LDL 101 or Conibear 160 when they strike the possum across the neck, but take longer if they strike across the head or shoulders. If these less-effective strikes could be avoided, the BMI 160 trap should be able to achieve consistent kills within 30–40 s. Trappers in New Zealand are unfamiliar with using this trap design, so the results obtained in these trials may reflect the inexperience of the trappers rather than any fault in the trap design. These results should not therefore preclude further trials on this trap and others that operate with a similar rotating jaw configuration.

At a jaw spacing of 20 mm, the Conibear 160 had clamping forces that ranged from 0–125 N. During the mechanical testing, it was noted that at a jaw spacing of 30 mm or greater the clamping force was >200 N. It is therefore critical that a trap is designed such that the clamping force is maximised at the jaw spacing most commonly resulting after capture of any particular target species. This is achieved in part by the BMI trap by reverse bending the jaws so that the spring levers can exert more clamping force when extended. It was also noted that the Conibear and BMI 160 jaws bent apart after being fired several times, and the resulting gap could have contributed to a decrease in the clamping force being delivered.

The times to unconsciousness recorded from possums captured in the LDL 101 and BMI 160 traps during pen trials showed that some possums were killed more efficiently than others. The times were aggregated in three groups, 30–40 s, 1–1½ min, and 2–2½ min (Fig. 3). We suggest that the fastest times to unconsciousness result from carotid occlusion and cerebral anoxia, and the longer times primarily from asphyxiation. If traps could be designed to maximise the number of strikes achieving carotid occlusion, then kill trapping could become significantly more humane and might be more acceptable to the public.

Both kill-trap types that progressed to field testing captured and killed non-target species, although these were all introduced species. The degree to which a trap system is target-selective is affected by factors including the abundance of non-target species present, the bait type used, and the set used by the trapper. In general, careful selection of bait type and set will keep the number of non-target captures to a minimum.

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