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Practicality and humaneness of euthanasia of pest birds with compressed carbon dioxide (CO_2) and carbon monoxide (CO) from petrol engine exhaust

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Abstract. Feral birds degrade the environment and have an adverse impact on human health, welfare and economy in many parts of the world. In eastern Australia, common myna (*Acridotheres tristis*), common starling (*Sturnus vulgaris*) and house sparrow (*Passer domesticus*) have recently become targets of community groups seeking to control impacts by selective live-trapping. We sought a safe and practical euthanasia method that could be recommended to such groups for humanely destroying trapped birds. We compared the practicality and humaneness of the following two commonly available inhalant euthanasia agents: (1) carbon dioxide (CO_2) from cylinders and (2) carbon monoxide (CO) from cooled exhaust from idling petrol engines. Test birds were euthanased in conditions that promoted calm (small groups of birds; small covered chambers with perches). Video recordings were analysed in real time and at 1/10 speed for signs of distress, and times to recumbency and last movement. In all, 25 mynas and 24 starlings were euthanased with CO_2, and 32 mynas, 30 starlings and 8 sparrows with CO. Times to recumbency for birds euthanased with CO_2 varied from 20 to 85 s and time to last movement from 65 to 153 s. For birds euthanased with CO, these times were 7–180 s and 43–240 s respectively. Mynas and starlings euthanased with CO_2 showed substantially more signs of distress (gaping and head-shaking) before recumbency than did birds euthanased with CO, although this was less pronounced if the concentration was increased slowly. No signs of distress were observed in any birds euthanased with CO, irrespective of the rate at which the concentration was increased. CO produced a comparably rapid, and more humane death than did CO_2 in birds of all three study species. The study indicated that, with simple precautions to avoid accidental exposure, CO in cooled exhaust from petrol engines provides a safe, rapid and humane agent for euthanasing mynas, starlings and sparrows, that is readily available at a very low cost. We tested only three species, and the results suggested that it would be useful to re-examine the embargo against animal euthanasia via engine exhaust, that exists in many jurisdictions.

Introduction

A growing awareness of the negative impacts of feral animals on biodiversity, economic prosperity and amenity (Lowe *et al.* 2000; Olsen *et al.* 2006; Tracey *et al.* 2007) has generated substantial community interest in the possibility of reducing the impacts of pest birds by selective live-trapping. Recently, common myna (*Acridotheres tristis*), common starling (*Sturnus vulgaris*) and house sparrow (*Passer domesticus*) have been singled out for attention by community groups in Australia; in other parts of the world, feral pigeons (*Columba livia*) have been the subject of sustained trapping effort over a much longer time frame (Johnston and Janiga 1995). In general, where species are declared feral, permission from government agencies is not required to trap and kill them, although there is usually a legal obligation for it to be done without cruelty. In their countries of origin, by contrast, the status of these species, that are invasive elsewhere, may be quite different. Starlings and sparrows, for example, are red-listed as birds of conservation concern in the UK; special permission is required to trap or kill them (RSPB 2009). Several types of traps that enable selective trapping of mynas and starlings have been developed recently and community groups are using them to catch quite large numbers of birds. The Canberra Indian Myna Action Group (CIMAG), for example, recently reported that more than 24 000 mynas and 3000 starlings had been trapped and euthanased since the group's inception in 2006 (http://www.indianmynaaction.org.au, verified June 2009). There is a growing demand from these groups for access to a simple and humane method of euthanasia that can be used to kill pest birds caught in live-trapping programs.

Our aim was to assess and report on a simple and humane method for killing live-trapped pest birds. Official recommendations for euthanasing pest birds (and other animals) vary greatly between jurisdictions in Australia and elsewhere; not all are appropriate for large numbers of birds. We predetermined, for example, that any methods that required individual restraint, e.g. cervical dislocation or lethal injection, were inappropriate for large batches of birds, because they imposed great stress on the birds as they were caught, greatly increased the risk of escape, and were unacceptably time-

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consuming. Additionally, the drugs required for lethal injection are not legally available to members of the public. Two methods that seemed potentially suitable for euthanasing large batches of mynas and starlings were inhalation of (1) CO_2 and (2) CO. CO_2 is readily available in cylinders, with no restriction on possession or use; it is commonly used to pressurise beverages. CO is readily available as a component of the exhaust of petrol engines.

We have been using compressed CO_2 for several years to euthanase mynas and starlings caught in selective traps (Tidemann 2005), and have pondered its suitability; first, because birds killed with CO_2 appeared to be showing signs of distress before loss of consciousness, and, second, because of cost, especially for large numbers of birds. Anecdotal reports suggested that, because of the cost (and logistical problems), very few community-based bird-control groups have been prepared to purchase CO_2 regulators and gas; the great majority, it seems, have been using car exhaust, which is extremely cheap, readily obtainable and, reportedly, humane (Bill Handke, CIMAG, pers. comm.). We found several published recommendations against the use of CO for euthanasia (e.g. AVMA 2007; Sharp and Saunders 2008), because of the presence of respiratory irritants (unburnt hydrocarbons and oxides of nitrogen, NO_x) and inadequate cooling of exhaust gas; however, we could find no published descriptions of CO_2 or CO actually having been trialled as euthanasia agents with mynas, starlings or sparrows. DEFRA (2005), in relation to euthanasia of badgers, concluded that objections about irritants in exhaust gas were probably not well founded in evidence.

Accordingly, we set out to compare the humaneness and practicality of euthanasia of these birds via inhalation of (1) CO_2 from pressurised cylinders and (2) water-cooled exhaust, containing CO from petrol engines. We designed a series of simple experiments to compare the effect of the two gases on the study animals, with a particular reference to the two stated objections to their use, including (1) unacceptably high exhaust gas temperatures and (2) the presence of respiratory irritants. The design provided for gas temperatures to be measured directly (and modified); the presence of irritants was assessed by monitoring behavioural responses of test birds.

Materials and methods

Study animals

Mynas and starlings were live-trapped in and around Canberra with selective valve traps (Myna Magnet traps, http://www.mynamagnet.com.au, verified March 2009, or Pee Gee traps, http://www.indianmynaaction.org.au). Before the trials began, birds were held for several days in a large outdoor aviary, with *ad lib* food and water to ensure that they were well fed and in good health. Sparrows were trapped by mist-net at nearby Murrumbateman, NSW, and immediately euthanased following the procedures outlined below.

Euthanasia procedures

Euthanasia procedures were designed to maximise animal welfare, even though this resulted in some loss of detail in the results (we are only able to provide ranges, rather than the more usual measures of central tendency; hence, no statistical comparisons are appropriate). We felt that the small loss of detail was unimportant, compared with the importance of determining how best to generate a stress-free death. Euthanasia chambers were provided with multiple perches and covered in shade cloth to provide an environment to minimise stress. Test birds were euthanased in small groups (8–16 individuals) rather than individually, to promote calm, although this meant that it was not possible to determine individual times to recumbency; detail of one bird falling off a perch was often obscured by another falling nearby. Similarly, it was not possible to determine individual times to complete loss of movement, because movement of one individual was frequently obscured by other birds, some moving, some not. The first and last recumbency and the last movement events were possible to score unambiguously, and seemed to be adequate to evaluate the birds' behaviour.

The trials were observed directly and recorded on video (Sony HDR-SR7E Handycam; SONY, Tokyo) through a transparent window in each chamber. Video recordings were later analysed in real time and at 1/10th speed for any behavioural evidence of distress, to determine individual times to recumbency (= bird falls off perch, that we equated with loss of consciousness), and last discernible movement of the last bird of each batch.

We did not have access to equipment for measuring gas concentrations (except %CO in selected exhaust, see below); therefore, to compare the effect of increasing the CO_2 concentration rapidly or slowly, we used the same gas source (cylinder plus regulator fully open) with different chamber sizes. We achieved a similar effect with CO by using different gas sources (engines) and different chamber sizes. Chambers were of three sizes (small, 100 L; medium, 223 L; large, 576 L), the first and last of which are chamber sizes commonly used by the public to euthanase pest birds; small = Pee Gee; large = Myna Magnet; the medium chamber has been designed for modular use with very large numbers of birds. A total of 119 birds was euthanased; in the first four trials, 25 mynas and 24 starlings were euthanased with CO_2; in the remaining eight trials, mynas (32), starlings (30) and sparrows (8) were euthanased with CO.

Carbon dioxide source

Compressed industrial CO_2 was delivered to the euthanasia chambers via a 3-m plastic hose from a D-size (15 kg) cylinder (BOC Gases, Canberra, ACT) and a fully opened regulator (COMET 500 CO_2 regulator #301681, CIGWELD Australia, Melbourne, Vic.). The 301681 regulator is stated by the manufacturers to deliver a sustained flow of $30\,L\,min^{-1}$, although they note that the flow rate is influenced by ambient temperature, among other factors.

Carbon monoxide sources

Carbon monoxide for the euthanasia trials was sourced from three sizes of four-stroke petrol engine, i.e. small, medium and large, all running at fast idle. The small (148 cc, 3.5 HP) and medium (600 and 630 cc, 18 and 20 HP respectively) engines were air-cooled units (2006–08 manufacture, Briggs & Stratton, Milwaukee, WI), not fitted with catalytic converters; exhaust gas from these was cooled by bubbling it through a 10-L water bath and then piping it to the euthanasia chamber via a 3-m plastic hose. The large engine was a water-cooled 1500-cc Daewoo Lanos (1997 manufacture), fitted with a catalytic converter;

exhaust from this engine, from a cold start, was cooled and transferred to the euthanasia chamber by passing it through a 4-m rubber hose.

Measurements of carbon monoxide concentrations in exhaust

Carbon monoxide outputs (%CO) of various engines were compared with a Coda 5-gas exhaust analyser (Coda Products, Newcastle; http://www.coda.com.au/Products/eas.html). The following two engines were used to plot CO concentrations from a cold start: (1) a very small (25 cc) engine without catalytic conversion (Honda 4-stroke whipper-snipper GZ25, 2008), and (2) a large (1500 cc) catalytically converted engine (Daewoo Lanos, 1997). Measurements of CO output of the small and medium engines were made at operating temperature. The very small engine was not used in subsequent trials.

Measurements of gas temperatures

Exhaust temperatures of the small and medium engines were measured with an infrared thermometer (ZyTemp, TN205 L; ZyTemp Products, HsinChu, Taiwan) at the end of the exhaust pipe and after passage through the water bath after 1 min of running and after 3 min of running (Table 1). Exhaust from the Daewoo and two other large, catalytically converted engines, namely (1) 2200-cc Ford Courier 1989 and (2) 2700-cc Toyota Hiace 2008, was used to investigate the temperature of car exhaust gas before and after supplementary cooling. In the case of the large engines, we measured the exhaust gas temperature after 1 min and 3 min of running, at the end of the exhaust pipe and after the gas had passed through a 4-m rubber hose (Myna Magnet gassing hose and adaptor). Hoses such as these, that fit snugly into a car exhaust pipe, are commonly used by members of the public for bird euthanasia.

Results

Euthanasia with carbon dioxide

Mynas ($n = 25$) and starlings ($n = 24$) euthanased with CO_2 fell from their perches (were rendered recumbent, which we equated with loss of consciousness) in short times after the initial introduction of the gas. Recumbency times varied from 20 to 85 s, and time until all movement had ceased varied from 65 to 153 s. The effect of chamber size, and hence the rate at which gas concentration increased (the regulator was at maximum flow in all trials), is clearly evident from Table 2; a more rapid rate of increase resulted in a quicker death.

No vocalisations were recorded during these trials. The following two types of movement, which we construed to indicate distress, were made before recumbency and, hence, presumably while the birds were still conscious: (1) gaping, in which the beak was repeatedly opened to maximum gape (30–50°); and (2) head-shaking, in which the head, and sometimes the whole body, was rapidly swivelled from side to side, two or three times in quick succession (over ~100 ms). Head-shaking was noticeable only when the video was slowed down; gaping could be seen quite clearly in real time. We recorded gaping in all birds of both species, and head-shaking in ~50% of mynas and ~25% of starlings. Head-shaking was invariably preceded and followed by gaping. No sparrows were euthanased with CO_2.

Measurement of exhaust gas temperature

The temperature of exhaust gas from various petrol engines before and after supplementary cooling, and after 1 min and 3 min of running, is shown in Table 3. The exhaust temperature of air-cooled engines is extremely hot at the exhaust pipe; however, it can be cooled readily to a temperature that will not be stressful to birds ($\leq$30°C). Water-cooled engines (i.e. nearly all cars) produce much cooler exhaust than air-cooled engines, with the increase in temperature over 3 min of running being slight. The extra cooling provided by the 4-m rubber delivery hose provided extra insurance that the temperature of the exhaust was well below the level that could stress birds.

Concentrations of CO in cooled exhaust from petrol engines

Figure 1 shows CO concentration in exhaust from a catalytically converted car engine from a cold start; Fig. 2 shows CO concentration in cooled exhaust from a very small engine without catalytic conversion, also started from cold. CO concentration in exhaust from the catalytically converted engine from a cold start was initially high at 6%, and dropped off to a stable low of $\leq$1% as the catalytic converter approached the operating temperature; the engine without a catalytic converter, by contrast, stabilised at a peak level of ~3%, once the operating temperature was reached.

Table 1 summarises peak CO concentration (%) in exhaust produced by a range of petrol engines (and the results of

Table 1. Peak CO concentration from source engines and time (range) to recumbency (= loss of consciousness) and last movement of mynas, starlings and sparrows euthanased with CO from cooled petrol engine exhaust

Engine size	Peak CO (%)	Chamber size	*n* Mynas	*n* Starlings	*n* Sparrows	Time to recumbency (s)	Time to last movement (s)
Small	6.5	Small		7		35–40	65
Small	6.5	Medium			8	25–41	62
Medium	9	Medium	8			15–30	65
Medium	9	Medium		8		19–26	54
Medium	9	Medium	10			27–34	72
Medium	9	Large	5	4		110–180	240
Large	6	Small	9			7–11	43
Large	6	Large		11		100–130	210

Table 2. Time (range) to recumbency (= loss of consciousness) and last movement of mynas and starlings euthanased with CO_2 from a cylinder and regulator

Only the first and last birds to fall and the last movement from the last bird are presented because euthanasia in small groups precluded measuring other individual values

Chamber size	*n* Mynas	Starlings	Time to recumbency (s)	Time to last movement (s)
Medium		11	20–34	65
Medium	9		26–39	80
Large		13	45–64	125
Large	16		49–85	153

euthanasia of mynas, starlings and sparrows with this exhaust). Peak CO concentrations varied substantially between engines, depending presumably on the sophistication of the combustion system. All of the small and medium engines that we tested were of recent manufacture, although the design in some cases may have been developed many years previously. CO concentration in cooled exhaust from small (148 cc) and medium (630 cc) engines at operating temperature was 6.5% and 9% respectively. The large engine, with catalytic conversion, initially produced exhaust containing CO, at 6%, which dropped to 1% 60 s after starting (Fig. 1).

Euthanasia with carbon monoxide

Table 1 summarises the results of euthanasia of 32 mynas, 30 starlings and eight sparrows, with CO in cooled exhaust from various engines and with three chamber sizes. The interaction of engine size (and hence volume of exhaust and CO produced) and chamber size is apparent. The shortest time to all birds falling off their perch was recorded with the large engine and a small chamber (7–11 s to recumbency, 43 s to last movement), although the range was large (recumbency 7–180 s, last movement 43–240 s). It is clear that the relationship may not be linear and there may be fine-level specific differences, although in general, the smaller the engine and the larger the chamber, the slower the process. The process overall was similar in each case, with the birds gradually becoming stupefied and losing consciousness, and eventually ceasing movement altogether. No vocalisations were observed, nor did we see gaping and head-shaking, which we had observed in birds euthanased with CO_2.

Discussion

It is clear to us from these trials that inhalation of cooled engine exhaust containing CO produced a humane death in mynas, starlings and sparrows. We did not observe gaping or head-shaking in any bird euthanased with CO, whereas pronounced gaping was observed in all trials involving CO_2; head-shaking was particularly evident in mynas, less so in starlings. We construe both gaping and head-shaking to be evidence of distress, because both behaviours occurred well before recumbency, i.e. presumably while the birds were still conscious. Webster and Fletcher (2001) reported similar signs of distress in domestic chickens euthanased with CO_2, although Gerritzen *et al*. (2006) found no more signs of distress in domestic chickens euthanased with CO_2 than with CO, suggesting that there may be species-specific and/or dose-related responses involved. Raj *et al*. (2006) reported that CO_2 was aversive to domestic chickens. CO_2 can be unpleasant to humans, owing to its pungent odour and acidic properties that cause irritation and pain to the mucosa, and because it causes feelings of breathlessness (Raj *et al.* 2006). It may be that birds experience greater discomfort than mammals from CO_2 because the feelings of discomfort affect the whole of the respiratory system, including the air sacs. Hawkins *et al*. (2006) concluded that laboratory rats euthanased with CO_2 'remained conscious, and. . .likely to be experiencing pain, for at least 10 to 15 seconds in high concentrations of CO_2'. CO_2 is in widespread use for euthanasia of poultry and other animals (Kingston *et al.* 2005; Gerritzen *et al.* 2006; AVMA 2007), although the evidence suggests that it may not be the most humane method available.

Apart from the issue of humaneness, a major obstacle to the use of CO_2 as a euthanasia agent is cost, especially for budget-constrained community groups. An informal 'straw poll' indicated that few, if any, of the now quite numerous myna action groups in eastern Australia use CO_2 as a euthanasia agent because of cost and logistical problems associated with transport of the apparatus (W. Handke, pers. comm.). A 15-kg cylinder of compressed CO_2 (enough to euthanase ~100 birds, depending on chamber and batch sizes) costs AU$204 for a 12-month period, plus a regulator at AU$121 (BOC Gases, Canberra, March 2009). Clearly, euthanasing large numbers of birds at once with CO_2 would not be cost-effective, in addition to being less humane than the alternative, cooled engine exhaust containing CO, which is virtually free of charge. Close *et al.* (1996) recommended exhaust from idling petrol engines passed through a water bath (such as we used with small and medium air-cooled engines) as a suitable euthanasia agent for a variety of

Table 3. Temperature of exhaust gas at exhaust pipe and at delivery after supplementary cooling (water bath or 4-m hose) from five different petrol engines after 60 s and 180 s of running

Engine cooling was factory fitted; exhaust cooling was customised

Engine size	Engine cooling	Ambient temperature (°C)	Exhaust cooling	Temperature (°C) At exhaust after 60 s	At delivery after 60 s	At exhaust after 180 s	At delivery after 180 s
Small	Air	23	Water bath	150	23	>250	30
Medium	Air	28	Water bath	73	29	135	30
Large	Water	17	4-m hose	19	19	21	21
Large	Water	20	4-m hose	21	19	28	24
Large	Water	24	4-m hose	29	25	31	30

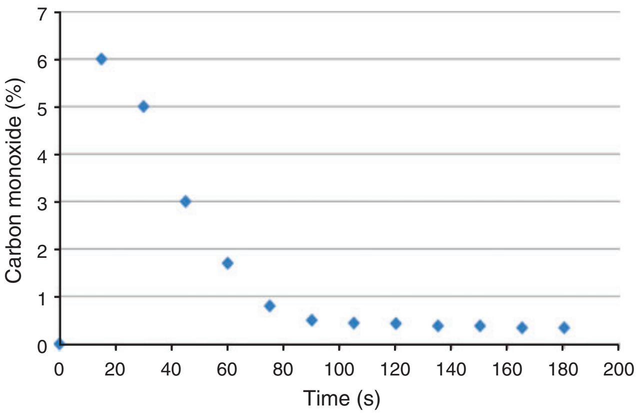

Fig. 1. Concentration of carbon monoxide (%CO) in cooled exhaust from a 1500-cc catalytically converted engine (small car) from a cold start. In a catalytically converted engine, CO emissions are initially high and stabilise at a relatively low level as the engine warms and the converter reaches the operating temperature.

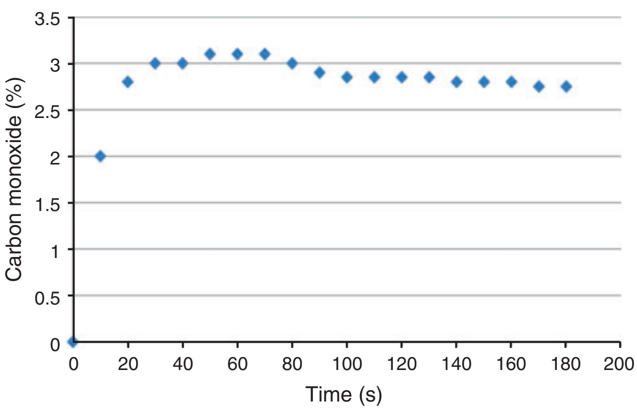

Fig. 2. Concentration of carbon monoxide (%CO) in cooled exhaust from a 25-cc petrol engine without a catalytic converter (four-stroke whipper-snipper) from a cold start. In a petrol engine without a catalytic converter, CO concentration rises initially and then reaches a plateau at a relatively high concentration.

species; however, the recent addition of catalytic converters to cars has meant that exhaust gas is no longer considered suitable by some authorities (e.g. AVMA 2007; Sharp and Saunders 2008). This embargo on the use of petrol engine exhaust has eventuated (1) because once a catalytically converted engine reaches the operating temperature it does not contain a high enough concentration of CO to be lethal and (2) because it has been thought that the gas is also likely to be hot and contain irritants. Our measurements of exhaust-gas temperatures show that cooling to an acceptable temperature ($\leq$30°C) is not difficult to achieve and that exhaust from cold starts contains more than enough CO to be quickly lethal, especially with a large motor that produces a large volume of gas. The complete absence of signs of distress in birds euthanased with cooled engine exhaust convinced us that irritants, if present, are not generating distress in the short times involved before unconsciousness. DEFRA (2005) concluded that CO from exhaust was a humane euthanasia agent for badgers and Gigliotti *et al*. (2009) concluded that it was humane for rabbits.

Our trials demonstrated that exhaust from petrol engines ensures a rapid, humane death in the test species, provided the exhaust is cooled before use. Alternatively, if the exhaust is sourced from catalytically converted cars, only exhaust immediately following a cold start should be used. It may be, because of progressively more stringent limits placed on emissions from cars (DOTARS 2009), that exhaust from more modern cars will eventually become unsuitable for euthanasia under any circumstances. At present in Australia, small non-road engines (e.g. push and ride-on lawn mowers, petrol-powered pumps, generators) are not required by law to be fitted with catalytic converters and thus provide an ideal potential source of CO, provided the exhaust is cooled by passing it through a water bath or long hose. One cautionary note is that exhaust from diesel engines is not suitable because it contains little CO and high levels of highly irritant nitrogen oxides NO_x (DEFRA 2005). We did not test two-stroke petrol engines, and consider it possible that the admixture of oil to two-stroke fuel would generate respiratory irritation and distress from the burnt oil.

Compressed CO has been recommended as a euthanasia agent superior to that sourced from engines by AVMA (2007), although there are two very serious drawbacks to compressed cylinders as a gas source. First, CO is highly explosive at concentrations above 12% (NIOSH 2007). CO in exhaust gases does not reach a high enough concentration to be explosive because it has already been through a combustion process. Second, the cost of compressed CO is prohibitive. An 11.8-kg cylinder of CO (enough to euthanase ~500 birds, depending on chamber size and batch numbers) costs AU$1006 for a 12-month period, plus a regulator at AU$596 (BOC gases, Canberra, March 2009).

Recommendations vary greatly for the 'ideal' CO concentration that should be reached in euthanasia chambers, and how quickly it should be attained. Our results indicated that some of the recommendations in the literature are higher than necessary for mynas, starlings and sparrows. Close *et al*. (1996) and AVMA (2007) made generic recommendations that a concentration of 6% CO should be used, whereas Gerritzen *et al*. (2006) found that a concentration of 1.5–2% was toxic to domestic chickens. Our trials with starlings and sparrows used a small engine (i.e. small exhaust volume) that produced a peak concentration of only 6.5% CO after 2–3 min of running; however, in both these trials the birds lost consciousness well before this time. It is also clear from the present study that it is not necessary to saturate the chamber with CO beforehand or immediately, as recommended by Close *et al*. (1996) and AVMA (2007). In our trials with CO, the concentration was increased at differing rates, starting from zero; however, in no instance did we see signs of distress in any of the three study species at any rate of increase in concentration. In any event, there seems little to be gained by recommending that euthanasia practitioners ensure a certain gas concentration if the majority of them do not have access to gas-measuring equipment. Instead, we recommend that simple behavioural evaluations, such as we used in the present study, are a better way of guarding against possible untoward idiosyncratic responses to cooled exhaust gas. It seems likely that cooled exhaust gas would also be a practical and humane euthanasia agent for other pest bird species, especially those that are the subject of live-trapping programs, such as feral pigeons.

One significant concern with the use of CO, sourced either from cylinders or engine exhaust, is the occupational health and safety issue of the toxicity of the gas to humans. CO can be extremely hazardous because it is difficult to detect without instrumentation and, in confined spaces, it is highly toxic (HSE 2009). In humans, exposure to 0.32% CO and 0.45% CO for 1 h will induce loss of consciousness and death, respectively; chronic exposure at lower concentrations can also cause subacute malaise (AVMA 2007; HSE 2009). However, if simple precautions are followed, such as performing euthanasia out of doors and with adequate ventilation to purge any residual toxic gas from euthanasia chambers before reuse, it is difficult to see risks additional to that imposed by the everyday use of any petrol engine.

Conclusions

We conclude that if simple precautions to avoid accidental exposure are followed, CO from cooled petrol engine exhaust is a more practical and humane euthanasia agent than CO_2 for mynas, starlings and sparrows. CO is safer for operators than CO_2, because it does not involve the transport of pressurised cylinders and it is produced only when an engine is running. CO is similarly rapid for killing these birds as is CO_2, and it is more humane, more widely available and far cheaper than CO_2. CO_2 can be prohibitively expensive for community groups – and problematic, because of occupational health and safety and logistic issues, for local government officers who may wish to provide euthanasia facilities in support of community actions. We tested only three species, and the results suggested that it would be useful to re-examine the embargo against animal euthanasia via engine exhaust, that exists in many countries. We recommend that official recommendations for euthanasia procedures be reviewed to reflect these findings.

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References

American Veterinary Medical Association (AVMA) (2007). 'Guidelines on Euthanasia.' Available at http://www.avma.org/issues/animal_welfare/euthanasia.pdf [Verified January 2009].

Close, B., Banister, K., Baumans, V., Bernoth, E.-M., Bromage, N., *et al.* (1996). Recommendations for euthanasia of experimental animals: part 1. *Laboratory Animals* **30**, 293–316. doi: 10.1258/002367796780739871

DEFRA (2005). Review of effectiveness, environmental impact, humaneness and feasibility of lethal methods for badger control. Report to European Wildlife Division. Department for Environment, Food and Rural Affairs, London.

DOTARS (2009). Summary of emission requirements for new petrol passenger cars in Australia 1972–2010. Australian Government, Department of Infrastructure, Transport, Regional Development and Local Government, Canberra. Available at http://www.infrastructure.gov.au/roads/environment/impact/emission.aspx [Verified February 2009].

Gerritzen, M. A., Lambooij, E., Stegeman, J. A., and Spruijt, B. M. (2006). Slaughter of poultry during the epidemic of avian influenza in the Netherlands in 2003. *Veterinary Record* **159**, 39–42.

Gigliotti, F., Marks, C. A., and Busana, F. (2009). Performance and humaneness of chloropicrin, phosphine and carbon monoxide as rabbit-warren fumigants. *Wildlife Research* **36**, 333–341. doi: 10.1071/WR06020

Hawkins, P., Playle, L., Golledge, H., Leach, M., Banzett, R., *et al.* (2006). Newcastle consensus meeting on carbon dioxide euthanasia of laboratory animals. University of Newcastle on Tyne, Newcastle on Tyne, UK.

Health and Safety Executive, UK (HSE) (2009). 'Carbon monoxide.' Available at http://www.hse.gov.uk/gas/domestic/co.htm [Verified March 2009].

Johnston, R. F., and Janiga, M. (1995). 'Feral Pigeons.' (Oxford University Press: New York.)

Kingston, K. K., Dussault, C. A., Zaidlicz, R. S., Faltas, N. H., Geib, M. E., Taylor, S., Holt, T., and Porter-Spalding, B. A. (2005). Evaluation of two methods for mass euthanasia of poultry in disease outbreaks. *Journal of the American Veterinary Medical Association* **227**, 730–738. doi: 10.2460/javma.2005.227.730

Lowe, S., Browne, M., Boudjelas, S., and De Poorter, M. (2000). '100 of the World's Worst Invasive Alien Species. A Selection from the Global Invasive Species Database.' (Invasive Species Specialist Group (International Union for the Conservation of Nature): Auckland.)

NIOSH (2007). 'International Chemical Safety Cards: Carbon Monoxide.' (National Institute for Occupational Safety and Health, US Centers for Disease Control: Atlanta, GA.) Available at http://www.cdc.gov/niosh/ipcsneng/neng0023.html [Verified March 2009].

Olsen, P., Silcocks, A., and Weston, M. (2006). The state of Australia's birds: invasive species. *Wingspan* **16**(Suppl.), 1–32.

Raj, A. B. M., Sandilands, V., and Sparks, N. H. C. (2006). Review of gaseous methods of killing poultry on-farm for disease control purposes. *The Veterinary Record* **159**, 229–235.

Royal Society for the Protection of Birds (RSPB) (2009). Population trends and conservation. Available at http://www.rspb.org.uk/wildlife/birdguide/name/s/starling/population_conservation.asp [Verified March 2009].

Sharp, T., and Saunders, G. (2008). 'GEN001 Methods of Euthanasia.' (NSW Department of Primary Industries: Orange, NSW.) Available at www.dpi.nsw.gov.au/__data/assets/pdf_file/0004/57253/gen-001.pdf [Verified March 2009].

Tidemann, C. (2005). Indian mynas – can the problems be controlled? In 'Proceedings of the 15th National Urban Animal Management Conference'. (Ed. M. Hayward.) pp. 55–57. (Australian Veterinary Association: Sydney.)

Tracey, J., Bomford, M., Hart, Q., Saunders, G., and Sinclair, R. (2007). 'Managing Bird Damage to Fruit and Other Horticultural Crops.' (Bureau of Rural Sciences: Canberra.)

Webster, A. B., and Fletcher, D. L. (2001). Reactions of laying hens and broilers to different gases used for stunning poultry. *Poultry Science* **80**, 1371–1377.

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