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Review of the use of bait boxes during operations to control Norway rats, *Rattus norvegicus* –a report to CIEH

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August 2011

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This independent report was commissioned by the Chartered Institute of Environmental Health as part of the debate on the need for greater public health interventions in resolving pest problems. Its views are not necessarily those of the CIEH.

*For further information, please see Buckle, A. P. and Prescott, C. V. (2010). Effects of tamper-resistant bait boxes on bait uptake by Norway rats (*Rattus norvegicus* Berk.). *International Journal of Pest Management*.*

Introduction

During the latter part of the 20th Century, many rodent control treatments started to use tamper-resistant bait boxes. These provide a secure way in which rodent baits can be used. On the face of it, this is a sensible way in which to prevent non-target species from accessing the rodent baits.

However, research carried out by the UK Government's Food and Environment Research Agency has shown that the use of tamper-resistant bait boxes can significantly extend the time that it takes a treatment to be successful.

This means that wildlife is more likely to be adversely affected through secondary poisoning. The National Pest Advisory Panel of the Chartered Institute of Environmental Health has commissioned Fera to produce a report on the work it carried out. This shows that, where tamper-resistant boxes are used unnecessarily, they create adverse environmental problems.

This view is endorsed by other environmental experts who are familiar with rodent control programmes. We, therefore, ask regulatory authorities and those carrying out pest control treatments to bear this in mind when deciding where and when to use such boxes.

Stephen Battersby
President
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Executive Summary

As most rodenticides are toxic to a wide range of vertebrate species, pest control operators are obliged to take precautions to prevent non-target species from accessing baits during treatments. However, the measures taken to protect the bait should not also discourage rats from eating it, because if rats are not controlled, there is a risk of disease transmission to humans and other animals, continuing damage to structures and contamination of commodities.

To minimise damage, it is clearly desirable to eradicate an infestation as quickly as possible and this can be achieved with anticoagulant baits in 2-3 weeks if there is a quick uptake of bait by all the rats. A quick uptake is more likely if the baiting method is in tune with rat foraging behaviour, in which the animals seek easy access, a quick escape and can feed in groups.

Tamper-resistant bait boxes with internal baffles would seem to overly restrict a rat's access and discourage group feeding.

Some commercially-available, tamper-resistant bait boxes seem low in height and would probably prevent most adult-sized rats from feeding in their preferred manner i.e. sitting on their haunches, rotating a food particle with the paws as it is eaten (Whishaw and Tomie, 1987). If rats feel uncomfortable inside a bait box, this might encourage bait transfer or, if bait is fixed in position, discourage any take at all.

Regardless of the baiting method, a quick uptake of bait is less likely when rats have abundant resources available to them, especially where cereals are stored in stable, unchanging habitats.

With abundant food and nesting opportunities, rats may have small home ranges in which they become familiar with their surroundings and easily detect new objects that they then typically avoid. Under these circumstances, any container, whether tamper-

resistant or not, would be treated the same by rats. Rats with larger home ranges would presumably find it difficult to retain a detailed knowledge of their habitat and might not always realise that a bait box is a new object.

While the nature of a bait container might determine how a rat reacts, its response also seems to be influenced by population density. It is notable that in very large populations (in the UK this has often been linked to anticoagulant resistance (Anon, 2002; Quy et al., 1995) bait uptake is rapid – population pressure perhaps forces rats to be less inhibited about approaching any type of container. Such situations are not the norm and if operators use any type of box, they should expect a delay in bait uptake by most rats in the population.

Analysis of data on rat activity at bait boxes placed on farms revealed that while it may be up to 2 weeks before any bait is eaten at some points, if there is no take from more than half the boxes visited by rats during the first week of baiting, the treatment is unlikely to be successful, no matter how long it continues (Quy et al., (1994).

To maximise the efficiency of rodent control, it would be prudent to retain the options of using a wide range of techniques, including burrow-baiting. Experience has shown that a flexible response coupled with the ingenuity of the operator can produce effective control with minimal non-target casualties. Sometimes a flexible response necessarily increases the risk to non-targets particularly when baits are made more accessible to the target species, but in such cases the risk can often be controlled by more frequent bait inspections.

Tamper-resistant containers baited with immovable block baits are appropriate if baits are inspected infrequently, but the evidence presented in this review suggests that relatively little rodent control will be achieved.



Rats carry many disease-causing pathogens as well as being responsible for fires and floods in buildings. Their presence is often a sign of a degraded area.



Rubbish is often left out in streets overnight or dumped in alleys, presenting a challenge to pest control services.

Background

As the rodenticides currently available are not species-specific, it is clearly important to prevent other animals from eating the bait during treatments. The usual practice to balance efficacy against safety is to carry out a site-specific risk assessment. However, there appears to be a trend among pesticide regulatory authorities, concerned about the risks to wildlife and particularly children from rodenticide exposure, to be more prescriptive on the type of protection that is necessary to keep baits safe.

This concern is probably linked to the gradual shift away from the use of first-generation anticoagulants towards the more toxic second-generation compounds (Cowan and Quay, 2003). New regulations by the US EPA, published in 2008, will require the use of tamper-resistant boxes for all indoor and outdoor (above-ground) bait applications. Under the review of pesticides following EU Directive 98/8/EC, assessment reports on the anticoagulant rodenticides warfarin, brodifacoum and difenacoum, published in 2009, include statements that Member States should require the use of tamper-resistant bait boxes in order to minimise non-target risks.

One of the first tamper-resistant bait containers was developed during the 1940s, the P3 (or Protected Poison Point) (Elton and Ranson, 1954). Its designers claimed it was almost completely rat- and mouse-specific (despite an internal baffle, sparrows did manage to find a way in) and a locking spring prevented children from opening it. It was noted that P3s were sometimes not entered if placed in 'difficult' environments, such as grain stores, did not draw in the whole of a rat population and restricted the number of rats that could feed at any one time.

In the 1970s, the US EPA became concerned that householders/pest control operators were not protecting baits adequately, citing statistics on human exposures to rodenticides (Jacobs, 1990). In 1983 and 1984, public hearings were held in which some participants claimed that a statutory requirement to use 'tamper-proof' boxes would reduce the effectiveness of treatments because rodents were said to be reluctant to enter and feed from bait stations with internal baffles.

Kaukeinen (1987) tested the response of wild rats to eight tamper-proof designs under semi-natural conditions and concluded that the safety features and construction materials appeared to interfere with rodent utilisation of some bait stations. There is now concern among rodent control practitioners that a ruling to place bait only in tamper-resistant bait containers in all circumstances would reduce the effectiveness of rat control significantly.

This review draws on research carried out by Fera (including its predecessor organisations) into the factors that influence the outcome of treatments carried out to control populations of Norway rats (*Rattus norvegicus*), particularly in relation to the baiting method.

However, Fera has not specifically tested commercial bait containers that are claimed to be tamper-resistant but research on rat behaviour and ecology has enabled predictions to be made about the likely consequences for control efficiency, if the use of such containers became mandatory.



Norway rats are commensal rodents, that is they live in close association with humans. This rat was found living in a disused pipe at the rear of a restaurant, where it fed each night on waste food from the kitchen.

Bait application methods and efficacy

Standard Fera practice was to use wooden or plastic bait trays protected by natural cover (i.e. materials found on-site, such as corrugated metal sheets, wooden boards, drainage pipes, slates, bales, empty fertiliser bags).

These bait protection measures were regarded as sufficient even for applications of brodifacoum and flocoumafen outdoors on farms in mid-Wales (Rennison and Dubock, 1978; Buckle, 1986), as the speed of control was fast enough (11-25 days, 10-21 days respectively) to minimise non-target casualties. Boxes were used infrequently and usually where cover was unavailable, for example, along hedgerows.

The reluctance to use boxes was in part associated with the initial avoidance by rats of any new object that appears in the environment (Shorten, 1954). In practice, operators found that boxes evoked a bigger response than wooden trays i.e. that rats would approach trays protected by natural cover within 2-3 days but would avoid boxes for 7-14 days. In contrast to the relatively short treatments on Welsh farms, Greaves et al., (1982) reported brodifacoum treatments on Hampshire farms taking 21-73 days to complete, resulting in a number of non-target casualties.

The difference in treatment efficiency between the two areas was attributed at first to anticoagulant resistance, but a re-analysis of the data suggested that the ecological conditions prevailing in each area were of more significance, in particular, the greater availability of stored grain on Hampshire farms and the more extensive nature of rat infestations (Quy et al., 1992a). These factors caused slower rates of bait uptake and thus lengthy treatments, regardless of the rodenticide being applied.

Although brodifacoum and flocoumafen were subsequently restricted to indoor use only, treatments with other second-generation anticoagulants, difenacoum and bromadiolone, in Hampshire also resulted in non-target deaths, albeit to a lesser extent.

In an attempt to reduce the risk to wildlife, bait trays protected by natural cover were increasingly replaced with bait boxes especially for all outdoor bait placements and then for most indoor placements as well – bait trays, if used at all, were only placed where non-targets could be excluded, such as inside a completely enclosed building.

A typical Fera bait box is approximately 360 mm (l) x 260 mm (w) x 140 mm (h), made of marine plywood with a metal lid. Each box has a 70 mm x 70 mm entrance at both ends and is open inside except for a baffle 25 mm high, which prevents bait spilling out of the entrances. A heavy object is usually placed on the lid to prevent it being blown off or knocked off accidentally.

By using boxes, the bait was better protected against the weather, interference from farm dogs and the inadvertent removal of the cover by the farmer. However, burrow-baiting remained a valuable part of rodenticide application methodology, especially in relation to its speed of control in 'difficult' environments.

Burrow-baiting has for many years been seen as the most effective means of intercepting rats between their day-time resting places and their night-time feeding sites (Middleton, 1954). In practice, it is unlikely that burrow-baiting alone would eliminate a rat population as some burrows might not be found or be inaccessible and some rats might prefer to nest inside discarded machinery or inside buildings. Moreover, uneaten bait is difficult to recover and rats sometimes eject bait from burrows thereby increasing the risk to non-target animals. Quy et al., (1996) found that the bait application method had a greater effect on the outcome of treatments than the palatability of the bait. In an experiment to relate bait palatability to performance in the field, baits containing bromadiolone or difenacoum in a variety of cereal bases were applied to control warfarin-susceptible rats.

Each of the 24 treatments began with baits laid in wooden boxes that had been put out at least one week before baiting began. When stored food was present at a site, container baiting was invariably unsuccessful and was therefore limited to a maximum of 3 weeks before the baits were redistributed to active rat burrows for a further 3 weeks.

As a consequence, baits that had been assessed under standard laboratory test protocols to have a mean acceptance as low as 3.7% (and therefore regarded as significantly unpalatable) were nevertheless effective if applied directly into burrow entrances, even when alternative food was present on the trial site.

The mean percentage population reduction after the container baiting was 37.1 and after the burrow baiting 96.8.

It can be argued that the wider dispersion of baits with burrow-baiting and a possible additive effect due to the previous container-baiting over-estimated the effect of the burrow baiting, but the magnitude of population reduction once burrows were baited suggested that the bait boxes of the type used in the trials constrained effectiveness and, at the very least, would lead to longer treatments (Cowan et al., 1994).

This was confirmed by a direct comparison between burrow-baiting and box-baiting (Anon, 2002) on 20 rat-infested farms. Infested sites were paired in terms of the distribution of rats and ease of access to areas containing burrows. One site in each of 10 pairs was randomly allocated to either burrow-baiting or box-baiting.



Each trial began with a census of the rat population using the tracking plate method (Quy et al. 1993). The initial quantity of bait at each point, whether a burrow or box, was dependent on the point estimate of population size. This avoided placing a disproportionate amount of bait in boxes, when the dimensions of rat burrows necessarily restricted the quantity that could be applied and thus might unintentionally bias results in favour of container baiting.

The bait was a loose-grain cereal containing 0.005 % difenacoum. Because it was difficult to specify a period, before bait was laid, which allowed most rats to overcome any wariness towards the containers, the boxes were positioned on the first day of the treatment; although it is often recommended that containers should be put out in advance of poison bait being laid, this procedure was in line with current commercial practice.

After bait was dispensed, burrows were lightly blocked (e.g. with grass): this provided some protection for the bait and also allowed activity to be monitored. More substantial blocking might have caused the burrow to be abandoned. Baiting continued for 3 weeks and to gain information on the relative efficiency of the 2 baiting methods, each population was re-censused using the tracking plate method during the second, third and first post-treatment weeks.

The mean take of bait from boxes during the first week was 1.2 g/rat/day, but no take was recorded on 6/10 sites. By the third week, the take had increased to 5.0 g/rat/day with takes at 9/10 sites. The mean percentage population reduction was $28 \pm \text{se } 16.3$; no site was cleared of infestation. The average take by rats from burrows during the first week was 15.5 g/rat/day with takes at all sites. After 3 weeks baiting, the mean percentage population reduction was $72 \pm \text{se } 12.7$, significantly different from the reduction due to container baiting. However, rats were eradicated from only 1 site. Undoubtedly, with unlimited time, both burrow-baiting and container-baiting would be equally effective, but burrow-baiting gave more than twice the level of control over 3 weeks.

Even if eradicating the last few rats meant that the 2 baiting methods had similar overall treatment lengths, relatively quick control of most rats would allow early reductions (i.e. before non-target animals started visiting bait points) in the amount of bait remaining in the environment to eliminate the residual population.

Rat behaviour towards bait containers

During investigations to determine the impact of anticoagulant resistance on treatment efficacy, a total of 48 trials were carried out on farms in a replicated experimental design (Cowan et al 1995). Half the trials were conducted in an area where anticoagulant resistance was very low or non-existent and the other half in an area where the prevalence of warfarin resistance was high and resistance to second-generation anticoagulants was also present.

All bait was dispensed into bait boxes. The baits contained either difenacoum or bromadiolone to which had been added a quantitative bait marker. At the end of each trial, a sample of the surviving rats was obtained by live-trapping – only 5 treatments were completely successful after 7 weeks of baiting, but in 10 there was no population reduction (Quy et al., 1994). (For the purposes of the research, the end-point of each trial was not 100% control, unless that was achieved before the 7-week limit.)

Fera research has found that non-transferable block baits are usually ignored by rats.

After analysis of their tissues, it was found that over 80% of the 642 survivors trapped from all unsuccessful treatments (i.e. those with <100% control) had eaten little or no bait (Cowan et al., 1995). The poor bait uptake among these rats was attributed particularly to the presence of cereals stored inside farm buildings under conditions that barely altered for weeks, sometimes months (Quy et al., 1992b).

The animals thus had an opportunity to become adapted to a food source that was not only attractive but was consistently available and thus predictable. Against this predictability, the novelty represented by novel baits and/or the bait containers might have elicited not only disinterest but active avoidance and under such conditions, animals exhibiting heightened neophobic responses would be at a selective advantage.

In contrast, rats living in constantly changing environments, such as probably occurs on most livestock farms, are likely to show less cautious behaviour towards novel baits and containers even when alternative food is plentiful. This helps explain the difference in efficiency between treatments carried out on predominantly livestock farms in mid-Wales and those on predominantly arable farms in Hampshire.

Inglis et al., (1996) monitored the foraging behaviour of wild rats under semi-natural conditions and found that neophobia to new containers was far stronger than neophobia to new foods. The strongest neophobic reactions occur when wild rats find new objects in a place where none had been experienced before, yet the animals will readily explore an unfamiliar area that necessarily contains strange objects.

Thus, strong neophobia is only triggered by new objects appearing in an already familiar environment, suggesting that containers would not be avoided if they were in place before rats invaded a site. This hypothesis was tested in a small-scale field experiment by Fera, in which wooden bait boxes were left in place (but empty) after a successful control treatment and were only re-baited when a new infestation became established. The outcome was compared with treatments in which the boxes were introduced onto the site at the start of the treatment. The results (unpublished) showed that much higher rates of bait uptake by rats were obtained from boxes that had been permanently in place.

In practice, during treatments in which bait containers, especially boxes, are used, no take at a particular bait point can be caused by rats actively avoiding the containers or more simply that the container is misplaced and rats haven't yet found it.

During the trials reported by Cowan et al., (1995), tracking plates were placed next to each bait box to distinguish those boxes that rats approached but didn't enter from those rats hadn't yet found. It became apparent that a third category existed, namely boxes that were entered by rats which then ate little or no bait, regardless of how palatable the bait had appeared to be in laboratory tests (Quy et al., 2003).

During some treatments, the majority of baits fell into this category suggesting that container neophobia was not an important factor. Bait piles inside the boxes were sometimes disturbed, but often no measurable take could be detected. If rats entered boxes without much hesitation, they then seemed unwilling to stay in them for more than a moment.

In other trials carried out by Fera, baits consisting of pellets, wax blocks or place packs have been taken by rats from containers and then subsequently abandoned in the open creating a potentially significant risk to non-target animals that, in the wider rodent control field, operators could do little about in terms of increased protection measures.

Hoarding or transferring food (and also inedible objects) is a common and well-recorded behaviour among rats. Its significance, in terms of the safety of rodenticide treatments, has probably increased with greater use of second-generation anticoagulants that are more toxic to other animals, especially birds, than first-generation compounds such as warfarin. This risk has been recognised by manufacturers who have produced wax block formulations, which are apparently relatively unattractive to birds (Johnson, 1988) and are now made with a central hole so that they can be fixed inside a container preventing rats from removing them.

In the environmental conditions prevailing on most UK farms, Fera research has found that non-transferable block baits are usually ignored by rats. (In contrast, blocks fixed inside bait stations have proved successful in eradicating rats from UK off-shore islands (e.g. Canna)). However, rats will transfer any type of bait from individual cereal grains to wax blocks and place packs.

That rats seem prone to transport food fits in with optimal foraging theory that says they do it to minimise the risk of predation while maximising food gain. Thus, a wax block that weighs 20-30 g is a significant reward worth making a risky journey to retrieve, but it would take too long to consume it on the spot (i.e. in the bait box). Alternatively, wheat grains are small rewards that can be consumed quickly and thus it is worth making repeated short journeys to collect them.

To demonstrate the potential impact of this theory on the outcome of rodenticide treatments, family groups of wild rats were established under semi-natural (arena) conditions and were presented with different bait formulations (without poison) in a random order: whole wheat grains (0.05 g/grain), pellets (0.3 g/pellet), wax blocks (20 g/block) and place packs (50 g/pack containing pinhead oatmeal) (Anon, 2002).

All baits were presented in a wooden bait box, which had been adapted to detect a microtag implanted into each rat and a magnetic tag stuck to each bait particle (pellet, block or pack – wheat grains were too small). It was thus possible to monitor when bait particles were being carried out of the box and which rat was carrying them.

If fear of predators encouraged rats to transfer bait, then making rats feel safer by placing extra cover over the box might reduce transfer. Similarly, placing baits further from where rats nest (i.e. decreasing bait-point density) might encourage them to consume the smaller bait particles (wheat grains, pellets) in the box, provided the distance isn't increased so much that the bait is unlikely to be found. The results suggested that modifying the distribution and protection of baits would have little effect. All types of bait were transferred regardless of travel distance (5-15 m) or adding/removing cover.

Whole-wheat grains, which were too small to tag, were also carried out of the box, as discovered by occasional direct observation. Although travel distances did not exceed 15 m, past recommendations on the spacing of bait points have indicated 5 m apart as a common standard. The location of discarded magnets showed that transferred pellets were eaten within 4 m of the bait box and were seldom carried back to the nest area.

Similarly, abandoned wheat grains were found on the arena floor close to the box. In contrast, wax blocks and place-packs were invariably carried back to the nest. Bait transfer was carried out mostly by the younger (smaller) males in each family group. These findings are consistent with other studies on rat foraging behaviour (e.g. Whishaw and Whishaw, 1996) and suggest that attempts to prevent bait transfer are likely to result in minimal bait take.

The microtag detection system also enabled the length of visits by individual rats to be calculated and compared under different conditions. It was also possible to determine how many rats were present in the box at the same time. Quy et al., (2003) found that among family groups housed in arenas, visits by single rats, regardless of age or size, to a bait box containing wheat grains were short, with a range of median values from 2-15 s/visit.

If rats were not alone, visits were longer, but juvenile rats would not remain for long in a box with a much larger adult, even though they were related to it. However, when the juveniles had grown to adult size, they stayed in the box with one or more other adults for the same length of time.

These results suggest that the foraging behaviour of rats is dictated more by fear of conspecific aggression than by fear of predation. The same technology was used to measure the length of visits to a bait box and burrow baits by rats in the field: the median visit length to burrow baits was 12 s (n=1304) and to a box 17 s (n=1272), a difference unlikely to be biologically significant. Berdoy and Macdonald (1991) also reported short visits to a feeding station where apparently only one rat could feed at a time: the majority of visits lasted 1-8 s. An interpretation of these results is that during a rodenticide treatment bait transfer becomes more likely when only one individual at a time can access the bait and, moreover, if bait can't be transferred (i.e. fixed in position), it may be ignored.

Bait transfer becomes less likely if rats can feed in groups; biologically, group-feeding presumably offers some protection from a predator attack.



A rat burrow in a housing estate in London. Placing bait directly into burrows where rats live and eat results in quicker control and minimises the risk of secondary poisoning to non-target species.

The Chartered Institute of Environmental Health

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They work in large, medium and small businesses and are involved in a wide range of jobs such as those that involve regulation in food safety, housing, health and safety, and environmental protection, including pest and vector control.

The CIEH works to promote improvements in environmental and public health policy by campaigning on key issues of concern, raising the status and understanding of environmental health – with national, regional and local government, employers, the media, the public and other stakeholders to ensure that the high professional standards, knowledge and competencies of environmental health practitioners are achieved and maintained.

In England, Wales and Northern Ireland, the CIEH sets standards and accredits courses and qualifications for the education of practitioners.

As a regulated awarding body, it is a major provider of accredited vocational qualifications. CIEH also produces leading sector publications and runs a comprehensive programme of educational events.

An important part of its role is to provide information, evidence and policy advice to international, national and regional governments, local authorities, industry and other stakeholders. It has a close working relationship with the World Health Organization.

In this regard in 2008 an Associate Parliamentary Group for Environmental Health, which consists of UK Members of Parliament, was established and met for the first time. The event saw the launch of the WHO publication on the public health significance of urban pests.

The CIEH is based in the UK but as one of the founding bodies of environmental health, it is keen to see standards rolled out internationally and to work to help support the environmental health movement in a number of developing countries.

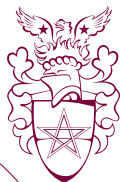
The National Pest Advisory Panel

In 2001, CIEH set up a specialist pest management panel, the National Pest Advisory Panel (NPAP) whose members are chosen for their individual expertise. They include pest controllers who are working or have worked for local authority pest control departments or commercial companies, consultants, academics and researchers.

The remit of the NPAP is to provide the CIEH with advice on all matters relevant to the control of urban and rural pests. This has included carrying out surveys; issuing a number of important guidance documents relating to the responsible use of public health pest management products; organizing seminars and presentations; and providing expert speakers at national and international meetings.

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The National Pest Advisory Panel
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