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Efficacy of alpha-chlorhydrin in sewer rat control

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SUMMARY

A single application of the male chemosterilant, α-chlorhydrin, to a problem sewer rat infestation resulted in reductions of rat numbers and distribution which was comparable to effects of warfarin baiting methods. Rat numbers were reduced by more than 85% by both methods. More rapid mortality and recruitment were evident for warfarin effects; the α-chlorhydrin treated population had a longer lag phase of growth so that reinfestation of sewer habitat to pre-treatment numbers, and distribution over a 40 square block area, required approximately 1·5–2 times longer after α-chlorhydrin treatment when compared with warfarin treatment. Comparisons of changes in rat densities in infested sewers following the two treatments indicate that recovery of warfarin treated populations is achieved by reproductive recruitment followed by dispersal while α-chlorhydrin treated populations recover by slower immigration and later reproductive recruitment. Alpha-chlorohydrin should be a useful addition to a limited arsenal of rat control agents because of its specificity for the Norway rat, its single dose effectiveness as a toxicant-chemosterilant, and its short environmental half-life.

INTRODUCTION

The use of chemosterilants for rodent control has offered the prospect of an alternative to poisoning campaigns (Marsh & Howard, 1973). The concept of regulating reproduction of wild mammals in control programmes has been discussed by Davis (1961). To be effective, the chemosterilant approach should not interfere with the endocrine balance of the males (who hold territory and maintain the social structure of established populations). Ideally the chemosterilant(s) should be single-dose effective, be species specific, and affect both sexes. Steroidal agents (provera and mestranol) can be effective but must be administered frequently and tend to induce aversion (Howard & Marsh, 1969; Marsh & Howard, 1969). These steroids had only transient inhibitory effects on reproduction in our hands (Andrews, Belknap & Keenan, 1974; Andrews & Belknap, 1975). A non-steroidal anti-oestrogen holds some promise for use on female rats (Gwynn & Kurtz, 1970), and α-chlorhydrin has shown promising but varying results in land-fill studies (Bowerman & Brooks, 1971; Kennelly, Garrison & John, 1970). However, Marsh & Howard (1969) and Andrews & Belknap (1975) have maintained prolonged control when the bait was taken in adequate amounts to sterilize

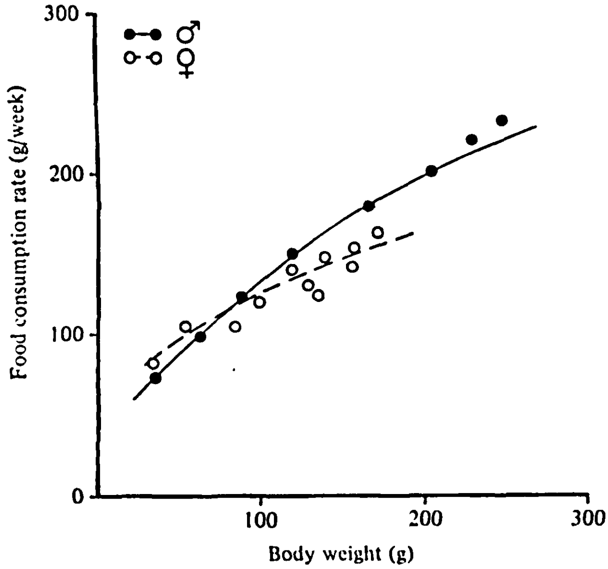

Fig. 1. Relationship between food consumption and body weight of wild Norway rats. ●, represent average values for 20 males; ○, represent average values for 20 females. Food consumption was measured daily and animals were weighed weekly from the time they were weaned (5 weeks) through the 13th week of age.

essentially all males, and to kill some members of the population. Bait acceptance was good in the dog food (Gaines Puppy Chow) vehicle used, and reinvasion from surrounding territories was minimal. On the basis of efficacy in land-fill sites and an opportunistic rat outbreak in a small city, we compared clean-up and warfarin baiting procedures with clean-up and α-chlorhydrin use.

METHODS AND MATERIALS

Rat numbers were estimated from bait consumption and body size measurements applied to a population of sewer rats during our investigations. These measurements tended to underestimate actual numbers; however, they were probably much more realistic than capture-mark-recapture (Lincoln Index) measures since wild rats readily develop avoidance behaviour toward traps. Our measurements of food consumption and metabolic efficiencies of wild Norway rats (*Rattus norvegicus*) indicate that each animal consumes food equal to its body weight each week (Fig. 1). We developed the bait consumption method by removing wild caught, pregnant females to the laboratory, and measuring the body weights and food consumption of laboratory born, weanling animals as they grew to adult status. Although feral animals may have access to alternative foods, rats living in or near sewers probably forage on the more readily available food at baiting stations, so that a minimum estimate of rat biomass can be assumed. Therefore, if various attractive foods (dog food or grain) are placed in measured quantities and recovered for measurement of consumption until the average daily consumption is apparent, the total biomass of rats can be measured indirectly; when foods were placed in sewers, only rats

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had access to them. If a model distribution of body weights is obtained by monitoring sizes of dead rats and faecal pellets found near baiting stations, a division of total biomass by the average body weight gives an index of rat numbers.

Since trapping was not practicable in sewers, we were forced to estimate the average body weights of animals within the sewer population from the weights of dead animals discovered in or near the manhole access points, and to compare those weights with estimates of rat sizes made from their faecal pellet sizes found at bait stations. Tracking and (fresh) faecal pellet counts and sizes were used as relative indices of rat body sizes of animals taking bait at baiting stations; measurements of faecal pellets can be related to body sizes of Norway rats in that length and width (but not weight) measurements of faecal pellets fall into size classes which are closely related to the body size classes of the animals from which the pellets are collected. High-bulk or grain based diets produce pellet size/body size ratios that are reliable predictors of body sizes within 50 g.

The protocol for each experiment involved the following procedures: (1) securing a 500 g packet of untreated bait at each sewer manhole in a 40 square block area; (2) reclaiming the packet within 3–4 days and measuring the amount of unused bait (after re-drying) to estimate bait consumption; (3) estimating the typical size of rats frequenting the bait stations by collection of faecal pellets and any dead rats, and by checking tracks; (4) replacing the 500 g bait package with treated (warfarin or α-chlorhydrin) bait; and (5) recovery of unused warfarin or α-chlorhydrin after 3 days. The location of 'takes' and amount of bait taken was recorded for each manhole access point in the 40 block area. Monthly follow-up was conducted by placing 500 g untreated dog food or grain packets at the same stations for three days, and recording the 'takes', the amount of bait taken, and body size estimates as described above. Bait consumption – body size estimates were recorded for each access point on a monthly basis for 6 months. The protocol was followed for a single warfarin treatment in 1973, and for a single α-chlorhydrin treatment in 1974; hence the same experimental protocol was run for each of the control agents used in the same 40 block area, but warfarin was used in 1973 and α-chlorhydrin was used in 1974. Pre-baiting with untreated vehicle was used immediately prior to each single baiting with a control agent. Population estimates were made for the sum of all manhole access points, and data from individual access points were used to estimate patterns of infestation.

Estimates of rat distribution patterns and of bait acceptance were obtained by measuring the frequency and amount of 'takes' at each of the sewer baiting stations. Changing bait vehicles from Gaines Puppy Chow (dog food) to wheat grain and following daily consumption for 3–4 days (to plateau levels) enabled us to test for 'shyness' toward particular baits. Frequency maps provided a useful temporal device for following rat distribution profiles. A fall in frequency and amount of all baits or foods taken, together with a decrease in the amount and frequency of rat 'sign' were interpreted as a loss of rat biomass and numbers.

RESULTS

Rat control measures were begun in Ralston, Nebraska in the summer of 1973; a survey of the city was conducted at the invitation of the City Council. A severely

Table 1. *Effects of control agents on sewer rats*

Experimental variables	Zero time control	Post-treatment months 1	2	3	4	5	6
Warfarin set							
Estimated number of rats	700	105	105	140	210	310	560
Number of infested blocks	32	4	4	5	7	8	20
$\bar{x}$ rat density Number per block	22	26	26	28	30	39	28
α-Chlorhydrin set							
Estimated number of rats	500	100	75	100	100	125	200
Number of infested blocks	20	6	6	5	4	6	10
$\bar{x}$ rat density Number per block	25	17	12	17	17	21	20

affected 40-block area was monitored, treated with warfarin bait for 3 days, and resurveyed by checking for food consumption, 'bait-take' frequency, and signs on a monthly schedule, during the fall, early winter and spring. Warfarin treatment and a clean-up campaign reduced problem neighbourhood infestations by approximately 100 rats per block; the (free ranging) neighbourhood rat members were cut by 90% within 1 month. In addition, sewer rat numbers were reduced to 15% of pre-treatment levels following the single 3 day administration of warfarin bait in sewer manholes and drains. Six months later, sewer re-infestation was apparent according to our survey, although dramatic numbers (Table 1) were not so apparent; the prevention of 'outbreak' infestations was probably due (in part) to a second city-wide clean-up effort which took place prior to the onset of winter.

In the spring of 1974, we began using α-chlorhydrin control measures in the city sewer system. The same 40-block area was covered by placing 5% α-chlorhydrin treated Gaines Puppy Chow (dog food) at the sewer access points. The protocol involved a survey of rats in manholes by pre-baiting with untreated dog food for 3 days, checking for bait consumption and rat signs in manholes, and then baiting with α-chlorhydrin-treated dog food for 3 days. The daily consumption of food and of α-chlorhydrin bait was recorded together with the frequency of 'takes'. Untreated dog food and/or grain consumption levels were followed at monthly intervals thereafter, for 6 months. The alternate of untreated grain bait was used to test for shyness toward dog food bait. The biomass of the rats and their relative distribution was estimated from a 3-day dog food consumption; bait acceptance was as good for the 3-day dog food trials and for the 3-day wheat grain trials as judged by a maximum of 10% variance in bait consumption. Following the single 3-day α-chlorhydrin treatment, evidence of rats showed a steady decline (Fig. 2). Moreover, the biomass remained low (in terms of bait consumption), and dog food bait acceptance was as good as for grain packets placed at baiting stations. The α-chlorohydrin caused a continued decline in rat numbers which was equivalent

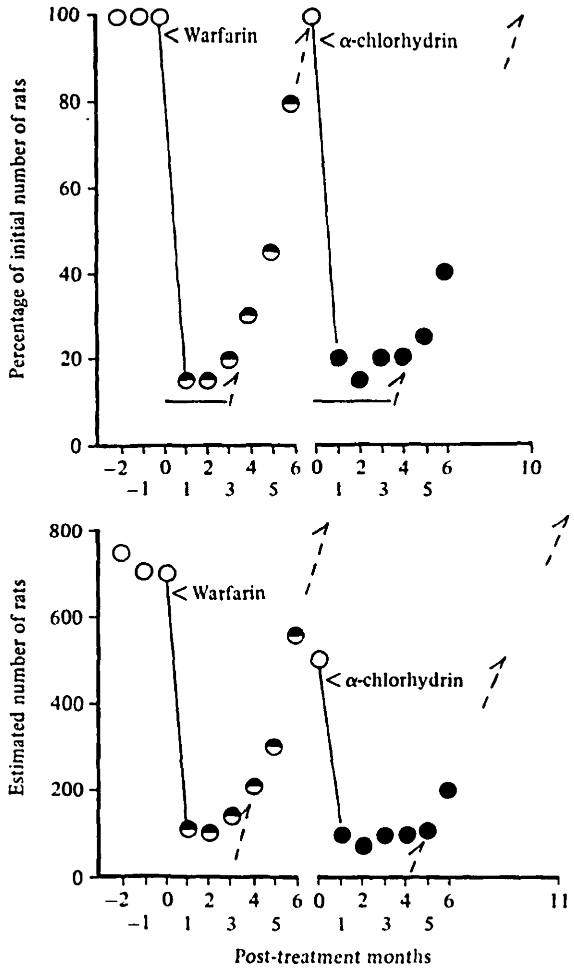

Fig. 2. Effects of control measures of sewer rats. Top illustrations present normalized data prior to (○) and following administration of warfarin (⊖) or α-chlorhydrin (●) baits to Norway rat infested sewers. Bottom illustrations present the same data as estimated (from bait consumption) rat numbers in the same 40 block area of sewers (same symbol code).

to that accounted for by warfarin bait exposure. The declining frequency of block by block infestation achieved by α-chlorhydrin baiting compared favourably with effects of warfarin treatment, except that a longer recovery (re-population) period followed α-chlorhydrin treatment (Fig. 3).

Moreover, the frequency of complaints registered in City Hall on a weekly basis dropped from 10 or more to zero. It appeared that the major reservoir of rats was harboured in an old sewer system and that rat numbers in the system were reduced and held low by α-chlorhydrin treatment. The longer lasting effectiveness of the treatment could be a result of the residual stability in surviving males. In any case, effective control with α-chlorhydrin treatment persisted for longer than 6 months, while warfarin treatment at 3 to 4-month intervals would be required to achieve the same control level.

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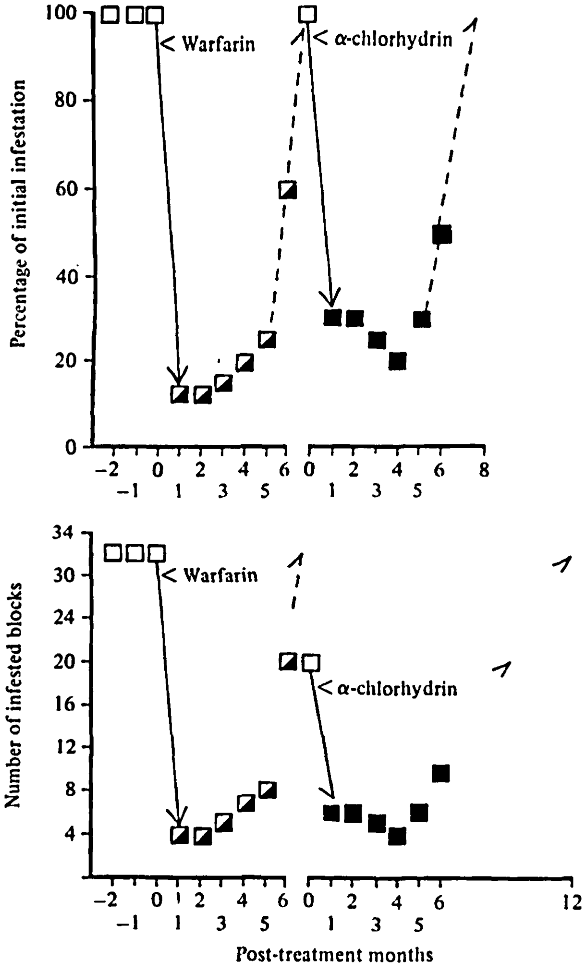

Fig. 3. Effects of control measures on the number of rat infested blocks. Top illustrations present normalized data prior to (□) and following administration of warfarin (◪) and α-chlorhydrin (■) baits to rats in infested sewer blocks. Bottom illustrations present the same data as actual numbers of infested blocks (same symbol code).

Comparisons of relative rat density changes in infested sewer blocks following single treatments with warfarin and α-chlorhydrin baits suggest differences in replacement patterns by survivors (Fig. 4). Surviving warfarin treated rat colonies increased their densities (average numbers per infested block) almost immediately after a treatment episode and then reduced density levels by dispersal to adjacent blocks. It is interesting that re-infestation of sewers followed the density change by about 60 days; these data together with sharply localized reinfestation of sewers suggest that the warfarin treated population rebounded by reproductive recruitment. By contrast, the density growth curve of the α-chlorhydrin treated population was still in lag phase when reinfestation had begun to increase; these data together with patterns of sewer reinfestation which were on the outer perimeter of the treated area, suggest that immigration preceded any sign of

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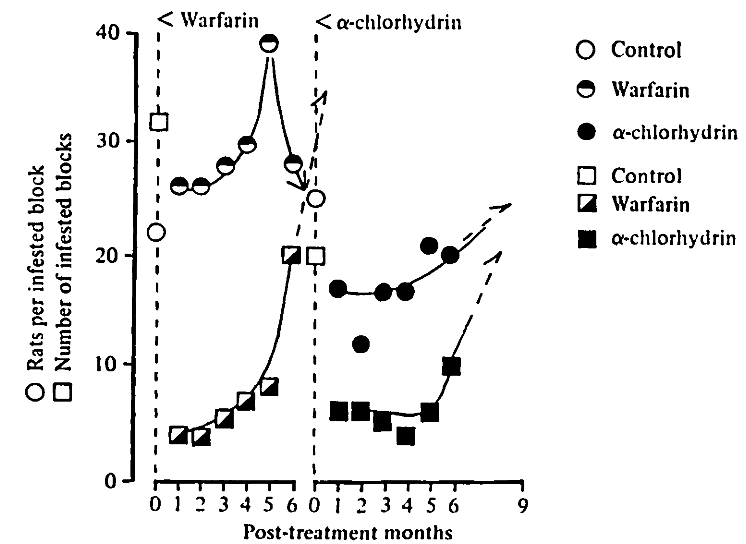

Fig. 4. Comparisons of Norway rat density and frequency of infested city blocks after application of rat control measures. The left panels illustrate effects of warfarin treatment (circles) on the densities of Norway rats per infested block and the number of infested blocks (squares); the right panels illustrate the effects of α-chlorhydrin treatment on Norway rat densities in infested blocks and the number of infested blocks. Open symbols are pre-treatment values, half-shaded symbols are warfarin post-treatment values, and closed symbols are α-chlorhydrin post-treatment values.

reproductive recruitment in the α-chlorhydrin treatment-recovery phenomenon. Differences in the slopes of recovery curves for the two types of treatment illustrate the persistent reproductive effect of α-chlorhydrin on sublethally treated survivors.

DISCUSSION

A battery of poisons is commonly used in rodent control (Gratz, 1973). To be effective, however, poisons must be effective in single doses, be readily accepted in baits, have a high lethal efficiency, and not produce 'bait shyness' or 'resistance'. There are few safe and effective candidates in the rodenticide arsenal which satisfy the above criteria. The only toxicants which are relatively safe to use because of their therapeutic ratios are dicoumerol derivatives and Norbormide (5(α-hydroxy-α-2 pyridylbenzyl)-7-(α-2 pyridylbenzylidene)-5-norbornene-2,3-dicarboximide); only Norbormide is highly specific for Norway rats. Results with Norbormide have been variable (Brooks & Bowerman, 1966), and genetic resistance has appeared in rats repeatedly exposed to dicoumerol baits (Jackson *et al.* 1975). Alpha-chlorhydrin meets the criteria listed above, is a safe control agent, and is effective in reducing rat populations for sustained periods in urban waste disposal systems, dumps and sewers. Control has been effective for more than 1 year following a single application in areas where there is no rat immigration (Andrews, Belknap & Keenan, 1974; Andrews & Belknap, 1975) and is likely to be a result of two effects of the drug. The first in the development of epididymal lesions resulting in permanent male sterilization with cellular changes in epididymal

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structure which are microscopically detectable within 6–8 h and grossly visible as soon as 30 h following drug administration (Hoffer & Hamilton, 1970). The second is that both sexes succumb to toxic effects with most deaths occurring about 72 h after a lethal dose.

Methods for more effectively treating sewers and land-fills with α-chlorhydrin and for evaluating drug acceptance have been developed. Sustained control of rats for a year or longer, following a single baiting with α-chlorhydrin, would make effective control economical, and the drug is a useful addition to the arsenal of poisons and more conventional control measures.

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