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Development of Nicarbazin Bait for Managing Rock Pigeon Populations

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ABSTRACT: Effective methods for managing populations of rock pigeons and other overabundant avian species are limited. An alternative to lethal control is reproductive inhibition. Nicarbazin is a widely used additive in poultry feed that also reduces hatchability of eggs. It is the active ingredient in OvoControl®G, a bait product recently registered as a means for reducing hatchability of eggs of urban Canada geese. In a series of trials with captive pigeons, we evaluated the effectiveness of several nicarbazin bait formulations to determine effects on reproduction and to quantify levels of nicarbazin absorbed into the blood. Although pigeons readily accepted a scaled-down version of the OvoControl goose bait, this formulation did not adequately reduce hatchability because of insufficient absorption of nicarbazin into the blood. Other bait formulations that contained 2,500 ppm nicarbazin produced similar results. Only bait formulated with 5,000 ppm nicarbazin produced sufficient amounts of the active ingredient in blood plasma of test birds. Eventual registration of the nicarbazin pigeon bait will provide additional management options for limiting growth of unwanted pigeon populations.

Key Words: *Columba livia*, nicarbazin, OvoControl, reproductive control, rock pigeon

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INTRODUCTION

Excessive feral or rock pigeon (*Columba livia*) populations in urban and suburban areas can represent significant health and aesthetic problems. According to at least one source this species is "The single-most serious pest bird…" in the United States (Pimentel *et al*. 2000). These authors estimate annual costs associated with pigeon control to be $1.1 billion. Furthermore, pigeons are reservoirs or vectors for >50 human and livestock diseases (Weber 1979).

Current pigeon management techniques focus on barriers and exclusion devices including nets and spike strips as well as lethal methods including DRC-1339 and Avitrol®. Non-lethal and humane means of reducing the size of feral pigeon populations at or near airports, shopping centers, restaurants, commercial sites, city parks, etc., are currently not available.

Nicarbazin is approved by the FDA for use as a coccidiostat in broiler chicken feeds. A side effect of nicarbazin, when inadvertently fed to chickens that lay eggs, is decreased egg production and hatchability. One mechanism by which nicarbazin exerts its effect (reduced viability of eggs) is by causing disruption of the vitelline (yolk) membrane allowing the yolk and albumin to flow together, conditions under which the embryo cannot develop (Yoder *et al*. 2005). Nicarbazin was investigated previously without success as a reproductive inhibitor in pigeons (Elder 1964). Today, nicarbazin is approved for population management in feral pigeons in Italy, where it is registered as a veterinary drug. Unlike Italy, in the U.S. the EPA regulates the product as a pesticide. Recently, the nicarbazin-based product OvoControl®G was registered with the EPA as a means to reduce hatchability of eggs of urban Canada geese (*Branta canadensis*). In the series of trials reported here, we document progress toward developing nicarbazin as a tool for managing populations of rock pigeons.

METHODS

Nesting Trial, January-March 2005

In a preliminary screening trial, captive pigeons readily consumed a smaller version of the bait that was developed and registered for Canada geese. Therefore, we initiated a nesting study with captive rock pigeons to document effects of the 2,500 ppm nicarbazin bait on hatchability.

We obtained pigeons from local trappers and pigeon breeders. Bird obtained from breeders were paired (male-female) based on records supplied by the breeders. Birds supplied by trappers were sexed by analysis of blood samples and then paired at random. We weighed each bird before putting it into its test cage. Each pair of birds was housed in a 1.3 × 1.3 × 2.0-m cage in a roofed outdoor aviary. We equipped each cage with a food bowl, water dish, and a plastic milk crate as a nesting platform. We supplied short sticks and other nest material ad libitum for nest-building.

After a 3-day acclimation period, each pair received a daily 20-g ration of the test diet without nicarbazin for 5 days. We removed the birds' maintenance diet at 0700 and then presented untreated test diet at 0800. We removed the test diet at 1100 and replaced it with maintenance food. We estimated consumption of the untreated test diet each day by weighing back the amount of test diet remaining in each food bowl. The target nicarbazin dose was 7.5 mg/bird/day. We assumed that, on average, a pigeon would ingest roughly 10% of its body mass in food (Schafer and Eschen 1985). It is unlikely that a pigeon would consume only bait in an entire day. Thus, the bait was formulated so that the daily target dose would be achieved if a pigeon ate treated bait as 10% of its daily intake. So, 3 g of 2,500 ppm nicarbazin bait per 300 g pigeon should provide an average daily target dose of 7.5 mg.

Following the pretreatment period, we then randomly assigned 10 pairs to receive nicarbazin-treated food and the remaining pairs to receive untreated test diet. Daily presentation of the test diets continued as during pretreatment. We measured consumption of the treated or untreated test diet by each pair of birds on the first 5 days of the treatment period and then 3 times weekly thereafter for the next 6 weeks.

We weighed each bird just before drawing a blood sample. We collected blood samples from all female birds on Days 10 and 47 of the treatment period. Serum samples were then shipped to USDA National Wildlife Research Center in Ft. Collins, CO where they were analyzed to quantify residues of 4,4'-dinitrocarbanilide (DNC), the bioactive component of nicarbazin (Johnston *et al*. 2001, Primus *et al*. 2001). Thus, DNC residues are a reliable marker of nicarbazin ingestion (Johnston *et al.* 2001).

We monitored each nest throughout the trial to document egg production. Approximately 10 days after the eggs in each first clutch were laid, we collected the eggs for DNC analysis. In addition, we examined and digitally photographed the embryo in each egg to document development of 10-day pigeon embryos. Incubation of all second clutches was allowed to proceed uninterrupted to determine hatchability.

Bait Acceptance Trial, April-May 2005

In this trial we evaluated the responses of captive feral pigeons to 4 new nicarbazin baits provided by the study sponsor, Innolytics LLC. The baits were designated as CPR 4311A (Bait A, the same as used in the nesting trial), CPR 4423B (Bait B), CPR 4423C (Bait C), and CPR 4423D (Bait D). Each bait was formulated with 2,500 ppm nicarbazin.

We obtained 32 feral rock pigeons from a local trapper, and housed them outdoors in groups of up to 15 birds/pen (3.1 × 1.9 × 9.3 m). Birds had free access to water and a maintenance diet of quail starter, commercial pigeon pellets, and cracked corn. After 2 weeks, we removed birds from the holding pens and randomly assigned them to individual test cages (45 × 45 × 45 cm) in a roofed outdoor aviary. We banded, weighed, and drew blood from each bird before placing it in its test cage. We assigned cages to treatments at random.

There were 8 pigeons in each test group. The birds were given 14 days to acclimate to their test cages before we started the trial. Each morning, we removed maintenance food at 0700. At 0800, we provided 20 g test diet to each bird. We removed test food at 1200 and provided maintenance food again. Consumption was determined by weighing back the food remaining in the test cups plus spillage recovered from pans below each cage, and after adjustment for mass changes due to absorption of moisture by the food.

On weekends, we did not measure consumption, but we provided each bird with the appropriate test diet for 3 hours. We collected blood for DNC analysis from each bird 10 and 24 days from the onset of presentation of the test diets. After Day 24, the test birds were euthanized.

We evaluated consumption of the baits by first calculating the mean weekly consumption for each bird. We then applied a 2-way repeated measures analysis of variance on the mean values, with bait type as the main effect and repeated measures across weeks.

Bait Acceptance Trial, August-September 2005

This trial involved 30 birds and was performed to evaluate additional nicarbazin bait formulations devised by the study sponsor. We obtained 15 birds from a local pigeon trapper and 15 more from a trapper in Colorado. All birds were held in outdoor group pens (3.1 × 1.9 × 9.3 m) for at least 3 weeks prior to the start of the trial. One week prior to the presentation of test foods, each bird was taken from its group pen and moved to an individual test cage (45 × 45 × 45 cm). We weighed each bird and took up to 1 ml of blood before placing it in its test cage.

To assign birds to test foods, we first ranked the 30 birds by body mass from lightest to heaviest. The 3 lightest birds formed the first group, the next 3 lightest birds formed a second group, and so on until the 3 heaviest birds formed the tenth and final group. Within each of the 10 3-birds groups, numbers 1, 2, and 3 were assigned at random. The 10 number 1 birds received the new type B2 bait, the 10 number 2 birds received the new type C2 bait, and the 10 number 3 birds received the new type D2 bait. Baits B2 and C2 contained 2,500 ppm nicarbazin; bait D2 contained 5,000 ppm nicarbazin.

Starting with test day 1, maintenance food was removed each morning at 0700. At 0800, 20 g test diet was provided to each bird. Aluminum trays suspended from test cages under each cup caught spillage. Cups containing test food not exposed to birds were put in vacant cages to determine mass changes due to moisture. Test food was removed at 1200, and maintenance food provided again. Contents of test food cups were weighed and consumption determined by subtraction after appropriate adjustments for spillage and moisture gain. Consumption was evaluated in a 2-way repeated measures analysis of variance with bait type and oil coating as main effects.

After Day 10, we bled and weighed birds again. There was a 2-day break, then testing resumed. The test diet was switched to the modified B2, C2, and D2 baits. These baits were the same basic formulations as before except each was overcoated with corn oil. For Days 11-20, test baits were presented and consumption measured as before. After the trial on Day 20, we bled and weighed the birds for a third time before returning them to their original group holding pens.

RESULTS

Nesting Trial, January-March 2005

By the second week of treated food presentation, consumption approached 20 g/cage for both groups of birds (Figure 1). Every pair exposed to nicarbazin-treated food consumed enough to acquire a theoretically effective dose of nicarbazin (Figure 2). Eight of the treated pairs produced fertile eggs, however. There was no obvious relationship between the amount of treated food consumed and the DNC residues detected in plasma or eggs produced by treated pairs (Figure 3). DNC residues in plasma decreased ($t = 2.29$, $P = 0.047$) from Day 10 to Day 47.

The only females in the treated group that did not lay

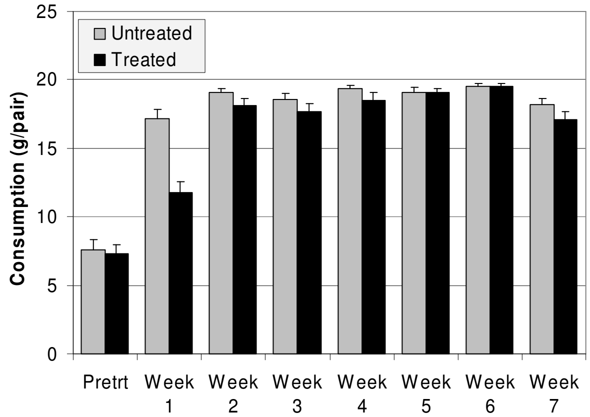


Figure 1. Mean consumption of test diet by 20 pairs of nesting pigeons during a pretreatment week when all food was untreated and then during 7 subsequent weeks when 10 pairs received untreated food and 10 pairs received food treated with nicarbazin. The test food was offered for 3 hours daily. Capped bars denote 1 SE.

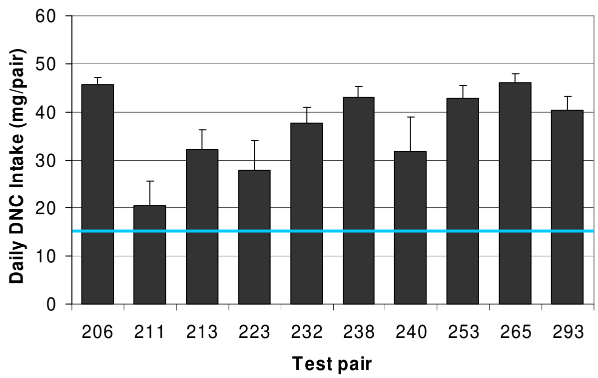


Figure 2. Mean daily intake of nicarbazin by pairs of nesting pigeons from the start of the treatment period through day before the first egg was laid by each pair. Pair 253 produced infertile eggs. Pairs 232 and 238 did not produce eggs. All others produced normal healthy eggs. The horizontal line indicates target level for daily nicarbazin consumption, 15 mg/pair. Capped vertical lines denote 1 SE.

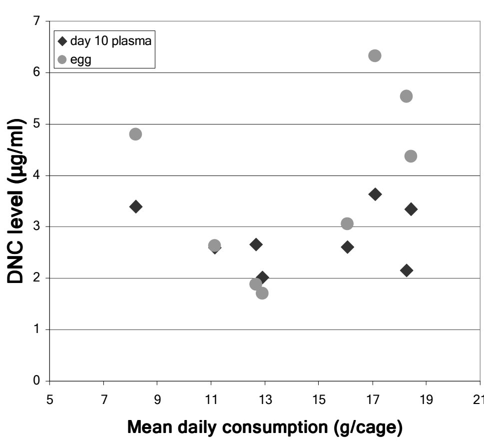


Figure 3. Relationship between consumption of nicarbazin-treated food and the DNC detected in plasma and in eggs produced by 8 pairs of pigeons.

fertile eggs were those with DNC levels on Day 10 in excess of 3.5 ppm (Figure 4). With the exception of one outlying value, there was a strong exponential relationship between DNC residues in plasma and those in eggs laid by female pigeons exposed to treated food (Figure 5). Six treated pairs produced second clutches which we left in place and allowed to hatch. All of the hatchlings appeared normal.

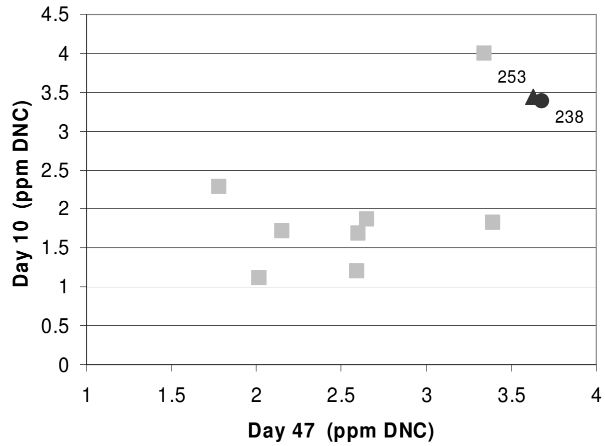


Figure 4. DNC levels in blood plasma from 10 female pigeons given daily access to 20 g of nicarbazin-treated food (2,500 ppm) for 3 hours. Blood was drawn on Day 10 and Day 47 of the treatment period. Bird 253 produced infertile eggs with amorphous yolk mass. Bird 238 did not lay eggs. The other 8 birds laid fertile eggs.

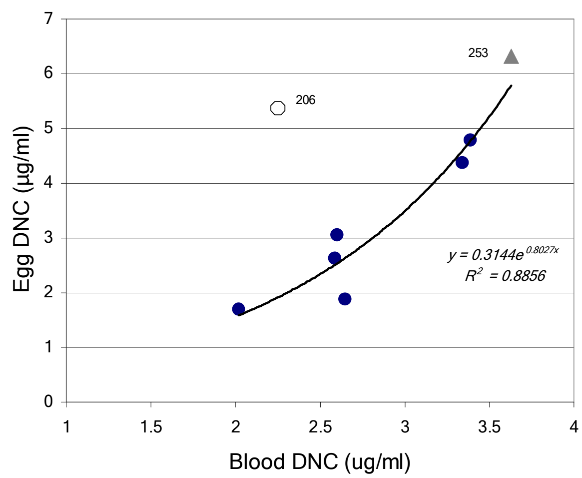


Figure 5. DNC levels in eggs increased exponentially with blood plasma levels in 8 female pigeons given daily access to 20 g of nicarbazin-treated food (2,500 ppm) for 3 hours. Blood was drawn on Day 10 the treatment period and eggs were collected 10 days after laying. Bird 253 produced infertile eggs with amorphous yolk mass. The other 7 birds laid fertile eggs. Bird 206 was considered an outlier and was not included in the exponential regression equation.

Bait Acceptance Trial, April-May 2005

Although each treatment group comprised 8 birds, the number that actually consumed bait varied from 4 (Bait D) to 7 (Bait C). Because of the variation produced by these non-eaters, no differences were detected among groups ($F_{3,28} = 0.98$; $P = 0.414$) or across the 4 weeks of the trial ($F_{3,84} = 2.35$; $P = 0.078$). In the last half of the trial, however, consumption of A and C baits consistently exceeded that of the other types (Figure 6).

Examination of DNC levels in pigeon plasma revealed no clear differences among the treatment groups (Figure 7). Individual DNC levels were strongly correlated between the Day 10 and Day 24 samples (Figure 8). None of these candidate baits provided consistently high DNC levels, however, so an additional bait acceptance trial was conducted.

Bait Acceptance Trial, August-September 2005

Acceptance of the test diets was not universal (Table 1). Two birds did increase their consumption when oil-coated bait was offered, however, and overall consumption of oil-coated bait ($\bar{x}$ = 4.08 g/bird, SE = 0.25) exceeded ($F_{1,447} = 18.93$, $p < 0.001$) that of bait with no oil coating ($\bar{x}$ = 3.15 g/bird, SE = 0.26). There was no difference ($F_{2,27} = 0.02$, $p = 0.981$) among the 3 bait types in overall consumption (Figure 9). Although the interaction between bait type and the presence of an oil coating was not statistically significant ($F_{2,447} = 2.08$, $p = 0.127$), mean consumption of bait type D2 did increase more substantially than the other bait types (Figure 9). Plasma DNC levels reflected the difference in nicarbazin levels between Bait D2 and the other 2 candidates (Figure 10).

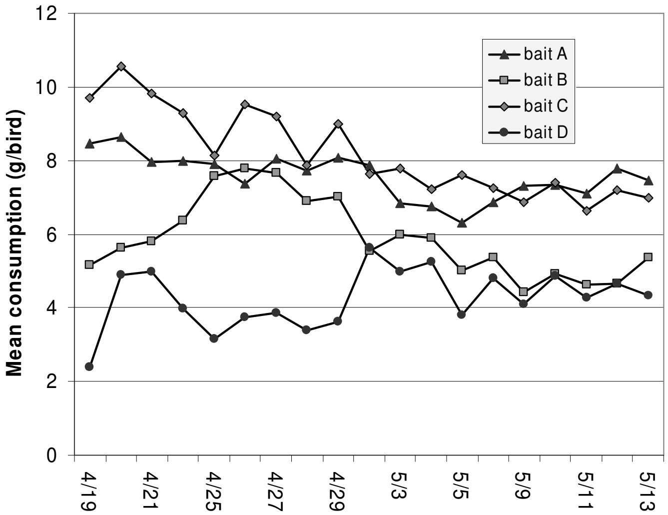


Figure 6. Mean daily consumption of nicarbazin-treated bait by individually caged rock pigeons. Birds were offered the test food each morning for 4 hours. The bait contained 2,500 ppm nicarbazin. There were 8 birds per bait type.

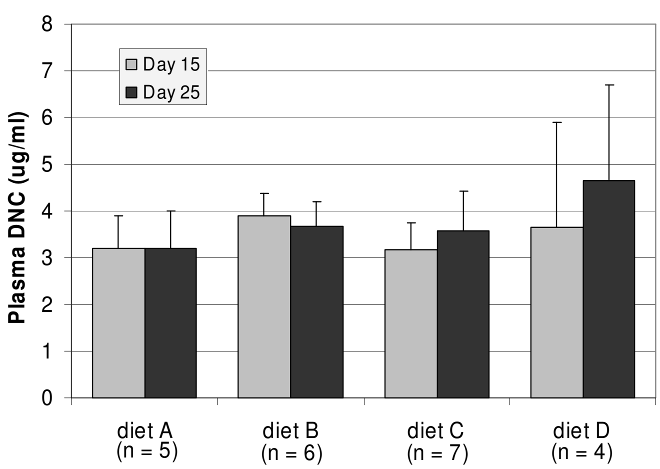
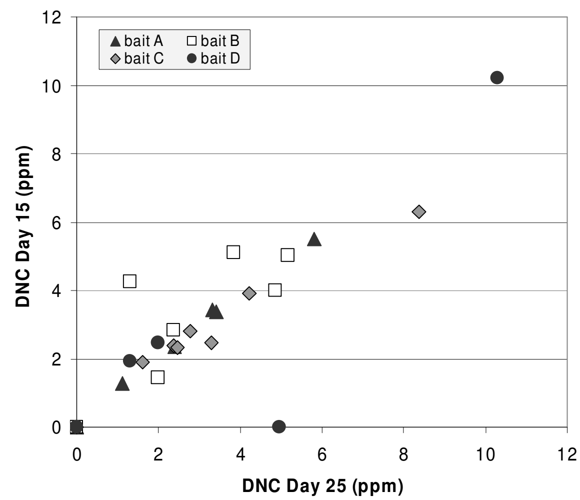
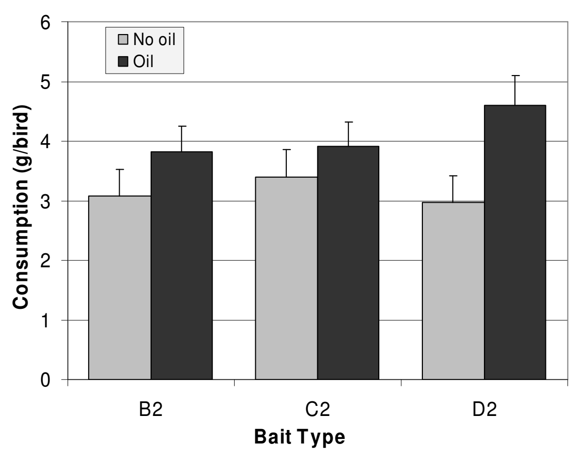


Figure 7. Mean DNC levels in blood plasma of feral pigeons given daily access to 20 g of nicarbazin-treated food (2,500 ppm) for 4 hours for 25 days. Blood was drawn on Day 15 and Day 25. There were 8 birds in each test group.



Number of birds that ate each of the test diets is given in parentheses. Capped vertical bars denote 1 SE.

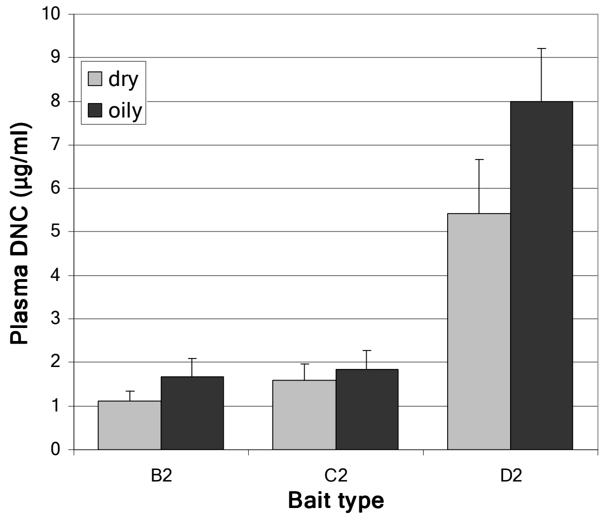
Figure 8. Plasma DNC levels from 32 captive rock pigeons exposed to 4 bait formulations containing 2,500 ppm nicarbazin. The trial lasted 24 days. Bait was presented 4 h each morning. Ten birds never ate sufficient amount of



bait for DNC to be detected.

Figure 9. Consumption of candidate nicarbazin bait formulations by individually-caged pigeons. Each bird was given 1 of 3 bait types for 4 h on 10 days. Then there was a 2-day break followed by a second 10-day trial using the same bait types, but each had an overcoating of corn

oil. There were 10 birds/group. Data represent the overall mean consumption across each trial for each test group.



Capped vertical bars denote 1 SE.

Figure 10. Mean DNC levels in plasma from test pigeons given 1 of 3 bait types for 4 h on 10 days. Following a 2-day break, there was a second 10-day trial using the same bait types except that each was coated with corn oil.

Table 1. Number of birds that consumed >1 g bait daily during 2 consecutive 10-day bait acceptance trials. Three bait formulations– B2, C2, and D2– were tested. During the second 10-day trial, a corn oil coating was added to each formulation (10 pigeons in each test group).

	Bait Type B2	Bait Type C2	Bait Type D2
Without Oil Coating	5	6	6
With Oil Coating	6	7	6

DISCUSSION

Despite what should have been more than adequate consumption of nicarbazin-treated food in the nesting trial, 80% of the pairs exposed to treated food produced fertile eggs. Evidently, insufficient amounts of the active ingredient were absorbed from the ingested food into the pigeon's blood. The reason for this result is not known. Regardless, because plasma DNC levels achieved were substantially lower than expected and were insufficient to affect reproduction in the treated pigeons, new bait formulations were developed to increase absorption.

Eventually, Bait D2 provided a satisfactory result in terms of producing sufficiently high DNC levels in plasma of test pigeons. The bait was readily accepted by most birds. The elevated nicarbazin level, 5,000 ppm, did not adversely affect palatability. The identification of a bait formulation that appears to satisfy criteria for acceptance and plasma DNC levels opens the way to conduct a definitive nesting study in which the anti-fertility properties of this new bait would be quantified using captive breeding birds.

MANAGEMENT IMPLICATIONS

Antifertility agents, such as nicarbazin, represent one approach to managing overabundant bird populations. This approach has the advantage of being nonlethal, which might enhance its appeal to certain segments of the public. At the same time, however, offending birds remain in place, so an actual decrease in the negative impacts of the population will not be realized immediately.

Because nicarbazin is rapidly excreted from the body, sufficient amounts must be ingested by the bird daily for the treatment to remain effective. This is advantageous because it greatly reduces the likelihood that nontarget birds will be inadvertently affected by nicarbazin baiting. But it also presents a challenge to devise baiting strategies to deliver the chemical reliably to target bird populations throughout the breeding season. In some parts of its range, the rock pigeon breeds all year, so population management will require that nicarbazin bait be available all the time. Where breeding is seasonal, baiting can be focused on a few critical weeks. Regardless, it is not realistic to expect nicarbazin or any other fertility control agent to prevent population growth alone. Rather, nicarbazin is best viewed as one component in an integrated strategy for managing overabundant pest species. Application of fertility control agents such as nicarbazin might be more effective as means of maintaining populations at low levels after they have already been suppressed via other methods rather than as the primary means of population reduction (Bomford 1990).

ACKNOWLEDGEMENTS

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