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CHEMICAL REPELLENTS

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# RESPONSES OF CAPTIVE FISH CROWS TO EGGS TREATED WITH CHEMICAL REPELLENTS

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**Abstract:** Eggs of many bird species are subject to predation by corvids. To evaluate whether predation might be reduced through food avoidance learning, we offered Japanese quail (*Coturnix japonica*) eggs treated with various repellent chemicals to captive fish crows (*Corvus ossifragus*). Topically applied methyl anthranilate (100 mg/egg), alone and in combination with injected methiocarb (18 mg/egg), effectively reduced ( $P = 0.015$ ) egg eating by crows. Crows that received topical methyl anthranilate alone, however, lost their avoidance response when untreated eggs were offered. Egg eating was not reduced ( $P > 0.05$ ) by 18 mg/egg injections of carbachol (carbamylcholine chloride) or methiocarb, or by a combined methiocarb (18 mg/egg) and methyl anthranilate (100 mg/egg) injection. Crows exposed to eggs injected with elevated levels of carbachol (40 mg/egg) or methiocarb (30 mg/egg) ate more eggs ( $P = 0.046$ ) than did crows that received topical methyl anthranilate treatments. Injected eggs might be more suitable for field use, however, because they are difficult to distinguish from untreated eggs and they are easier to prepare. The persistence displayed by some crows during their 5-day exposure to treated eggs suggests that successful application of repellent egg treatments will require an extended period of training for target predators to acquire an avoidance response.

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**Key words:** carbachol, chemical repellent, *Corvus ossifragus*, egg predation, fish crow, methiocarb, methyl anthranilate, predator management.

Fish crows and other corvids frequently prey on eggs, often to the detriment of avian species or populations of special concern (Kalmbach 1937, Shields and Parnell 1986, Massey and Fancher 1989, Post 1990). Although lethal control measures are sometimes necessary and effective (Butchko 1990), alternatives to lethal control are being sought.

One nonlethal approach to reducing egg predation that has shown promise is food-avoidance learning. Hanners and Southern (1980) proposed that aversive conditioning be incorporated into management plans to control predation on nesting birds. Nicolaus et al. (1983) tested the concept and reported that free-ranging American crows (*C. brachyrhynchos*) stopped eating chicken eggs dyed green after the crows had been exposed to such eggs treated with 30 mg of trimethacarb, a reversible cholinesterase inhibitor that produces postingestional illness.

We conducted a series of feeding trials with captive fish crows to document their responses to eggs treated with known repellent compounds: methiocarb (Rogers 1974, Mason and Reidinger 1982, Avery 1989); carbachol (Nicolaus et al. 1989); and methyl anthranilate (Ma-

son et al. 1989). We used fish crows because they are known egg predators (Post 1990) and because their responses to repellents have not been studied. We used Japanese quail eggs rather than larger chicken eggs because many species preyed upon by corvids lay small eggs, and corvids may prey selectively on smaller eggs (Montevicchi 1976).

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## METHODS

### Study Subjects

We captured fish crows in drop-in decoy traps (Johnson and Altman 1983) at the Denver Wildlife Research Center's Florida Field Station, Gainesville. Crows were housed in pairs in 1.2- × 1.2- × 1.8-m cages in a roofed, outdoor aviary with access to water and commercial dog food. We weighed each bird before and after testing, then banded and released it.

## Test Procedures

*Daily Regime.*—We tested birds singly in 9.2- × 3.1- × 1.8-m outdoor enclosures. Crows had continuous access to water and shaded perches. Partitions prevented test birds from seeing each other while they were feeding. We removed each crow's bowl of dog food at 0700 on each test day after 3 days of acclimation. One hour later, we put 50 g of dog food and 2 repellent-treated quail eggs into each enclosure. We placed eggs in a shallow scrape in the ground 1–2 m from a perch. We placed a 50-g bowl of dog food outside the enclosures to determine mass gain or loss to the environment. Each morning, we videotaped 1 test bird for 2 hours. Videotaped observations proved inadequate for statistical analyses but confirmed that methiocarb and carbachol treatments were emetic.

At 1200, we retrieved the test food bowl, noted the condition of the eggs, removed them, and returned the maintenance food bowl. We classified eggs as eaten, moved but not eaten, or untouched. Dog food was reweighed and consumption determined by subtraction after adjustment for water gain or loss.

Each experiment consisted of a 5-day treatment phase during which we offered 2 treated eggs daily, followed by a 5-day posttreatment phase during which 2 untreated eggs were offered. To increase the likelihood of eliciting an avoidance response when treated eggs were offered, crows were not pre-exposed to untreated eggs. We released birds that did not move an egg by day 4 of the 5-day treatment phase. Birds that moved  $\geq 1$  egg by day 4 were used in the posttreatment phase and offered untreated eggs for 5 days or until the crow moved an untreated egg.

*Egg Treatment.*—We prepared treated eggs by first removing 4 mL from each with a disposable syringe. This material was later blended with the contents of a chicken egg and a pre-measured quantity of repellent. We then injected 3 mL of the mixture into each egg to achieve the desired treatment rate. Eggs were then heated, half submerged in water, for 5 minutes at 85–90 C. This hardened the contents of the eggs, lessening the chance that treated egg material would spill once the crows broke the shell. After the eggs cooled, we sealed the holes with hot-melt glue and refrigerated the eggs until use.

In Experiment 1, we exposed crows ( $n =$

6/group) to 1 of 5 treatments: (1) 18 mg carbachol (99% purity, Aldrich Chem. Co., Milwaukee, Wis.) injected; (2) 18 mg methiocarb (in the form of 75% wettable powder, Mobay Chem. Corp., Kansas City, Mo.) injected; (3) 18 mg methiocarb plus 100 mg methyl anthranilate (99% purity, Aldrich Chem. Co., Milwaukee, Wis.) injected; (4) 18 mg methiocarb injected plus 100 mg methyl anthranilate topically applied just before presentation to the birds; and (5) 100 mg methyl anthranilate topically applied.

In Experiment 2 we presented crows with unheated eggs injected with either 30 mg methiocarb or 40 mg carbachol. We used 8 birds/group, but in all other respects the procedures were the same as in Experiment 1. We dispensed with cooking the egg to eliminate a step that might be inconvenient in the field. We also tested higher treatment rates because we wanted crows to receive an effective emetic dose from their initial encounter with treated eggs. We hypothesized that this would help discourage crows from repeatedly testing eggs.

## Data Analyses

We analyzed consumption of dog food with a repeated measures analysis of variance (ANOVA), with treatment group as the independent factor and days as the repeated factor. Changes in mass of test birds from the beginning to the end of the trials were analyzed in 2-way, repeated measures ANOVAs.

Because data did not meet assumptions for parametric statistical analysis, we applied Friedman's test (test statistic  $\chi^2$ , Sokal and Rohlf 1969) and analyzed separately the number of eggs eaten and number of eggs moved but not eaten by test groups, with days as the blocking factor. In Experiment 1, we applied a nonparametric a posteriori simultaneous test procedure (Sokal and Rohlf 1969) to isolate differences ( $P < 0.05$ ) among pairs of treatments. Using a Kruskal-Wallis test, we compared the numbers of eggs eaten by crows in Experiment 2 with those eaten by crows exposed to topical methyl anthranilate treatments in Experiment 1.

We also compared the relative effectiveness of treatments by plotting crows' exposure to treated eggs versus the period of time birds refrained from moving eggs following their last exposure. Egg moving was the response of interest because in the field an egg moved from a nest is effectively lost even if it is not damaged.

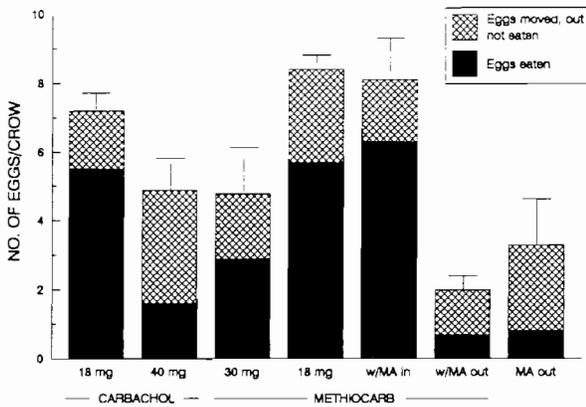


Fig. 1. Mean number of eggs eaten or moved but not eaten during daily 4-hour trials by individually caged fish crows. Bars indicate 1 SE of the total. Treatments were 18 and 40 mg carbachol injected, 18 and 30 mg methiocarb injected, 18 mg methiocarb plus 100 mg methyl anthranilate (MA) injected (w/MA in), 18 mg methiocarb injected plus 100 mg methyl anthranilate topically applied (w/MA out) and 100 mg methyl anthranilate topically applied (MA out).

A negative slope of the regression line would indicate that slow-learning birds (greater exposure to treated eggs) lost the avoidance response more quickly than did faster learning birds. A positive slope would indicate that greater exposure to the treatments produced more effective avoidance responses.

For the topical methyl anthranilate treatments (alone and with injected methiocarb), we used the total number of eggs moved, eaten or not, as the exposure measure because simply contacting eggs exposed birds to the topical treatment. For the other groups, we used the number of treated eggs eaten as the measure of exposure because crows had to ingest egg contents to be exposed to these treatments.

## RESULTS

### Experiment 1

The number of eggs eaten differed among treatment groups ( $\chi^2 = 12.33$ , 4 df,  $P = 0.015$ ). Topical methyl anthranilate treatments, alone and with injected methiocarb, were more effective ( $P < 0.05$ ) than other treatments (Fig. 1). The number of eggs moved but not eaten did not differ among groups ( $\chi^2 = 4.05$ , 4 df,  $P = 0.40$ ). Mass of birds did not vary among test groups ( $F = 2.32$ ; 4, 25 df;  $P = 0.085$ ) or from the beginning to the end of the trial ( $F = 1.82$ ; 1, 25 df;  $P = 0.190$ ).

Consumption of dog food was not affected by egg treatments ( $F = 0.55$ ; 3, 20 df;  $P = 0.65$ ), but consumption on day 1 (7.3 g/bird) was lower

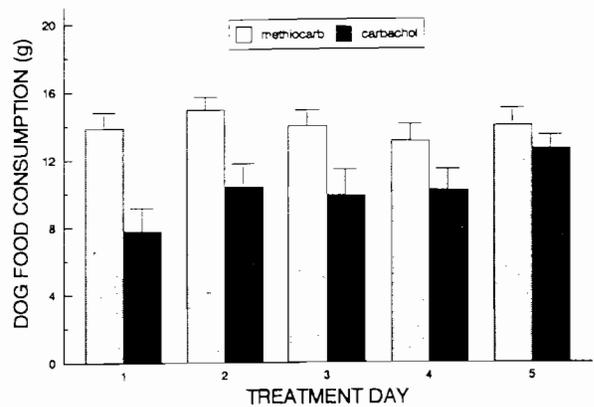


Fig. 2. Mean daily consumption of dog food by individually caged fish crows ( $n = 8$ /group) exposed to either 30 mg methiocarb/egg or 40 mg carbachol/egg. Bars indicate 1 SE.

( $F = 22.02$ ; 4, 80 df;  $P < 0.001$ ) than on subsequent days (13.1 g/bird). A treatment by day interaction ( $F = 2.16$ ; 12, 80 df;  $P = 0.022$ ) reflected greater consumption on day 1 by the methiocarb group (10.7 g/bird) than by other treatment groups (6.2 g/bird).

Every crow in the 18-mg-carbachol, 18-mg-methiocarb, and 18-mg-methiocarb plus injected methyl anthranilate groups ate untreated eggs on the first posttreatment day. Birds in these groups had consistently eaten eggs throughout the treatment period (Fig. 1).

Among crows that received injected methiocarb and topical methyl anthranilate, 1 that ate an egg on treatment day 2 and 2 others that moved eggs on treatment day 4 did not touch untreated eggs during posttreatment. Two other birds in this group resumed eating untreated eggs after intervals of 4 and 7 days, respectively. One bird resumed moving but not eating eggs after a 1-day interval. After their initial encounter with treated eggs, 2 birds in the methyl anthranilate-only group did not touch another egg. Others resumed moving, but not eating, untreated eggs after intervals of 1–4 days.

### Experiment 2

Each crow ate  $\geq 1$  egg, but more treated eggs were eaten by crows in the 30-mg-methiocarb group than by birds exposed to 40 mg carbachol ( $\chi^2 = 5.00$ , 1 df,  $P = 0.026$ ). Crows exposed to these injected treatments ate more eggs ( $H = 8.05$ , 3 df,  $P = 0.046$ ) than did those exposed to topical methyl anthranilate treatments in Experiment 1 (Fig. 1). There was no difference ( $\chi^2 = 3.00$ , 1 df,  $P = 0.084$ ) in the number of eggs moved but not eaten (Fig. 1).

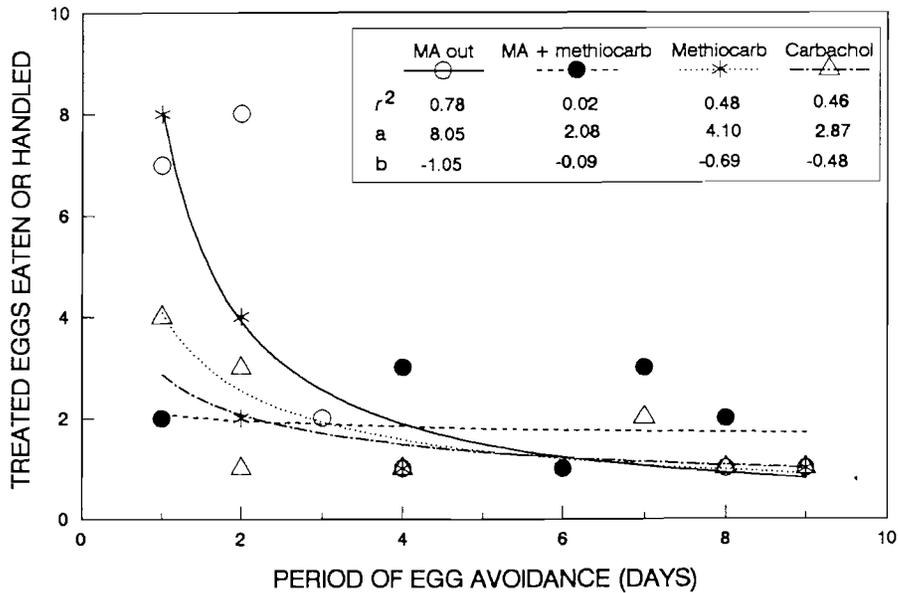


Fig. 3. Relationship between the number of treated eggs eaten (carbachol and methiocarb groups) or moved but not eaten (topical methyl anthranilate [MA] and topical methyl anthranilate plus methiocarb groups) by individual fish crows and the interval between their last encounter with a treated egg during the treatment phase and their initial encounter with an untreated egg in the posttreatment phase. Regression curves are of the form  $Y = aX^b$ .

After eating 1 treated egg, 6 of 8 birds in the 30-mg-methiocarb group and 5 of 8 birds in the carbachol group did not eat any more treated eggs. Of the remaining 2 birds in the methiocarb group, 1 ate just 1 additional treated egg while the other bird sampled 7. The remaining birds in the carbachol group ate 1, 1, and 2 additional treated eggs, respectively.

Following a 5-day treatment period, each crow was given untreated eggs. Five of the 8 methiocarb birds ate untreated eggs on the first day they were offered. Two others moved but did not eat untreated eggs, and the other bird did not move any eggs during the 5-day posttreatment phase. In the carbachol group, 3 crows ate untreated eggs the first day they were offered, and another moved eggs without eating them. The other 4 crows did not move or eat an egg during the remainder of the trial.

Daily consumption of dog food was greater ( $F = 10.47$ ; 1, 14 df;  $P = 0.006$ ) in the methiocarb group (14.0 g/crow) than in the carbachol group (10.2 g/crow). The pattern of consumption did not vary across days (Fig. 2), and there was no interaction between treatment and day.

On average, crows in the methiocarb group lost 4 g (SE = 4) during the trial compared with a mean loss of 11 g (SE = 7) in the carbachol group. However, we did not detect changes in mass within or between groups ( $F = 0.81$ ; 1, 14 df;  $P = 0.383$ ).

### Comparative Learning Responses

Except for the group that received the injected methiocarb plus topical methyl anthranilate treatment, there was a general negative relationship between exposure to repellents and the birds' subsequent avoidance of eggs (Fig. 3). Crows that repeatedly sampled treated eggs resumed egg-eating behavior when untreated eggs were offered. This was most evident in the 18-mg-carbachol, 18-mg-methiocarb, and 18-mg-methiocarb plus injected methyl anthranilate groups. Each bird in these groups had repeated exposure to treated eggs (Fig. 1) and yet each moved or ate an untreated egg on the first post-treatment day. Conversely, crows that learned quickly to avoid treated eggs tended to extend avoidance response to untreated eggs for longer periods. Only in the injected methiocarb-topical methyl anthranilate group did egg avoidance appear to be independent of the degree of exposure to treated eggs (Fig. 3).

### DISCUSSION

Of the treatments we tested, the 2 that included topical methyl anthranilate application were superior in deterring captive fish crows. However, the topical methyl anthranilate treatment alone was associated with the steepest drop in learning response curves (Fig. 3). This was apparently because some birds were not suffi-

ciently affected by the treatment, continued to test eggs, and quickly recognized and ate untreated eggs during posttreatment.

When topical methyl anthranilate was combined with injected methiocarb, no bird ate or moved >3 treated eggs, and the learning response curve was flat (Fig. 3). The contact irritancy of methyl anthranilate provided an immediate deterrent signal and produced initial avoidance. Birds that persisted and actually ingested portions of the treated egg developed postingestional distress caused by methiocarb that apparently slowed the loss of the avoidance response.

Although topical methyl anthranilate and topical methyl anthranilate-injected methiocarb treatments were effective with captive crows, we are uncertain if they will effectively deter egg predators in the field. If normal eggs and eggs to which a readily perceived external sensory cue is added are presented simultaneously, corvids might readily distinguish between them (Nicolaus 1987, Dimmick and Nicolaus 1990). Similarly, if treated and untreated eggs are presented sequentially, then crows could quickly recognize the difference and resume eating eggs. The rapid decline of the learning curve for the methyl anthranilate-only group (Fig. 3) supports this interpretation.

There may be several reasons why injected methiocarb and carbachol treatments were not more successful in Experiment 2. Conceivably, crows may have previously had rewarding experiences eating bird eggs, and a few exposures to normal-looking eggs injected with an aversive agent were insufficient to overcome their positive experiences. Although treatments were emetic, it is possible that they produced insufficient adverse effects to alter crow behavior.

The difficulty in dissuading some crows from eating or moving eggs, even after they had an emetic dose of treated egg, may be attributable to test conditions. The continued picking up and moving of eggs may have been an expression of behavior other than an intention to eat. Free-ranging corvids have numerous behavioral options, and in the field there is probably little incentive to return to forage at a consistently unrewarding site.

## MANAGEMENT IMPLICATIONS

Given the persistence displayed by some test crows, a large number of unrewarding experiences might be necessary to induce avoidance

of eggs, particularly if the birds' prior experiences had been consistently favorable. For example, Dimmick and Nicolaus (1990) provided a 23-day aversion acquisition period, and Nicolaus (1987) exposed territorial corvids to treated eggs for 3 months.

Thus, whenever possible, treated eggs should be deployed well in advance of the availability of the eggs to be protected. This will allow avian predators to feed repeatedly on the treated eggs at a given site and learn that it is not profitable to prey on eggs there. By the time the eggs to be protected are present, predators will be conditioned to avoid eggs at that location.

Eventual choice of an egg predator deterrent will be influenced by factors such as effectiveness, cost, stability under exposure to the environment, and potential nontarget hazards. Although topical methyl anthranilate treatments were effective in our trials, practical considerations may limit their usefulness in the field. Methyl anthranilate degrades rapidly in sunlight (Askham 1992) and the necessity of frequently reapplying the repellent to maintain treatment potency may prove inconvenient and time consuming. Nevertheless, our findings suggest that further evaluation of methyl anthranilate, alone and combined with other repellents, is warranted as nonlethal methods for managing egg predation are developed.

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