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Responses of Captive Fish Crows (*Corvus ossifragus*) to Acetaminophen Baits and Bait Stations for Brown Tree Snake (*Boiga irregularis*) Control on Guam

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One component of brown tree snake (*Boiga irregularis*) management on Guam is the use of a toxic bait that consists of acetaminophen tablets inserted into a dead neonatal mouse (DNM), which in turn is placed within a cylindrical polyvinyl chloride (PVC) bait station suspended above ground. Whereas this technique is effective in killing snakes, possible hazards to nontarget species, especially the Mariana crow (*Corvus kubaryi*), are of concern. We used the fish crow (*C. ossifragus*) as a surrogate for the Mariana crow to evaluate (1) oral toxicity of acetaminophen, (2) behavior of crows exposed to DNM containing acetaminophen tablets, and (3) ability of crows to remove DNM from cylindrical bait stations. In the oral toxicity test, all five crows that were each force-fed two 40-mg acetaminophen tablets survived and at least two birds regurgitated the tablets. Five additional crows received a double dose (four 40-mg tablets); each regurgitated all of its tablets, but one bird died. Crows given DNM containing two 40-mg acetaminophen tablets consumed the DNM but avoided eating tablets by picking them from the carcass and either setting them aside or dropping them from the perch. Forty individually caged crows were tested with various size bait station cylinders containing an untreated DNM. Only the longest (45.7 cm), narrowest (5.1 cm) cylinder prevented crows from removing the DNM. In brown tree snake control operations, it appears that the risk of accidental exposure of Mariana crows to toxic acetaminophen bait can be minimized through appropriate bait station design. Even if crows encounter a DNM containing acetaminophen, they are likely to reject the tablets before consumption or regurgitate if tablets are accidentally ingested.

Acetaminophen	Bait station	Fish crow	Brown tree snake
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Brown tree snakes were accidentally introduced to Guam after World War II and their predatory actions have caused the extinction of most of the island's native bird species (Savidge, 1987) and

many native lizard species (Rodda & Fritts, 1992). The snakes also create potential health hazards by entering houses and biting infants and young children (Fritts, McCoid, & Haddock, 1990). Further-

more, millions of dollars in damaged equipment, lost productivity, and repair costs result from snake-caused power outages (Fritts, Scott, & Savidge, 1987).

Effective control of brown tree snakes on Guam in small plots of forest (~6 ha) has been demonstrated with dead neonatal mice (DNM) baits treated with 80 mg acetaminophen (Savarie, Shivik, White, Hurley, & Clark, 2001). The baits were placed in bait stations (5.1-cm-diameter \times 30.5-cm-long white PVC tubes) to reduce exposure to nontarget animals such as the endangered Mariana crow (*Corvus kubaryi*). It is estimated that only about 20 Mariana crows are on Guam and they share forested habitats with the brown tree snake, which is the major cause for the near extirpation of the crow and extinction of other forest birds (National Research Council, 1997). If large-scale control of snakes with acetaminophen baits is conducted on Guam, the potential primary hazards of the baits to crows need to be known (Johnston et al., 2002).

The Mariana crow is considered an endangered species by the Territory of Guam and by the US government (National Research Council, 1997). We felt that the risk, however slight, of injury or death to a Mariana crow through an accident or inadvertent mishap should be avoided. Therefore, we did not conduct trials with captive Mariana crows, either on Guam or at sites in the US. Instead, we opted to use a surrogate species, the fish crow (*Corvus ossifragus*). This was an appropriate surrogate for the Mariana crow for several reasons. First, both species are omnivorous and exhibit a variety of foraging methods (Goodwin, 1976; National Research Council, 1997). Body mass of the Mariana crow is approximately 250 g (National Research Council, 1997), whereas the fish crow is 20–30 g larger (data from this study), so size differences are not appreciable. Fish crows are locally abundant, readily trapped, and we have considerable prior experience maintaining them and testing them in behavioral trials (e.g., Avery & Decker, 1994). In this study, we document (1) oral toxicity of acetaminophen to fish crows, (2) behavior of fish crows exposed to DNM containing acetaminophen tablets, and (3) ability of fish crows to remove DNM from cylindrical PVC bait stations. These findings will be used in developing ecologically sound baiting strategies to reduce brown tree snake populations and to minimize risk to Mariana crows on Guam.

Methods

Test Subjects

We trapped fish crows in Alachua County, Florida, using a modified Australian crow trap (Gadd, 1996). The entire study involved 60 crows. We maintained crows in groups in outdoor pens (3.1 \times 9.3 \times 2.2 m) equipped with several shaded perches, food and water bowls. There were no more than 10 birds per pen. Maintenance food was dry dog food (Old Roy®, 26% protein from Wal Mart), supplemented on a regular basis with sliced apples, bread, and hard-boiled eggs.

Toxicity of Acetaminophen

On day 1, five fish crows were taken from their group holding pen and housed singly in test pens within a roofed, outdoor aviary. Test pens (3.1 \times 3.1 \times 1.8 m) consisted of panels made of aluminum frames and plastic-coated welded wire and were equipped with a central perch, a water bowl, a grit cup, and a food dish. On the morning of day 4, each bird was removed from its test pen, weighed, and force-fed two 40-mg acetaminophen tablets. After force-feeding, we observed each bird for 20 min to verify that the tablets were not regurgitated. Birds were then observed at hourly intervals for signs of illness or intoxication for the next 6 h. We kept the birds in their test pens for 1 week and observed them briefly each day for signs of illness. On the morning of day 11, each bird was weighed, banded, and released. We then repeated the entire procedure using five new birds and a dose rate of 160 mg/bird (four 40-mg tablets).

Response to Acetaminophen-Treated DNM

We removed five fish crows from their group holding pen and housed them singly in test pens with water and normal maintenance diet. On days 4–8, we also offered DNM to each bird and videotaped two birds each day to document their handling of the DNM. On day 8, we removed the maintenance food at 1600 h and fasted the birds overnight. The next morning, each bird received one treated DNM at 0800 h. Each DNM was treated by inserting two 40-g acetaminophen tablets through the mouth of the DNM and pushing them inside the DNM as far as possible. As on previous days, two birds were videotaped. At 1000 h, we inspected each pen to be

certain that the bird consumed the treated DNM. At the same time, we observed each bird for signs of illness or discomfort (ataxia, ruffled feathers, lethargy, etc.). We returned maintenance food to the test pens and continued to observe each bird at least once daily for signs of illness or discomfort for the next 7 days. Then each bird was weighed, banded, and released. This entire procedure was then repeated with five additional birds.

Removal of DNM From Bait Stations

We tested five birds at a time. Each bird was removed from its holding cage, weighed, and placed into an individual test pen. Each pen was equipped with a PVC bait station suspended from the central perch by twine. During a 3-day acclimation period, each bird received its normal maintenance food plus two DNM (5–6 g each) daily. On day 4, we removed each bird's maintenance food at 0700 h. One hour later, we presented each bird with one DNM inserted halfway into the PVC bait station. Two birds were videotaped daily to record their responses to this presentation. Every 2 h, we checked the status of the bait station and the DNM. After 6 h, we removed the DNM from each bait station and returned the maintenance food to the pen. This procedure was repeated on days 5–7. Then each bird was weighed, banded, and released. We applied analysis of variance (ANOVA) to examine changes in body mass among treatment groups.

We tested a total of 40 fish crows. There were four sizes of bait station and we exposed 10 crows to each one. For each size of bait station, five crows were provided with an auxiliary perch secured to the cage so that the bird had easy access to one end of the bait station. The other five birds did not have an auxiliary perch. Bait stations were 5.1 or 10.2 cm in diameter, and 30.5 or 45.7 cm long. We used a two-way ANOVA to examine the effects of tube length and diameter on total number of DNM removed, regardless of auxiliary perch.

Results

Toxicity of Acetaminophen

Body mass of test birds dropped following their transfer to individual test cages, but then recovered to near initial levels by the end of the trial (Fig. 1). There was no mortality among the five crows force-

fed two 40-mg acetaminophen tablets. Direct observations of three birds for 25–32 min postdosing revealed no sign of regurgitation of the tablets. The two videotaped birds did vomit, however, with the onset at 31 and 46 min after dosing, respectively. Four of the five birds acted subdued after dosing and did not fly about their pens or change perches when observers walked past as they normally did on previous and subsequent days.

One crow died at the four-tablet (160 mg) dose rate. It first vomited 21 min after dosing, and vomited six more times in the next 16 min. Later, 67 min after dosing, the bird was unsteady and seemed to have difficulty perching. It was found dead 3 h after dosing. Three of the other four birds were videotaped. Each of them regurgitated tablets. The onset of vomiting was 11, 15, and 19 min after dosing, respectively. We collected four regurgitated tablets from each test cage, dried them for 24 h, and weighed each set. The combined mass of regurgitated tablets from the five test birds was: 0.0556, 0.0978, 0.1048, 0.1352, and 0.1924 g, respectively. Combined mass of four intact tablets was 0.2192 g. The lowest regurgitated mass came from the pen with the bird that died.

Response to Acetaminophen-Treated DNM

With a single exception, crows given untreated DNM tore the DNM apart and ate it bit by bit. One

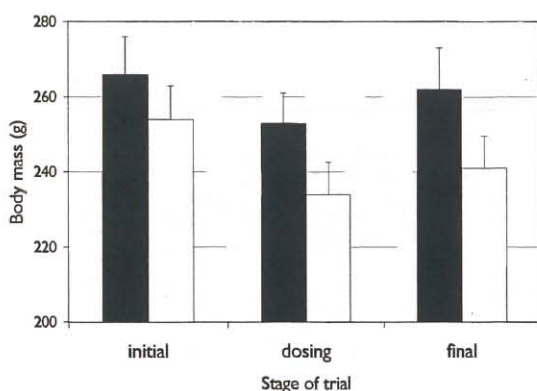


Figure 1. The body mass of fish crows used in the acetaminophen toxicity trial was measured when the birds were initially placed into individual test cages, when they were dosed with acetaminophen tablets, and finally when they were released. The test group that received two 40-mg tablets is indicated by filled bars; open bars represent the four-tablet group ($n = 5$ birds/group). Capped vertical bars denote 1 SE.

time, one bird swallowed the whole intact DNM. In every other instance, that bird and all other birds pulled the DNM apart and ate it in pieces. With treated DNM, the birds that we observed on videotape located the tablets as they tore into the DNM and removed the tablets from the carcass. Twice, the birds placed the tablets on the perch (Fig. 2). Birds that encountered tablets in the DNM frequently shook their heads and wiped their bills on the perch. All 10 test birds were released in good health.

Removal of DNM From Bait Stations

With few exceptions, crows lost some body mass when moved from communal holding cages to individual test cages (Fig. 3). This pattern was similar across treatment groups, $F(3, 36) = 2.14$, $p = 0.112$. Mean losses of body mass ranged from 1.7% (SE = 0.9%) in the 5.1-cm-diameter, 30.5-cm-long group to 6.5% (SE = 2.0%) in the 10.2-cm-diameter, 45.7-cm-long group.

Nine of 40 crows (22.5%) removed at least one DNM from a bait station. At least one crow removed DNM from each type of bait station except for the 45.7-cm-long, 5.1-cm-diameter design (Table 1). Two-way ANOVA showed that bait station length affected DNM removal, $F(1, 36) = 5.50$, $p = 0.025$, whereas diameter did not, $F(1, 36) = 2.45$, $p = 0.127$. Birds removed an average of 1.1 (SE = 0.4) DNM from the 30.5-cm-long tubes compared with 0.2 (SE = 0.1) DNM from the 45.7-cm-long tubes.



Figure 2. When fish crows encountered acetaminophen within a dead mouse carcass, they removed the tablet and sometimes placed it on the perch (white mass beside the bird's left foot).

Five birds with an auxiliary perch took DNM, each involving a 30.5-cm-long bait station (Table 1). These birds took their DNM first on day 1 or day 2. Conversely, three of four birds that took DNM without an auxiliary perch first did so on day 3, although the fourth bird learned to remove the DNM on day 1. The five birds that used the perch were able to reach into the shorter bait station tube to grab the DNM with little difficulty. Birds that did not use the perch accessed the tube by two methods. Mostly they used one foot to hold onto the cord by which the tube was tied to the perch and swing down below the perch where they grabbed the bottom rim of the tube opening with the other foot. They were then able to maintain balance with their wings as they reached into the tube to grab the DNM (Fig. 4). One bird deviated from this method by flying directly up to the opening of the tube from below the perch and grabbing onto the bottom rim of the tube with both feet. It then kept its balance by flapping its wings as it pushed into the tube to grab the DNM (Fig. 5).

Discussion

Although a 160-mg force-fed dose of acetaminophen was lethal to one crow, the birds appeared to possess behaviors that generally reduce the risk of acquiring a lethal dose. First, every bird given the

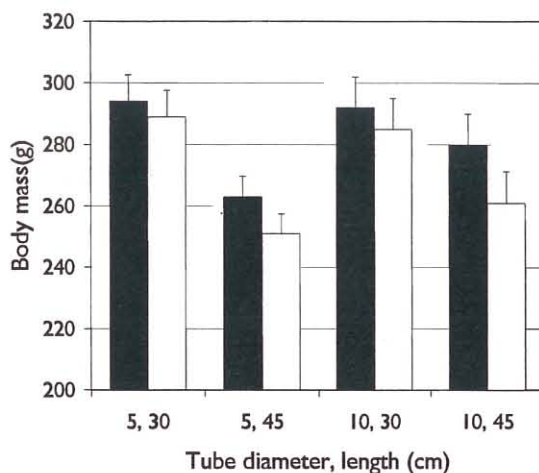


Figure 3. Mean body mass of fish crows declined slightly from initial (filled bars) to final (open bars) values in each of four test groups ($n = 10$ birds/group) during behavioral trials to assess the crows' responses to different-sized PVC bait station tubes containing a dead neonatal mouse. Capped vertical bars denote 1 SE.

Table 1. Number of Captive Fish Crows That Removed DNM From Brown Tree Snake Bait Stations

Bait Tube Diameter (cm)	Bait Tube Length (cm)			
	30.5		45.7	
	Perch	No Perch	Perch	No Perch
5.1	2 ^a	0	0	0
10.2	3	2	0	2

^aOne bird did not use the auxiliary perch even though it was available.

For each diameter-length combination, 10 crows were tested. Half of the crows in each group were provided with an auxiliary perch to facilitate access to the bait station. The trials lasted for 6 h on 4 consecutive days.

higher dose vomited, and at least two, possibly more, of the crows given the 80-mg dose vomited. Thus, crows are able to purge themselves of potentially lethal material after it is ingested. Second, with a single exception, crows did not swallow the DNM whole but instead picked them apart and ate them piecemeal. When crows encountered acetaminophen tablets inside the DNM, birds invariably recognized the tablets as objectionable and removed them before consuming the DNM. By picking apart the DNM, crows limit their exposure to the toxin.

Of the bait station designs tested, only the 5.1-cm-diameter, 47.5-cm-long tube was bird proof. The distance from the end of the tube to the center where the DNM was placed was too great for a fish crow to reach given the narrow opening. We observed that although several of the test birds looked into the tube

and obviously were aware of the DNM, none attempted to remove a DNM from this bait station design.

The applicability of our findings to the situation in Guam depends largely on the degree to which the behavior of fish crows in captivity represents that of free-flying Mariana crows. Perhaps the Mariana crow deviates substantially from the fish crow in how it consumes DNM prey or in its willingness to investigate cylindrical bait stations. Reportedly, captive Mariana crows tear apart DNM before eating them and do not swallow that type of prey whole (S. R. Derrickson, personal communication). That fact is encouraging, and hopefully free-flying Mariana crows will respond similarly. Regardless, we conclude that if appropriate bait station design is used,

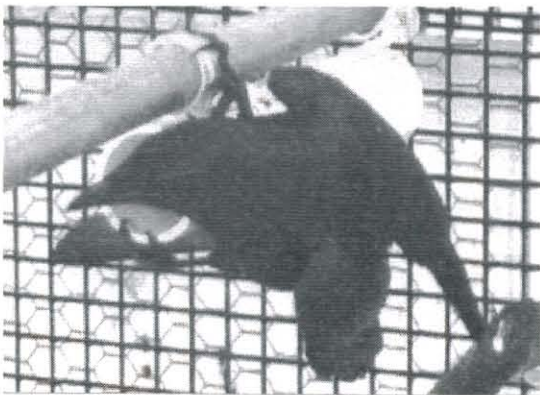


Figure 4. The most common means used by crows to access bait stations was to hold onto the top by one foot with the other foot on the lower rim of the tube.



Figure 5. One crow accessed the bait station by flying directly to the bait station, holding onto the lower rim with both feet, and balancing with its wings so it could reach into the tube and grab the dead mouse.

the chance of a Mariana crow being exposed to a lethal dose of acetaminophen is remote.

Author Note

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