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REFLECTING TAPES REPEL BLACKBIRDS FROM MILLET, SUNFLOWERS, AND SWEET CORN

RICHARD A. DOLBEER, ***U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, OH 44870***

PAUL P. WORONECKI, ***U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, OH 44870***

RICHARD L. BRUGGERS, ***U.S. Department of Agriculture, Denver Wildlife Research Center, Building 16, Federal Center, Denver, CO 80225***

Bird damage to agricultural crops continues to be a problem in localized areas of the United States and other countries (DeGrazio 1978, Dolbeer 1980, Wright et al. 1980). Besides economic losses, bird damage may exacerbate conflicts between agriculture and the enforcement of laws protecting wildlife and their habitats (Anon. 1983, Stone et al. 1984, Flickinger et al. 1986).

There is a continual need for the development of new means for keeping birds out of crops. Nonchemical techniques are especially attractive because of the expense of governmental registration of chemical repellents and toxicants (Hood 1978) and the economic and technical difficulties surrounding their use. One new technique for repelling birds is reflecting tape or ribbon made of mylar, marketed as Bird Scaring Reflecting Tape® (reference to trade names does not imply endorsement by the U.S. Government). The tapes (11 mm wide, 0.025 mm thick, metallic red and silver on opposite sides) flash in sunlight and wind when suspended above a field and produce a "roaring" noise under certain wind conditions. Reflecting tapes have shown promise in reducing bird activity in field trials in the United States, Philippines, India, and Bangladesh (Bruggers et al. 1986). However, no replicated experiments have evaluated the performance and optimal deployment of these tapes. We evaluated the effectiveness of reflecting tapes at 3 spacing intervals for reducing bird damage to ripening millet, sunflowers, and corn and de-

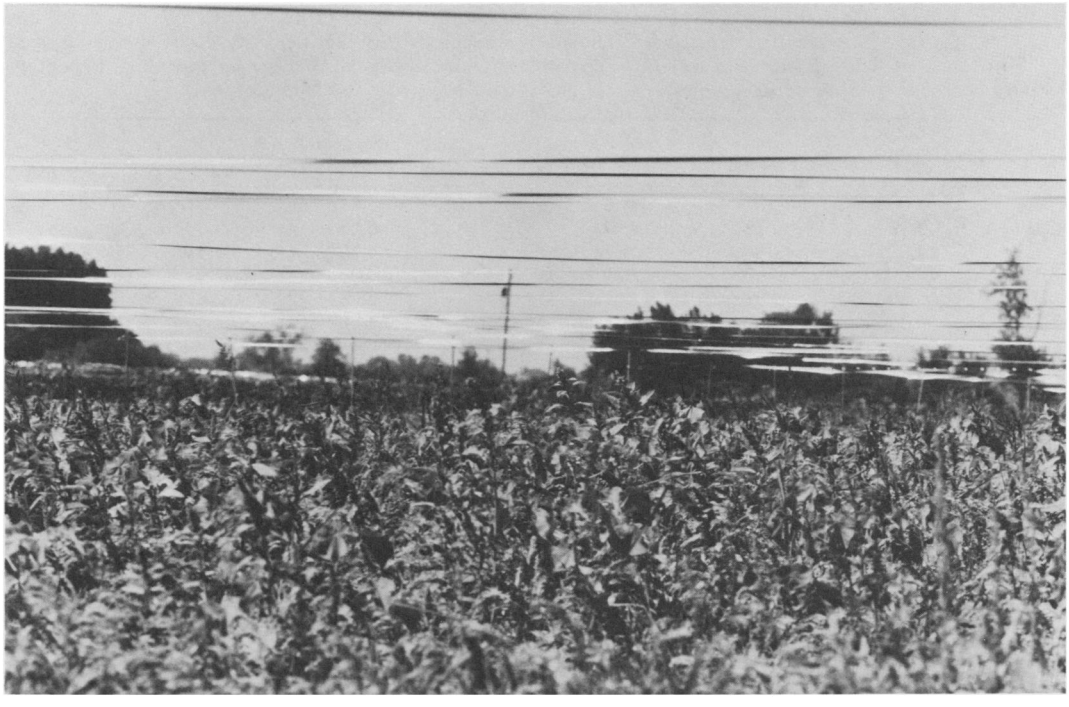

Fig. 1. Bird Scaring Reflecting Tape® suspended above a field of millet at Ottawa National Wildlife Refuge, Ohio, 1985 (Photo by R. L. Bruggers).

termined the cost/hectare of deploying these tapes and their durability under field conditions.

METHODS

This study was done in 1985, primarily at Ottawa National Wildlife Refuge (ONWR), Lucas County, Ohio, with a satellite study site 70 km away in Erie County, Ohio. The ONWR site was a 100-ha unit of the refuge located 1.5 km south of Metzger Marsh and Lake Erie. Up to 100,000 birds, primarily red-winged blackbirds (*Agelaius phoeniceus*), brown-headed cowbirds (*Molothrus ater*), and European starlings (*Sturnus vulgaris*), roost there in late summer (Dolbeer et al. 1984). The location in Erie County was adjacent to a 2,400-ha National Aeronautics and Space Administration facility consisting of predominantly unmowed old-field habitat.

Millet

At ONWR 18 fields of proso millet were planted, 15 on 15 June and 3 on 10 July. Fields were 30 × 70–100 m (0.21–0.30 ha) in size. The 18 fields were grouped into 6 blocks of 3 fields each based on location. The 3 late-planted fields were in 1 block. The 3 fields within each block were 60–70 m apart and blocks were >200 m apart.

In each block, 1 field was randomly selected to have reflecting tapes strung across the narrow (30-m) dimension from 1.8-m wooden poles (driven 0.3 m in the ground) in parallel strands at 3-m intervals. Another field in each block had tapes strung at 7-m intervals and the remaining field served as an untaped control. Tapes were installed when the seed panicles began to form, from 9 to 12 August for the early-planted blocks and on 28 August and 2 September in the late-planted block. Tapes were strung with 2–4 twists/30 m and with enough slack to allow undulations of about 0.5–1.0 m at the center of the strand. Tapes were suspended 0.5–1.0 m above the millet (Fig. 1).

Bird counts were made in each millet field (usually once daily) from 10 August to 19 September in the early-planted blocks and from 28 August to 5 October in the late-planted block. Counts were started at various times from 0700 to 1800 hours. An observer walked along the edge of each field and either counted (for small numbers) or estimated (for large flocks) the number of birds in the field. Broken tapes were noted and repaired during these counts.

Bird damage was assessed on 10 September in the

Table 1. Total numbers of blackbirds[a] observed during 39 counts/field between 10 August and 5 October 1985 in 18 millet fields (6 blocks of 3 fields each) at Ottawa National Wildlife Refuge, Ohio.

Block	Untaped fields	Taped fields	
		7-m spacing	3-m spacing
A	3,002	3,107	8
B	3,100	12	0
C	14,001	1,350	27
D	7,300	4,700	2,501
E	1,000	7,001	1
F	300	500	0
Mean	4,784A[b]	2,778B	423C

[a] >90% brown-headed cowbirds, <10% red-winged blackbirds.
[b] Means with different letters differ ($P < 0.05$), randomized block analysis of variance (2 and 10 df) and Duncan's multiple range test. Data were subjected to square-root transformation.

Table 2. Percent of millet panicles with ≥10% bird damage in 18 millet fields (6 blocks of 3 fields each) at Ottawa National Wildlife Refuge, Ohio, 10 September 1985[a] (n = 180 panicles/field).

Block	Untaped fields	Taped fields	
		7-m spacing	3-m spacing
A	46.1	35.6	6.7
B	63.3	2.8	23.9
C	45.0	63.3	7.2
D	41.7	27.2	70.6
E	68.3	2.8	5.0
F	44.0	4.4	3.6
Mean	51.4A[b]	22.7B	19.5B

[a] Block F, planted 1 month later than the other blocks, was assessed for damage on 11 October 1985.
[b] Means with different letters differ ($P < 0.05$), randomized block analysis of variance (2 and 10 df) and Duncan's multiple range test.

early-planted blocks and on 5 October in the late-planted block. Twelve plots were located along each of 3 transects that ran the length of each field. The first plot was randomly located in the first 1/12 length of the field and the remaining 11 were systematically located at 1/12-of-the-field increments. At each plot 5 consecutive panicles were clipped and the number having ≥10% bird damage noted. We used ≥10% damage as a conservative criterion to avoid miscategorizing panicles as damaged that had a few glumes with undeveloped seeds or a few seeds missing because of wind shattering. The panicles were then placed in a paper bag (1 bag/transect) and were dried at 40 C for 1 week. The seeds then were winnowed from the panicles and weighed.

Sweet Corn

Six fields of sweet corn (14–23 × 100 m), grouped into 2 blocks of 3 fields each, were planted on 12 June at ONWR. Tapes were installed on 9 August, with the same spacing scheme and height above the crop as in the millet fields, from 3-m steel electrical conduit pipes (1.9-cm diam) driven 0.5 m in the ground. Bird and mammal damage was assessed on 27 August, 25 days after 50% of the ears had silked, and mammal damage was assessed again 10 days later. Eight plots were located in each of 4 transects as in the millet fields. In each plot, the top ear on each of 5 consecutive plants was examined and the incidence of bird or mammal damage noted.

Sunflower

Four fields of oil-seed sunflower (27–46 × 61 m) were planted on 6 June in Erie County and 4 fields (14 × 100 m) were planted on 12 June at ONWR. The fields were grouped in 4 blocks of 2 fields each. Reflecting tapes were installed from 3-m conduit poles at 5-m intervals over 1 field in each block. Bird observations were made as in the millet fields from 15 August to 1 October. Bird damage was assessed on 5, 16, and 26 September and 4 October (29, 40, 50, and 58 days after 50% bloom) at ONWR and on 4, 13, and 26 September (23, 32, and 45 days after 50% bloom) in Erie County. Sampling plots were located as in the sweet corn, and the percent of seed removed by birds was visually estimated for each sampled head (Dolbeer 1975).

RESULTS

Millet

A total of 48,573 birds was recorded in the 18 millet fields during 39 counts/field between 10 August and 5 October. About 99% (47,910) were blackbirds with mourning doves (*Zenaida macroura*) (271) and house sparrows (*Passer domesticus*) (256) being the next most common species.

The total number of blackbirds/field was greater for untaped than for taped fields (Table 1). Flocks of ≥1,000 blackbirds were recorded in a millet field 17 times: 10 in untaped fields, 6 in fields with 7-m tape spacing, and 1 in a field with 3-m tape spacing. Untaped fields had 11.2 times more blackbirds than did fields taped at 3-m intervals.

There were no differences ($P > 0.05$) among treatment groups in the mean numbers of mourning doves. However, more ($P < 0.05$)

Table 3. Percent of ears damaged by blackbirds and mammals (white-tailed deer and raccoons) in 6 sweet corn fields (2 blocks of 3 fields each) at Ottawa National Wildlife Refuge, 1985 (n = 160 ears sampled/field on 27 August and 120 on 6 September).

Type of damage	Untaped field	Taped fields	
		7-m spacing	3-m spacing
Bird[a]	17.2A[b]	6.3B	3.2B
Mammal[a]	3.2A	0.3A	2.2A
Mammal[c]	16.8A	10.0A	20.4A

[a] Sampled 27 August, 25 days after 50% of ears silked.
[b] Means in rows with different letters differ ($P < 0.05$), randomized block analysis of variance (2 and 2 df) and Duncan's multiple range test.
[c] Sampled 6 September, 35 days after 50% of ears silked.

house sparrows were recorded in the untaped fields ($\bar{x}$ = 27.2) than in the 7- (7.5) and 3-m (6.0) fields.

The mean percentage of panicles with ≥10% damage by birds was greater ($P < 0.05$) in the untaped fields than in the taped fields (Table 2). All 6 untaped fields had >40% of the panicles with ≥10% damage, whereas only 1 each of the 3- and 7-m fields had >40% damage. Furthermore, circumstances unique to these 2 taped fields can explain at least part of their high damage. The 7-m field in Block C was adjacent to a corn field and blackbirds that fed in the corn moved at ground level under the tapes into the millet field. In the 3-m field in Block D, the tapes were strung with too many twists and too much tension. This resulted in the tapes curling around on themselves to take on a taut, cord-like appearance with little flashing or sound production.

The mean seed weight/180 panicles was 124.9, 180.7, and 159.3 g in the untaped, 7-, and 3-m fields, respectively. Although the pattern was the same as for percent damage, with the untaped fields having the lowest mean seed weights, the means were similar ($P > 0.10$) among the 3 treatments. However, if the 7-m field in Block C and the 3-m field in Block D are deleted, the mean weights for the 2 taped treatments are greater ($P < 0.05$) than for the untaped fields. Furthermore, substantial variation in the quality of the millet stands both within and among fields added considerable variation to the seed weight estimates independent of bird damage.

Table 4. Total numbers of blackbirds, American goldfinches, house sparrows, and mourning doves recorded in 8 sunflower fields (n = 2/treatment per county) in Lucas and Erie counties, Ohio, 1985. Birds in the fields in Lucas and Erie counties were counted 43 and 20 times, respectively, between 15 August and 1 October.

Species	Lucas County[a]		Erie County	
	Untaped fields	Taped fields	Untaped fields	Taped fields
Blackbirds	12,362	1,804	0	0
Goldfinches	355	1,989	768	826
House sparrows	2,165	312	77	2
Doves	68	46	191	275
Total	14,950	4,151	1,036	1,103

[a] Ottawa National Wildlife Refuge.

Sweet Corn

The percent of ears damaged by blackbirds 25 days after silking (about 5 days after the corn would have been harvested commercially) was greater ($P < 0.05$) in the 2 untaped fields than the 7- and 3-m fields (Table 3). There were no differences ($P > 0.10$) among the 3 treatments in damage caused by mammals at 25 or 35 days after silking (Table 3). Based on tracks and the type of damage, we believe most mammal damage was by white-tailed deer (*Odocoileus virginianus*), although some raccoon (*Procyon lotor*) damage was noted.

Table 5. Temporal trends in mean percentage of seed eaten by birds in 2 blocks of taped and untaped sunflower fields (n = 2/treatment), Ottawa National Wildlife Refuge, Ohio, 1985.

Date	Days after 50% bloom	Untaped fields	Fields with 5-m spacing
5 Sep	29	33.5	12.9
16 Sep	40	57.0	19.4
26 Sep	50	83.6	50.0
4 Oct	58	98.3	91.4

Table 6. Approximate quantities of material required and costs for installing 34-m strands of reflecting tape at 3-, 5-, and 7-m intervals over a 1-ha (100 × 100-m) field. This configuration assumes 4 rows of poles 33.3 m apart; poles within rows are 3, 5, and 7 m apart.

Spacing of tape strands (m)	1.8-m wood poles		34-m tape strands		Labor		Total cost ($)	
	No.	Cost ($)[a]	No.	Cost ($)[b]	Hours[c]	Cost ($)[d]	1.8-m poles	3-m poles
3	136	8.16	102	24.97	5.10	17.85	50.98	83.62
5	80	4.80	60	14.69	3.00	10.50	29.99	49.19
7	60	3.60	45	11.02	2.25	7.88	22.50	36.90

[a] $0.30 each prorated to $0.06 each over 5-year period. The 3-m metal poles used on corn and sunflowers cost $1.50 each prorated to $0.30 each over 5 years. Thus, multiply these costs by 5 for 3-m poles.
[b] $0.72/100 m.
[c] Assuming 0.75 min/pole and 2 min/strand of tape.
[d] $3.50/hour.

Sunflowers

Blackbirds totaled 75% of the birds observed in 4 sunflower fields at ONWR, whereas American goldfinches (*Carduelis tristis*) totaled 75% of the birds recorded in the 4 Erie County fields. No blackbirds were recorded in the Erie County fields. Because the bird species composition differed in the 2 counties and goldfinches and blackbirds appeared to respond differently to the reflecting tapes (Table 4), we analyzed the 2 sets of data separately. Statistical analyses were not performed because there were only 2 replications of each treatment/county.

The tapes appeared to have no deterrent effect on goldfinches; about equal numbers were recorded in untaped and taped fields in Erie County (Table 4). Goldfinches inflicted almost all damage in Erie County fields (doves fed only on heads and seed that had fallen to the ground) and there was no apparent difference in mean percent damage between taped ($\bar{x}$ = 18.3) and untaped ($\bar{x}$ = 20.3) fields.

Blackbirds, however, appeared to be similarly affected by the tapes in sunflowers as they were in millet and sweet corn. At ONWR almost 7 times more blackbirds were recorded in the 2 untaped fields than in the 2 fields with tapes at 5-m spacing (Table 4). Flocks of ≥100 blackbirds were recorded in these sunflower fields on 33 occasions; 28 were in untaped fields and 5 were in taped fields. A similar pattern was shown for house sparrows but goldfinches showed an opposite pattern with 5.6 times more birds recorded in the taped fields than in the untaped fields (Table 4). As the tapes had no apparent deterrent effect on the goldfinches in Erie County, the greater number of goldfinches in taped fields at ONWR perhaps resulted from goldfinches avoiding competition with blackbirds that preferred the untaped fields.

Bird feeding pressure was intense in the sunflower fields at ONWR and although the taped fields received substantial damage, it was consistently less than in the untaped fields at each of the 4 assessments (Table 5). The maximum difference in damage between the 2 treatments (34–38 percentage points) occurred at 40–50 days after bloom when the crop normally would have been harvested.

Deployment Costs and Durability of Tapes

Cost of deploying tapes over a field varies with spacing and length of strands, field configuration, type of poles, labor, and assumptions regarding prorated costs over years of use. Reasonable costs (Table 6) are $22.50–50.98/ha with 1.8-m wood poles and $36.90–83.62/ha with 3-m metal poles. Actual costs would deviate from these estimates under various circumstances. For example, if the sup-

port poles remained in place for use in subsequent years, labor costs for installing poles could be prorated over the life of the poles.

Based on the damage levels and costs (Tables 3, 6), the use of reflecting tapes in the sweet corn fields would have resulted in a net benefit to a farmer selling the corn in the fresh-produce market. With a population of about 56,000 ears/ha, untaped fields averaged 9,600 ears/ha lost to birds compared to losses of 3,500 and 1,800 ears/ha for fields taped at 7- and 3-m intervals, respectively. At a price of $0.05/ear, this amounts to a savings of $305–390/ha in the taped fields, about 4.6–8.2 times the $37–84 cost/ha for taping fields. Yield estimates were not obtained in the sunflower and millet fields so definite cost-benefit calculations cannot be made. However, because of the lower value of these crops, the benefits would certainly not have been as favorable as in corn. For example, if we assume an average yield of 1,225 kg/ha for sunflowers and a price of $0.26/kg (Anon. 1986), the untaped fields at ONWR at 50 days after bloom (Table 5) lost 1,025 kg of seed/ha worth $265 to birds, compared with a loss of 615 kg/ha worth $160 in the taped fields. This translated to a $105 savings/ha in the taped fields compared to $49 expense for taping, a 2.1 benefit-to-cost ratio. Obviously, the cost of taping the sunflower fields in Erie County would have exceeded any benefits because the tapes proved ineffective against goldfinches.

For 30-m strands of tape, the daily breakage rate averaged ≤1% (≤1 break/100 strands per day) for the first 20 days after installation. It then rose to about 4% by 30–35 days. For 14-m strands, the daily breakage rate was 0 for the first 20 days and ≤1.5% for days 21–40. After 40 days, the rate rose to about 4%. Most breaks occurred at the points of attachment to the poles, or where 2 tape ends were spliced together. However, after 30–40 days of exposure to sun and wind, the tapes weakened and breakage occurred at other points. A few breaks occurred where a tape rubbed against a plant.

The most critical factor influencing breakage of tapes was the method of attachment to poles. If tapes were simply wrapped around and tied to a pole with a tight knot, breakage often occurred at the knot within a few days. We therefore attached a 15- to 20-cm strip of 2-cm-wide nylon reinforced packing tape to the reflecting tape where it was wrapped 2 or 3 times around the pole. Then the knot was tied on the back side of the pole so that the reflecting tape, with the nylon-reinforced tape as support, was flat against the side of the pole at the point of stress. This greatly reduced breakage.

DISCUSSION

This study demonstrated that reflecting tapes stretched over agricultural crops deter certain species of birds, thus confirming the results from initial trials by Bruggers et al. (1986). In general, 3-m spacing seemed most effective, but repellent effects were noted with 5- and 7-m spacing also.

Gull, waterfowl, and heron numbers have been reduced in fish ponds and at other sites by stringing monofilament or thin wires at intervals of ≤15 m over areas to be protected (McAtee and Piper 1936, Lagler 1939, Blokpoel and Tessier 1984). The repellent action perhaps results from the birds' reluctance to fly through a grid of thin wires that they cannot see clearly. However, the mode of action of the highly visible reflecting tapes is probably different. In fact, we noted that the tapes were least effective where they had been stretched and twisted to the point that they were not prominently visible.

There were differences among bird species and between birds and mammals in their response to the tapes, which may help explain the repellent mode of action. Red-winged blackbirds, cowbirds, and house sparrows gen-

erally avoided the taped fields, whereas goldfinches and mourning doves appeared to be little influenced. Blackbirds and house sparrows usually feed in more cohesive flocks than do goldfinches and mourning doves. Perhaps the undulating movement, flashing, and sound of the tapes are more disruptive to species that depend on visual and auditory communication to maintain flock cohesiveness while feeding. We also noted no deterrent effect on deer, which fed primarily at night when the flashing phenomenon was minimal.

The cost of material and labor and the maintenance effort required make reflecting tape generally impractical for protecting large (e.g., >4 ha) fields of crops, such as field corn, sunflowers, and rice, that are frequently damaged by blackbirds in North America. However, for small fields of high-value crops (e.g., sweet corn, fruits, farm plots in developing countries, experiment station plantings), reflecting tapes may offer a simple and safe means to reduce damage by certain avian species. Additional testing will be needed to determine the effectiveness of the tapes in fruit crops that attract a variety of bird species. The tapes may also prove useful as bird deterrents in nonagricultural settings, such as toxic or polluted sites and urban or residential roosting sites.

In conclusion, we believe reflecting tapes can be useful in repelling certain species of birds. However, we caution that in our evaluations, repellency was not absolute, even for the species most affected by the tapes, and in all cases the birds had a convenient unprotected source of food to exploit. Under circumstances where all desirable sources of food in an area would be taped, the reflecting tape might be less effective. As with most pest management programs, the tapes should be used as part of an integrated approach to reducing damage. Additional repellent devices, alternate food sources, and cultural methods such as bird-resistant cultivars may have to be used in combination with the tapes to achieve maximum protection or repellency.

SUMMARY

We evaluated the bird-repellent effectiveness and cost of reflecting tapes suspended in parallel strands at intervals of 3, 5, and 7 m above 0.14- to 0.30-ha fields of agricultural crops. Tapes suspended at 3- and 7-m intervals reduced ($P < 0.05$) the number of brown-headed cowbirds and red-winged blackbirds feeding in millet fields and the percent of panicles damaged compared with untaped fields. Blackbird damage to sweet corn was similarly reduced in fields taped at 3- and 7-m intervals, but the tapes did not reduce deer damage. Blackbird numbers and damage were reduced in sunflower fields taped at 5-m intervals; however, goldfinches and mourning doves appeared unaffected by the tapes. The estimated cost of deploying the tapes was $22.50–83.62/ha. Reflecting tapes can provide a simple and safe means of repelling certain species of birds from high value crops or from other localized sites.

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VOMITING BY FERAL PIGS AFTER 1080 INTOXICATION: NONTARGET HAZARD AND INFLUENCE OF ANTI-EMETICS

PETER H. O'BRIEN, ***New South Wales Department of Agriculture, Agricultural Research Centre, Private Mail Bag 19, Trangie 2823, Australia***

ROLAND E. KLEBA, ***New South Wales Department of Agriculture, Agricultural Research Centre, Private Mail Bag 19, Trangie 2823, Australia***

JENNY A. BECK, ***Stock Routes and Rural Lands Protection Board, P.O. Box 168, North Quay, Brisbane 4000, Australia***

PETER J. BAKER, ***New South Wales Department of Agriculture, Agricultural Research Centre, Private Mail Bag 19, Trangie 2823, Australia***

Feral pigs (*Sus scrofa*) are a major pest of agriculture in Australia. They are responsible for damage to crops (Giles 1976, Pavlov 1980), pasture degradation (Hone 1980), physical damage (Pullar 1950), and lamb predation (Plant et al. 1978, Pavlov et al. 1981, Pavlov and Hone 1982), which may result in losses in excess of $A70m/year (Tisdell 1982). Further, feral pigs are potential vectors and reservoirs of a number of exotic diseases (Geering 1981).

Poisoning with sodium monofluoracetate (1080) is the most widely used method to control feral pigs. Most pigs vomit after ingesting 1080 under experimental conditions (Table 1). In addition, vomitus is frequently observed near bait stations during poisoning programs (P. H. O'Brien and R. E. Kleba, pers. obs.). The high incidence of vomiting following 1080 ingestion has 4 implications: (1) vomitus containing 1080 may cause secondary poisoning of nontarget species close to, and at distance from, 1080 bait stations, (2) secondary poison-