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Probabilistic Model to Optimize Formulation and Baiting Strategies for the Pesticide CPTH (3-chloro-4-methylaniline hydrochloride)

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ABSTRACT: A probabilistic model was validated for estimating avian mortality associated with the application of the avicide CPTH (3-chloro-4-methylaniline hydrochloride) to minimize sprouting rice damage in the southern United States. CPTH exposures for individual birds were predicted by random sampling from species-specific non-parametric distributions of bait seed consumption and CPTH residues detected on individual bait seeds. Mortality was predicted from the species-specific exposure versus mortality relationship. Individual variations in this response were captured in the model by Monte Carlo sampling from species-specific distributions of slopes and median toxicity values (LD_{50}) for each bird. The model was used to evaluate the effects of formulation, bait preparation and application procedures on target and non-target mortalities. The results of these analyses indicate that: 1) decreasing the concentration of CPTH on the treated bait seeds from 400 to 300 μg CPTH/seed will improve bait performance by decreasing non-target mortalities, 2) the current dilution ratio of 1 treated seed to 25 diluent seeds is optimal and 3) preparing a bait seed product in which CPTH is homogeneously distributed throughout the bait seed mixture will significantly increase bait performance by increasing red-winged blackbird (target) mortality and decreasing mortality for savannah sparrows and meadowlarks (non-targets).

KEY WORDS: 3-chloro-4-methylaniline, CPTH, DRC-1339, pesticide, probabilistic model, risk assessment

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INTRODUCTION

The use of a bird toxicant in any wildlife management scenario is accompanied by a significant degree of public scrutiny and public opposition (Plumart 2003). To ensure the continued use of CPTH (3-chloro-4-methylaniline hydrochloride), the only avian toxicant available to pest control operators in the United States, this compound needs to be used in a sensitive and responsible manner. This requires application of CPTH in a way that minimizes mortality to non-target species while maintaining a high degree of efficacy to target species. Current application practices use pre-baiting to screen for the presence of non-target species and to ultimately increase consumption of CPTH baits by target species. However, effective field monitoring or demonstration of target versus non-target mortality is nearly impossible due to the delayed onset of CPTH toxicity and the mobility of the potentially exposed birds. This creates a difficult situation for wildlife management professionals to demonstrate that CPTH is effecting selective control of pest avian species.

The computer model validated in this study offers a means to accurately estimate target and non-target mortality for birds exposed to CPTH baiting operations. The "take" of target and non-target species can be estimated by multiplying the percent mortality estimates from the model by the numbers of each species observed on the CPTH baited fields. Furthermore, the model can be used to evaluate a much greater variety of bait formulation and application parameters than could be practically evaluated by field, aviary, and/or pen studies. This has been demonstrated by optimizing CPTH formulations and application procedures for the most common target and non-target species observed in winter/spring CPTH baited rice fields in Louisiana and Texas.

This modeling approach led to the "discovery" of two independent, relatively simple approaches to improve the performance of CPTH rice baits. The first approach indicates that the selectivity of CPTH with respect to meadowlarks (*Sturnella* spp.) and savannah sparrows (*Passerculus sandwichensis*) could be improved by decreasing the target concentration of CPTH from 400 to 300 μg/seed. While this approach requires a modification of the current formulation of the CPTH treated rice seeds, no change in the field application procedure is required. A more significant improvement is predicted by adopting the second approach. This approach requires modification of the bait formulation and field application procedures to produce a product in which CPTH is homogeneously distributed throughout the entire batch of rice seed bait. Without increasing the amount of CPTH applied to a bait site (grams CPTH/acre), this latter scenario predicts increased efficacy towards target species combined with decreased non-target mortality for meadowlarks and savannah sparrows. As none of the parameters investigated offered an improvement in selectivity with respect to mourning doves (*Zenaidura macroura*), it is imperative that CPTH baits be applied when mourning doves are not present. The presence of killdeer (*Charadrius vociferous*) in baited fields is insignificant, as the dietary preferences of this species nearly exclude any CPTH dietary exposure and related

Table 1. Model assumption distribution parameters.

Assumption	Units	Mean	Lower Limit	Upper Limit	Standard Deviation	Distribution
Red-winged blackbird						
♀ bodyweight	grams	41.50	29.00	55.00	2.74	Normal
♂ bodyweight	grams	63.60	53.00	81.10	4.43	Normal
♀ control seed consumption	seeds	32.10	0	171.60	28.10	Empirical
♂ control seed consumption	seeds	40.90	0	163.90	30.70	Empirical
♀ treated seed consumption	seeds	19.50	0	96.30	18.00	Empirical
♂ treated seed consumption	seeds	29.20	0	172.20	26.40	Empirical
Log LD_{50}	mg/kg BW	0.54	0.40	0.68	0.05	Normal
Slope – log dose vs. probit mortality curve	-	9.18	8.45	9.91	0.24	Normal
Killdeer						
♀ bodyweight	grams	101.00	87.70	121.00	10.40	Normal
♂ bodyweight	grams	92.10	83.90	109.00	10.40	Normal
♀ control seed consumption	seeds	0.59	0	9.10	2.00	Empirical
♂ control seed consumption	seeds	0.59	0	9.10	2.00	Empirical
♀ treated seed consumption	seeds	0.08	0	1.00	0.24	Empirical
♂ treated seed consumption	seeds	0.08	0	1.00	0.24	Empirical
Log LD_{50}	mg/kg BW	2.8×10^{-11}	-0.16	0.16	0.05	Normal
Slope – log dose vs. probit mortality curve	-	19.60	14.00	25.20	1.87	Normal
Meadowlark						
♀ bodyweight	grams	89.40	60.00	118.80	9.80	Normal
♂ bodyweight	grams	112.00	88.50	141.00	11.10	Normal
♀ control seed consumption	seeds	5.30	2.20	22.60	7.60	Empirical
♂ control seed consumption	seeds	5.30	2.20	22.60	7.60	Empirical
♀ treated seed consumption	seeds	5.03	0	22.60	7.56	Empirical
♂ treated seed consumption	seeds	5.03	0	22.60	7.56	Empirical
Log LD_{50}	mg/kg BW	0.53	0.37	0.70	0.06	Normal
Slope – log dose vs. probit mortality curve	-	8.60	8.09	9.09	0.17	Normal
Mourning dove						
♀ bodyweight	grams	115.00	109.00	121.00	1.76	Normal
♂ bodyweight	grams	123.00	117.00	129.00	1.85	Normal
♀ control seed consumption	seeds	157.20	0	435.40	133.20	Empirical
♂ control seed consumption	seeds	157.20	0	435.40	133.20	Empirical
♀ treated seed consumption	seeds	267.00	0	614.00	185.00	Empirical
♂ treated seed consumption	seeds	267.00	0	614.00	185.00	Empirical
Log LD_{50}	mg/kg BW	0.534	0.37	0.70	0.06	Normal
Slope – log dose vs. probit mortality curve	-	8.59	8.09	9.09	0.17	Normal
Savannah sparrow						
♀ bodyweight	grams	19.50	12.60	26.40	2.29	Normal
♂ bodyweight	grams	20.60	16.00	24.00	1.35	Normal
♀ control seed consumption	seeds	5.60	0	18.60	8.30	Empirical
♂ control seed consumption	seeds	5.60	0	18.60	8.30	Empirical
♀ treated seed consumption	seeds	2.87	0	38.90	4.26	Empirical
♂ treated seed consumption	seeds	2.87	0	38.90	4.26	Empirical
Log LD_{50}	mg/kg BW	1.36	1.06	1.56	0.10	Normal
Slope – log dose vs. probit mortality curve	-	3.61	3.60	3.62	0	Normal

effects. While our probabilistic modeling-based approach incorporated bird behavioral parameters (i.e., aversion – species-specific seed consumption rates vs. CPTH seed concentration), it would be prudent to conduct field and/or aviary feeding studies with the modified baits before adopting either approach for a large-scale baiting program.

MATERIALS AND METHODS

Probabilistic Model

The probabilistic model to determine the probability of death for individual birds feeding on CPTH baited rice seed was developed using Crystal Ball Professional Software (Decisioneering Inc., Denver, CO), an integrated MS Excel (Microsoft, Redmond, WA) add-in program which permits Monte Carlo analysis for simulations involving various elements of uncertainty.

CPTH Exposure

Distributions of number of rice seeds consumed were developed using necropsy data from target and non-target species collected after feeding on Louisiana rice fields baited with rice or 2% CPTH treated rice bait in March and April of 2003 and 2004 (Table 1). Birds were shot as they were leaving bait sites. Birds were maintained in a frozen state and shipped to the National Wildlife

Research Center for subsequent analysis. The number of rice seeds in the gastrointestinal tract of each bird was subsequently determined via necropsy. Each iteration of the model represented 1 bird feeding on a CPTH rice seed baited plot. For each iteration, a random number from the species and sex specific estimated rice seed consumption distribution was selected as the total number of bait seeds (treated and untreated) consumed. The number of treated seeds consumed by each bird was calculated by random generation of a value in a binomial distribution based on the number of seeds consumed and the fraction of treated:diluent seeds in the mix. The number of diluent seeds consumed by each bird was determined by subtracting the number of treated seeds from the total number of seeds consumed. The distribution of CPTH on treated and diluent seeds was generated from the chemical analysis of individual seeds after mixing CPTH treated and untreated (1:25) seeds for various time intervals in a cement mixer, a common practice for preparation of CPTH baits. The CPTH concentrations on treated and diluent seeds were determined randomly from these CPTH seed concentration distributions. Daily exposure was calculated as the sum of the CPTH content of all seeds consumed by each bird. Dose was calculated as exposure divided bodyweight. Bodyweight values were randomly selected from species and sex specific distributions (Table 1) (Dunning 1984).

Estimation of Percent Mortality

The probability of mortality for an individual bird was calculated as a function of exposure and sensitivity (dose vs. mortality) (Johnston *et al*. 2005).

Effect of Treated Seed CPTH Concentration on Mortality Estimates

For each species, the effect of CPTH bait seed concentration on bait seed consumption was estimated by linear regression analysis of CPTH bait seed concentration for pre-baiting (0 µg CPTH/treated seed) and treated seed (400 µg CPTH/treated seed) application versus mean bait seed consumption (Table 1). The linear regression equation was used to estimate the percent change in bait seed consumption (predictor variable) for baits containing 600, 300, 200, 150, 100, 50, and 25 µg CPTH/treated seed (dependent variable); for each model iteration, seed estimates based on consumption of 400 µg baits were corrected by this factor. These bait seed consumption estimates and target treated seed CPTH concentrations were incorporated into the mortality model to generate species-specific mortality estimates for each treated seed CPTH concentration level.

Effect of Treated/Diluent Seed Ratios and CPTH Concentrations on Mortality Estimates

For each species, the effects of altering the ratio of 2% CPTH treated bait seeds and diluent brown rice seeds on mortality were determined. Mortality estimates were determined using treated:dilution ratios of 1:12.5, 1:25, 1:50, 1:75, and 1:100. The effects of altering the distribution of CPTH on the treated bait seeds and diluent brown rice seeds on mortality were also determined. Distribution assumptions ranged from 6% to 96% of CPTH transferred from the treated to diluent seeds.

Determination of CPTH Concentrations on Treated and Diluent Rice

A 2-lb package of 2% CPTH rice seed (Pocatello Supply Depot, Pocatello, ID) was added to a cement mixer (Clarke Power Products, Perrysburg, OH) containing 50 lb brown rice. The treated and untreated (diluent) rice were mixed for 120 min. Samples (approximately 30 mL) were collected from the top, middle, and bottom of the mixing container at 1, 3, 5, 10, 30, 60, and 120 min. CPTH content of rice seed was determined as previously reported (Kohler 2004).

Model Validation/Field Evaluation of Blackbird Mortality

Field evaluations were conducted in 14 fields near Evangeline Parish, LA. Forty-two target species (red-winged blackbirds, *Agelaius phoeniceus*) and 20 non-target species (9 savannah sparrows; 8 white-crown sparrows, *Zonotrichia leucophrys*; and 3 field sparrows, *Spizella pusilla*) were captured with cannon nets as they were leaving the baited areas at the bait sites and maintained in holding cages with access to food and water. Birds were observed for 10 days to permit the determination of CPTH induced mortality (Cummings *et al*. 1992, 2002).

RESULTS

Model Validation

The estimated mean blackbird mortality for this baiting scenario was 50.5% (95% confidence interval 48.0-51.7% mortality) (Table 2). For the field study, observed mortality for red-winged blackbirds was 50%. The mean time to death was 48 hours post-capture. Upon subsequent necropsy, all dead birds exhibited cream-colored pericardial deposits that are indicative of CPTH poisoning (DeCino *et al*. 1966, Johnston *et al*. 1999). The only mortality observed in captured non-target species was for savannah sparrows: 2 of 9 (22%) savannah sparrows died during the holding period. The model estimated mean savannah sparrow mortality for this baiting scenario was 16.3% (95% confidence interval 8.39-22.8% mortality) (Table 2).

Table 2. Predicted mortalities for target and non-target avian species.[a]

Species	Percent Mortality	95% Confidence Interval
Killdeer	0.05	0.001 - 0.17
Meadowlark	10.50	7.8 - 14.3
Mourning dove	83.90	82.9 - 84.1
Savannah sparrow	16.30	8.4 - 22.8
Red-winged blackbird	50.50	48.0 - 51.7

[a] current use practice; 400 µg CPTH/treated seed, 1:25 treated:untreated seed ratio

Non-target and Target Mortality Estimates

Non-target mortality estimates for birds exposed to rice fields baited with 2% CPTH treated rice seeds diluted 1:25 with brown rice ranged from 0.05% (95% CI = 0.001% to 0.17%) for killdeer to 83.9% (95% CI =

82.9% to 84.1%) for mourning doves. The estimated mean mortality for target birds (red-winged blackbird) was 50.5% (95% CI = 48.0 to 51.7) (Table 2).

Effect of Treated Seed CPTH Concentration on Mortality Estimates

Increasing the treated bait seed concentration from 400 to 600 µg per seed (while maintaining the treated: untreated ratio of 1:25) increased the estimated mortality for all species except savannah sparrows and red-winged blackbirds. Decreasing the treated bait seed CPTH concentration from 400 to 50 µg reduced the predicted mortalities for all species except killdeer. Reducing the CPTH treated seed concentration from 50 to 25 µg CPTH per treated seed decreased mortality estimates for all species (Table 3).

Effect of Treated/Diluent Seed Ratios on Mortality Estimates

Increasing the treated:diluent seed ratio from 1:25 to 1:12.5 increased the estimated percent mortality for all species. The relative increase in estimated mean mortality was 36% for red-winged blackbirds and 92% for savannah sparrows. While the relative percent increase in estimated mortality was 300% for killdeer, the mean mortality prediction for killdeer was only 0.2%. Decreasing the treated:diluent seed ratio from 1:25 to 1:100 decreased the estimated mortality estimates for all species, except killdeer which was essentially 0 throughout this range of treated seed dilution ratios (Table 4).

Effect of Mixing Time on Transfer of CPTH from Treated to Diluent Seeds

Quantification of CPTH on individual treated and diluent rice seeds enabled us to determine the percent of CPTH transferred from the treated to the diluent seed during the mixing process. After only 1 min of mixing, an average of 5.1% (std dev = 0.10%) of the CPTH had been transferred. At 3 min, a typical mixing time for operational field preparation of CPTH rice baits, an average of 6.5% (std dev = 0.09%) of the CPTH had been transferred from the treated to diluent rice seeds. After 120 min of mixing, the longest mixing time evaluated, an average of 21.6% of the CPTH on the treated rice seed baits had been transferred to the diluent rice seed.

Effect of CPTH Transfer from Treated to Diluent Bait Seeds on Mortality Estimates

The model was used to estimate target and non-target mortality for baiting scenarios in which 6, 9, 15, 25, 50, and 96% of the CPTH had been transferred from the treated to the diluent rice seeds. For red-winged blackbirds, increasing the transfer from 6% to 96% resulted in a 25% relative increase in estimated mortality. For meadowlarks and savannah sparrows, this increased transfer of CPTH from treated to diluent seeds resulted in relative estimated percent mortality decreases of 54% and 52%, respectively. Estimated mortality effects on killdeer and mourning doves were minimal; mourning dove mortality increased by 2% and killdeer mortality never exceeded 0.5% (Table 5).

Table 3. Effects of CPTH treated seed concentration on mean mortality estimates.

CPTH Treated Seed Conc (µg/seed)	Killdeer		Meadowlark		Mourning Dove		Savannah Sparrow		Red-winged Blackbird	
	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*
600	0.30	500	11.4	9	90.6	4	11.2	-31	42.3	-16
400[a]	0.05	0	10.5	0	87.0	0	16.3	0	50.5	0
300	0.60	1,100	6.2	-41	86.7	0	12.9	-21	49.5	-2
200	1.18	2,263	2.7	-75	78.7	-9	8.5	-48	44.6	-12
150	1.33	2,557	1.1	-89	69.5	-20	5.6	-66	33.4	-34
100	0.59	1,086	0.4	-97	51.1	-41	1.9	-88	25.6	-49
50	0.10	102	0.0	-100	21.5	-75	0.4	-97	9.5	-81
25	0.00	-100	0.0	-100	3.1	-96	0.0	-100	1.2	-98

^ percent mortality
* percent change as compared to current use practice
[a] current use practice

Table 4. Effect of treated:diluent seed ratio on mean mortality estimates.

Dilution Ratio	Killdeer		Meadowlark		Mourning Dove		Savannah Sparrow		Red-winged Blackbird	
	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*
1:100	0.05	0	3.1	-70	71.8	-14	4.6	-72	21.8	-57
1:75	0.05	0	4.6	-56	73.3	-13	5.6	-65	27.8	-45
1:50	0.05	0	6.7	-36	81.0	-3	8.4	-48	37.2	-26
1:25[a]	0.05	0	10.5	0	83.9	0	16.3	0	50.5	0
1:12.5	0.20	300	17.3	65	86.3	3	31.3	92	68.7	36

^ percent mortality
* percent change as compared to current use practice
[a] current use practice

Table 5. Effect of CPTH transfer from treated to diluent rice on mean mortality estimates.

Percent CPTH Transferred	Killdeer		Meadowlark		Mourning Dove		Savannah Sparrow		Red-Winged Blackbird	
	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*	PM^	PC*
6	0.05	0	10.5	0	83.9	0	16.3	0	50.5	0
9	0.05	0	11.4	9	85.1	1	14.8	-9	53.0	5
15	0.50	900	10.0	-5	85.7	2	14.7	-10	48.1	-5
25	0.10	100	9.6	-9	84.7	1	13.9	-15	49.9	-1
50	0.10	100	18.5	76	85.6	2	10.8	-34	56.6	12
96	0.05	0	4.8	-54	85.8	2	7.8	-52	63.0	25

^ percent mortality
* percent change as compared to mortality when 5% CPTH is transferred

Relative Impact of Input Variable on Mortality Estimates (Sensitivity Analysis)

The most significant variables were the number of treated bait seeds and total number of bait seeds consumed per bird. The inherent sensitivity of individual birds to CPTH toxicity was the next most significant variable. This was followed by bodyweight.

DISCUSSION

The mortality of red-winged blackbirds feeding on CPTH baited rice fields was determined by capturing birds as they were leaving the baited fields and maintaining the birds for 10 days of observation. Fifty percent of the captured red-winged blackbirds died during this observation period. The 48-hour mean post-exposure time to death is typical for CPTH induced acute toxicity. Additionally, post-mortem necropsy analyses of these birds indicated the presence of cream-colored deposits around the heart and liver, typical signs of CPTH poisoning (DeCino *et al*. 1966, Johnston *et al*. 1999). This indicates that all of the red-winged blackbird mortality observed during the post baiting holding period was the result of CPTH bait ingestion. Two of nine captured savannah sparrows died during the observation period.

For the baiting scenario used for this field study (2% CPTH treated rice diluted 1:25 with untreated brown rice), the model estimated mean blackbird mortality at 50.5% with a 95% confidence interval of 48.0% to 51.7% mortality. As the model-estimated mortality and the observed mortality were virtually identical, differing by only 0.5%, the observed value falls within the 95% confidence interval of the model predicted value. The 22% observed non-target mortality for savannah sparrows also falls within the 95% confidence interval (8.39-22.8% mortality) of the model predicted mortality for this species. These findings validate this model leading us to conclude that the probabilistic computer model is a valid approach for estimating mortality for target and non-target birds feeding on CPTH baited rice fields.

As the most frequently observed non-target birds in Louisiana rice fields are killdeer, meadowlarks, mourning doves, and savannah sparrows (Pipas *et al*. 2003), we were interested in estimating the risk of mortality to these species. The risk of mortality is a function of a species exposure and sensitivity to a toxicant (National Research Council 1983). The median lethal dose (LD_{50}) is commonly used as an indicator of a species sensitivity to a toxicant. The sensitivities of meadowlarks, mourning doves, and red-winged blackbirds to CPTH are essentially identical; the LD_{50} for these 3 species is 3.4 mg CPTH/kg bodyweight (Johnston *et al*. 2005). CPTH acute toxicity tests have not been conducted with killdeer or savannah sparrows (Eisemann *et al*. 2003). For killdeer, we applied a conservative or "worst case" scenario: we assumed that the toxicity of this species was similar to that of the boat-tailed grackle (*Quiscalus major*), the most sensitive species evaluated for CPTH toxicity with an LD_{50} of <1 mg/kg (Shafer *et al*. 1983). We assumed the CPTH sensitivity of the savannah sparrow to be identical to that of the American tree sparrow (*Spizella arborea*). This too is a conservative strategy, as the American tree sparrow is more sensitive to CPTH than the other sparrow species (white crowned sparrow, *Zonotrichia leucophrys*; house sparrow, *Passer domesticus*; Sudan golden sparrow, *Auripasser luteus*) that have been evaluated for CPTH toxicity. With an LD_{50} of 22.9 mg CPTH/kg bodyweight, the savannah sparrow was the least sensitive species evaluated (Borchert 2001).

CPTH exposure for killdeer is likely to be insignificant: the killdeer diet consists largely of invertebrates and seeds are consumed infrequently (Jackson and Jackson 2000). Even though killdeer were the most sensitive species evaluated, the model generated an extremely low mortality prediction of 0.05% for this species (Table 2). Meadowlark and savannah sparrows are omnivores; their diets contain significant quantities of seeds and invertebrates (Wheelright and Rising 1993; Lanyon 1994, 1995). For these species, we would expect an intermediate level of CPTH exposure. Mean mortality estimates for meadowlarks and savannah sparrows were 10.5% and 16.3%, respectively. Even though the savannah sparrow was the most CPTH-resistant species evaluated, given its dietary linked potential CPTH exposure, the model predicted savannah sparrow morality to be greater than killdeer and meadowlarks, which are both more sensitive to CPTH. Even though the mourning dove LD_{50} for CPTH is identical to that of meadowlarks and red-winged blackbirds (3.4 mg CPTH/kg bodyweight), the model predicted highest levels of mortality for mourning doves. The mourning dove diet consists predominantly of seeds (Mirachi *et al*. 1994); potential CPTH exposure and associated mortality are significant. These model predictions illustrate the impact of both CPTH exposure and sensitivity on mortality. However, sensitivity analyses suggest that exposure (seeds consumed) has a greater impact on mortality than does a species' sensitivity (LD_{50}) to CPTH. Since it is generally infeasible to alter a species' sensitivity to a pesticide, we explored the possibility of increasing target and/or decreasing non-target mortality by effecting CPTH exposure via formulation or bait preparation modifications.

Decreasing the amount of CPTH applied to the treated bait seeds has the potential to further increase the selectivity (target vs. non-target mortality) of CPTH baits (Table 3). However, the model results illustrate that the effect of changing the treated seed concentration on CPTH dose was influenced by two potentially "opposing" factors: 1) decreasing the amount of CPTH on each seed decreased the CPTH dose per seed consumed, and 2) for some species, the number of seeds consumed increased with decreasing CPTH bait seed concentration. The increased seed consumption (decreased aversion) at lower CPTH seed concentrations is significant for red-winged blackbirds and minimal for meadowlarks. This phenomenon has been observed in caged feeding trials (Cummings *et al*. 2003) and was noted by comparing seed consumption during pre-baiting with untreated brown rice versus seed consumption during baiting with CPTH treated seeds. For red-winged blackbirds, these opposing factors are approximately equal in magnitude: decreasing the CPTH concentration from 400 to 300 µg CPTH/treated seed resulted in a relative mortality decrease of only 2% for target red-winged blackbirds. For meadowlarks and savannah sparrows, the effect of the first factor (decreased dose per seed) predominates; the non-target mortality predicted for meadowlarks and savannah sparrows decreased by 21% and 41%, respectively. The net relative mortality change (relative percent change in target mortality - relative percent change in non-target mortality) for this proposed formulation modification is 19% (-2% + 21%) for savannah sparrows and 39% (-2% + 41%) for meadowlarks, both of which are desirable outcomes.

Modifying the dilution ratio of 2% CPTH treated rice baits:diluent brown rice produced mortality changes for target and non-target species (Table 4). Decreasing the dilution ratio by a factor of 2 (1:25 to 1:12.5) resulted in a greater relative increase in mortality for non-targets (savannah sparrows and meadowlarks) than for targets (red-winged blackbirds). The net relative mortality change was -56% for red-winged blackbirds and savannah sparrows and -26% for red-winged blackbirds and meadowlarks, both of which are undesirable. Increasing the dilution ratio by a factor of 2 (1:25 to 1:50) produced a relative mortality change of -26% for red-winged blackbirds, which is also undesirable. These results suggest that the current dilution ratio of 1:25 is optimal for controlling red-winged blackbirds with minimal toxicity to non-targets; changing the dilution ratio of treated to diluent rice is not a practical means of improving the performance of 2% CPTH rice baits.

Increasing the mixing time for the treated and diluent rice seeds increased the amount of CPTH transferred from treated to diluent rice. For field application of baits, a mixing time of approximately 3 min is commonly used. Increasing the mixing time by a factor of 2 or 3 (6 to 10 min) would result in the longest mixing time that would likely be practical and/or tolerated by applicator personnel. This would result in approximately 9% transfer of CPTH from the treated to the diluent rice seeds. The model estimated that this level of CPTH transfer from treated to diluent rice would cause an undesirable– 4% (5-9%) net relative percent change in mortality. It appears that increasing mixing time for the current CPTH rice seed bait formulation would not improve CPTH rice baits.

If the treated and diluent rice baits could be mixed so that a homogeneous distribution of CPTH was achieved, 96% of the CPTH on the treated rice seed would be transferred to the diluent rice. This scenario offers significant improvements in the ratio of non-target/target mortality; a relative 25% increase in red-winged blackbird mortality would be accompanied by at least a 50% relative decrease in savannah sparrow and meadowlark mortality. This equates to a very desirable 75% net relative percent change in mortality for red-winged blackbirds and meadowlarks or red-winged blackbirds and savannah sparrows. Using this scenario, mourning dove and killdeer mortality estimates would show relative increases of only 2% and 0%, respectively.

The desirable mortality effects associated with a homogeneously prepared CPTH bait offer advantages for non-target birds such as meadowlarks and savannah sparrows that consume moderate quantities of bait seed. When fields are baited with bait mixed for 3 min, the treated seed contains approximately 375 µg CPTH/treated seed; the remaining 25 µg is distributed among the diluent seed. There is a significant risk of mortality for most any bird that consumes a treated bait. For the homogeneous baits, the toxicant is distributed among a greater number of rice seeds; the average bait seed concentration is 15 µg/seed (400 µg/26 seeds). For savannah sparrows and meadowlarks, which typically consumed 2-6 seeds during baiting, exposures of 30-90 µg would be expected. For a 20-g savannah sparrow or 100-g meadowlark, this equates to doses ranging from 1.5 to 4.5 mg/kg for savannah sparrow and 0.3 to 0.9 mg/kg for meadowlarks. As the LD_1 values for meadowlarks and savannah sparrows are 1.8 and 5.2 mg/kg, respectively, low levels of mortality would be expected for these non-target species. For red-winged blackbirds, which typically consumed 20-30 rice seeds per baiting, exposures of 300 to 450 µg are expected. For a 50-g red-winged blackbird, this equates to expected doses of 6-9 mg/kg. As the LD_{99} for red-winged blackbirds is 6.2 mg/kg, significant mortality estimates are predicted for this target species.

As CPTH toxicity data are available for more than 50 different species of target and non-target birds, this model can be used to tailor CPTH baiting strategies for a nearly infinite combination of potentially exposed species. In this way, the model presented here is adaptable to CPTH rice seed baiting in a variety of locations and seasons. Use of this model to develop selective CPTH baiting strategies will help to ensure the continued availability of this unique wildlife damage management tool. Finally, the modeling approach presented in this study is applicable to a variety of toxicants and species and can be used to optimize baiting strategies to increase responsible use of pesticides and to provide valuable estimates of target and non-target mortalities for risk assessments, regulatory (e.g., NEPA) requirements and for managerial decision-making.

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