ACUTE AND CHRONIC TOXICITY OF COMPOUND DRC-1339 (3-CHLORO-4-METHYLANILINE HYDROCHLORIDE) TO BIRDS

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Abstract: DRC-1339 (3-chloro-4-methylaniline hydrochloride) is the only toxicant currently registered by the U. S. Environmental Protection Agency (USEPA) for lethal bird control. DRC-1339 was first registered in 1967 for starling control at feedlots. It may currently be used to manage blackbirds, rock doves, crows, ravens, magpies, gulls and starlings for purposes of protecting human health and safety, agricultural crops and threatened or endangered species. A large body of toxicity information is available because of the nature of DRC-1339 uses and its 35-year history of use. Laboratory testing has resulted in estimates of median lethal dose (LD_{50}) for 55 species of birds. Acute dietary toxicity testing has been conducted on 6 species of birds. Additionally, dietary testing has been conducted on 12 species by offering treated bait used in actual bird control projects. Four species have been tested for reproductive toxicity. This paper presents and discusses extant toxicity data available for blackbirds and various nontarget species of concern.

Key words: 3-chloro-4-methylaniline hydrochloride, 3-chloro-4-methylbenzenamine hydrochloride, acute toxicity, birds, chronic toxicity, CPTH, DRC-1339, Starlicide.

INTRODUCTION

During the 1940s, importation embargos and World War II impacts decreased the availability of active ingredients used in rodenticides and other vertebrate toxicants. At the same time, because of the escalating war efforts, there was an increasing need for effective products to protect goods from rodent and bird damage. In 1942, the Wildlife Research Laboratory and the Patuxent Wildlife Research Refuge began screening compounds for bioactivity at their Berkeley, California; Denver, Colorado; Gainesville, Florida; and Laurel, Maryland facilities. Beginning in 1966, the work was continued by the Denver Wildlife Research Center (DWRC) and the Patuxent Wildlife Research Center (Patuxent). Over the 45 years of this program, the labs conducted more than 85,000 standardized bioactivity tests on approximately 15,000 chemicals, plant products, drugs and other materials on more than 150 species of domestic and wild birds, mammals and plants. Standardized toxicity testing conducted under this screening program was designed to rapidly screen compounds on a broad array of species for repellent and toxic properties. The testing was conducted to replace compounds in short supply or compounds with known or suspected problems with nontarget species.

DRC-1339 (3-chloro-4-methylaniline hydrochloride) was identified during this screening program as a promising avicide for blackbirds, starlings, rock doves, and corvids. Development of this avicide included testing it on as many species (birds, mammals, aquatic organisms and plants) as possible to assess the potential for nontarget effects and its' safety. As a result, this compound has 1 of the most extensive databases for acute oral toxicity to birds of any U. S. Environmental Protection Agency (USEPA)-registered pesticide. One of the attributes that made DRC-1339 an attractive control agent was the wide range of sensitivity of species to the compound. Acute oral toxicity data suggested some taxonomic groupings of birds were far less susceptible to CPTH than others. Pest birds (blackbirds, corvids, rock doves, gulls and starlings) were among the most susceptible.

In recent years, the data supporting the efficacy and safety of DRC-1339 products have been questioned. We feel that much of the criticism is unwarranted. However, we understand that the root of the criticism lies in the fact that much of the new data are unpublished,

and some of the published toxicity estimates vary due to the sources of the data that were used to generate the estimates. In this paper, we present all of the data pertaining to the acute and chronic toxicity of DRC-1339 to birds. We present not only the published point estimates of the toxicity, but in nearly all cases, the raw data that were used to generate those values. It is our objective to accurately present and interpret the available data to provide a common point from which future assessments of nontarget risk can begin.

METHODS

Nearly all of the acute oral toxicity data developed during the screening program were conducted by a small group of scientists at DWRC and Patuxent under the same test method (Tucker and Crabtree 1970, ASTM 1995). Birds were captured from the wild and held in quarantine/acclimation prior to testing. Doses were administered to the birds via oral intubation using polyethylene tubing and usually water or propylene glycol as a vehicle. Following dosing the birds were held for 5 to 7 days to observe any delayed toxic effects. Dosing usually began at 100 mg/kg and progressed to higher or lower doses at quarterlog intervals on successive days, depending upon the response of the test animals. Dose levels were sometimes narrowed as the range between effective and ineffective doses narrowed. Median lethal dose (LD_{50}) levels were determined using methods outlined by Thompson and Weil (1952). Probit analysis was used when tests included sufficient numbers of animals and dose levels. Six acute oral toxicity studies were conducted according to standard USEPA guidelines for acute oral toxicity testing (USEPA 1982a). These studies involved oral intubation of 5 or 6 groups of 10 birds (1 untreated and 4 or 5 treated groups) with geometrically spaced dose levels (Appendix 1).

Acute dietary toxicity has been tested according to acute dietary toxicity testing guidelines recommended by the USEPA (1982b) on the mallard (*Anas platyrhynchos*) and the northern bobwhite (*Colinus virginianus*) (Appendix 2). In these tests a minimum of 5 dose levels and 1 control group were simultaneously tested. Each group contained a minimum of 10 birds. Birds were provided only treated feed for 5 days after which they were provided untreated feed and observed for an additional 14 days. The Coturnix quail (*Coturnix coturnix*), ring-necked pheasant (*Phasianus colchicus*), rock dove (*Columba livia*), and European starling (*Sturnus vulgaris*) were tested for dietary toxicity under less rigorous conditions. However, the exposure periods used in these tests ranged from 24 to 125 days, significantly longer than that used in the USEPA guideline. Twelve additional North American species were tested under worst-case field exposure conditions. The test diet was formulated according to bait formulation directions for the DRC-1339 Staging Area label (USEPA Reg. No. 56228-30) by making a 2% DRC-1339 brown rice bait and diluting it at either 1:27 or 1:25 with untreated brown rice. Birds were offered this diet and fresh water *ad libitum* for a period of 5 days at either 1 or 12 hours per day, and the birds were observed for an additional 3 days following the last exposure period.

The reproductive toxicity of DRC-1339 has been tested on the Coturnix quail, the northern bobwhite, the ring-necked pheasant, and the rock dove (Appendix 3). Some of these tests preceded the establishment of USEPA guidelines (USEPA 1982c). None of the tests used the same general protocol. Exposure periods ranged from 4 to 120 days and only some of the tests included postexposure observation periods. The number of breeding pairs used per test ranged from 2 to 30. One test with ring-necked pheasants administered doses via oral intubation and did not use breeding pairs, but instead rotated males within treatments groups.

Appendices 1, 2, and 3 provide detailed information regarding the design of each test conducted with DRC-1339 for evaluating acute oral, acute dietary, and reproductive toxicity, respectively. The data presented in the appendices include the citation for the original publication of an estimated LD_{50}. Any subsequent citation of the same data was not included. The raw data from which the LD_{50} estimates were made are also included. In most instances the raw data were taken from the original laboratory data sheets. These data include the number of animals used at each dose level tested, mortality rates, time to death, and whether a control group was included in the experiment.

ACUTE AND CHRONIC TOXICITY DATA – DRC-1339

Acute Oral Toxicity

Estimates of acute oral toxicity (LD_{50}) of DRC-1339 are available for 55 species of birds, of which 50 are native to North America (Fig. 1, Appendix 1). Seventy-six individual toxicity tests have been conducted involving at least 1 species in each of 22 taxonomic families (Howard and Moore 1991, American Ornithologists' Union [AOU] 2000). Five families contain target species (Columbidae, Corvidae, Laridae, Icteridae, and Sturnidae), but not all species tested within these families are considered targets. The remaining 16 families contain species which would be considered nontarget species if exposed during baiting operations (Appendix 1).

DRC-1339 is registered as a toxicant for controlling 21 problem bird species. Of the 21 species, 9 have been tested for sensitivity to DRC-1339. Because a significant amount of work has gone into refining baiting strategies for target species, many of the tested species have been tested more than once. Nineteen individual tests have been conducted on target species with tests

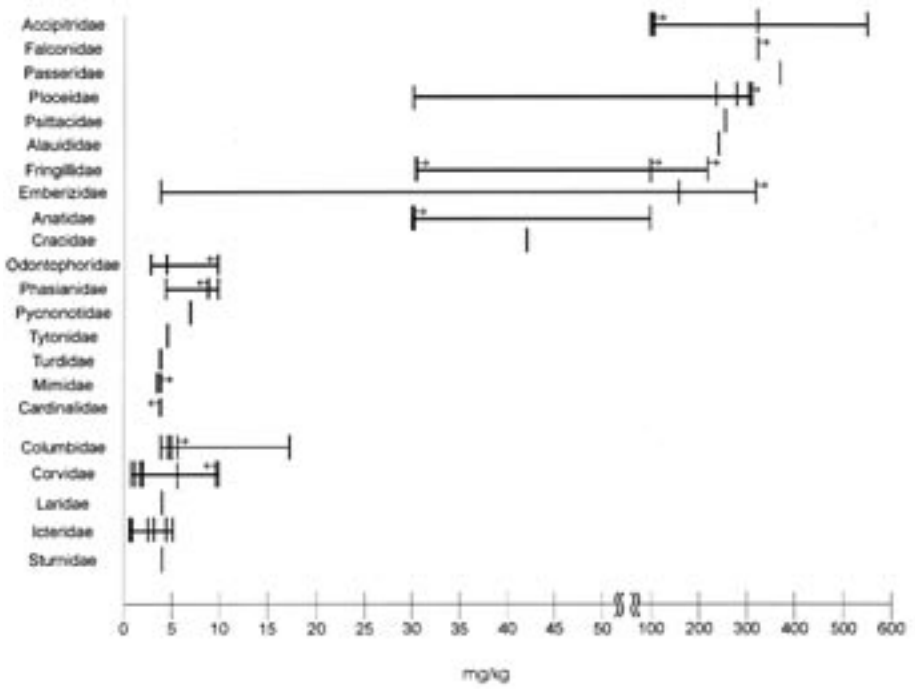

Fig. 1. Estimated acute oral toxicity (LD_{50}) of DRC-1339 to 22 families of birds. Hatch marks with arrows indicate the value was greater or less than what the mark indicates (Modified from Eisemann et al. 2001).

averaging 15 (range 4 to 100) animals per experiment. With the exception of Sturnidae and Laridae, in which only 1 species was tested, 5 or more species were tested within each target family. Tests have averaged 3 to 4 dose levels per test and more than 5 dose levels have been tested on all but 2 species.

DRC-1339 is very highly toxic to target species. Acute oral toxicity estimates for columbids, corvids, icterids, the herring gull (*Larus argentatus*) and starling are generally lower than 6 mg/kg. Within the Corvidae, 3 species of jays, which are not target species, have also been tested. Like all other tested members of this family, all 3 jays are highly sensitive to DRC-1339, with LD_{50}s below 6 mg/kg. Only 1 columbid, the rock dove, is considered a target species. However, the 4 additional dove species that have been tested all have estimated LD_{50}s of 6 mg/kg or less, which is 2 to 3 times more sensitive than the rock dove.

The sensitivity of nontarget species to DRC-1339 is not as clear as what is observed for target species. The available data indicate significant differences among Orders and most Families. All 5 species tested within the Order Falconiformes are 100 to <500 times less sensitive than the most sensitive target species. Estimated LD_{50}s for birds in this Order range from <100 to 562 mg/kg. On the other hand, DRC-1339 is very highly toxic to the barn owl (*Tyto alba*), a predatory bird in the Strigiformes, with an LD_{50} estimate comparable to those of all target species. The LD_{50} estimates for the 3 tested waterfowl, Anseriformes, fall in the range of highly to moderately toxic with values of <30 to 100 mg/kg (Bascietto 1985). With the exception of the chachalaca (*Ortalis vetula*), members of the Galliformes are sensitive with estimated LD_{50}s ranging from 5 to 10 mg/kg.

Eleven species of North American nontarget passerines, Order Passeriformes, representing 7 families, have been tested. Species within the families Alaudidae, Fringillidae and Passeridae (introduced) that have been tested are only moderately sensitive to DRC-1339. In contrast, the tested species within the Mimidae, Turdidae, Cardinalidae are highly sensitive. However, as observed in the Emberizidae, there can be wide variation in sensitivity among species within a family. The dark-eyed junco (*Junco hyemalis*) and the white-crowned sparrow (*Zonotrichia leucophrys*) are moderately tolerant of DRC-1339 with LD50s greater than 150 mg/kg. Tests conducted recently indicated the American tree sparrow (*Eremophila alpestris*) is as sensitive as target species. This finding changed the prevailing assumption that most small granivores were relatively tolerant of DRC-1339.

Five species of African passerines (Plocidae) were also tested in hopes of developing DRC-1339 to control them. Tests showed that with the exception of the red-billed quelea (*Quelea quelea*), these small granivores were relatively tolerant with LD_{50}s over 200 mg/kg. Even the quelea, with an LD_{50} of 31.6 mg/kg, was not considered sensitive enough to continue development of the avicide (Shefte et al. 1982).

Acute Dietary Toxicity

The results of 2 dietary toxicity tests conducted according to USEPA recommendations (USEPA 1982b) as well as others that used longer exposure periods, showed trends in sensitivity similar to those observed in the acute oral studies. Both species of quail and the rock dove were sensitive to dietary DRC-1339, with LC_{50}s lower 25 ppm. However, the mallard and ring-necked pheasant were much more tolerant of dietary DRC-1339 with LC_{50}s in the range of 300 ppm. In addition, 5 North American passerine species from the family Emberizidae, a family thought to be relatively insensitive to DRC-1339) were tested for dietary toxicity, the savannah sparrow (*Passerculus sandwichensis*), the song sparrow (*Melospiza melodia*), the chipping sparrow (*Spizella passerina*), the white-crowned spar-

row, and the field sparrow (*Spizella pussila*). Birds in these tests were exposed to feed typical of material used in baiting programs. Exposure periods were ad libitum exposure for periods of 1 or 12 hours per day for 5 consecutive days, followed by a 3-day observation period when birds were provided unlimited clean feed. None of the 71 birds tested died under these exposure conditions (Appendix 2).

Chronic Toxicity

The variable test designs used in reproductive studies make interspecies comparisons difficult. None of the studies were conducted according to USEPA-recommended guidelines (USEPA 1982c) which recommend that 5 groups of birds be provided the treated diet 10 weeks prior to the onset of egg laying and an additional 10 weeks during laying. The study most similar to the USEPA design was conducted on the Coturnix quail. In this study, 4 dose levels and 1 control group were tested, with each group containing 6 breeding pairs. Birds were exposed for 28 days during the egg-laying period. Results indicated that, because of the higher incidence of breakage during handling, eggshells may have been weaker at the 3.2 ppm dose level. At a dietary concentration of 10 ppm, statistically significant ($p=0.05$) negative effects were observed in the number of eggs produced and the number of live chicks. Hubbard et al. (2003) conducted a reproductive study with the ring-necked pheasant to address the effect of DRC-1339 on breeding pairs and the effect on males and females, separately. In this study, doses were administered by liquid gavage 3 times, one dose every 3 days. Males were not paired with females for the duration of the study. Instead, males were rotated through all females within their respective treatment group. Results of this study showed a significant effect in reduced brood sizes of males dosed with DRC-1339. The effect was greatest at the 4 mg/bird dose level. The only other variable that showed a consistent negative trend for both males and females was clutch size (Appendix 3).

Mode of Action

The biochemical mechanism behind the toxic action of DRC-1339 and the ultimate cause of death are not clearly understood for any species of animal (Giri et al. 1976). The literature suggests that once ingested, CPTH is rapidly hydrolyzed to 3-chloro-p-toluidine (CPT), which is believed to be the toxic compound (Young et al. 1926, Apostolou 1969, Barger 1974, Felsenstein et al. 1974, Giri et al. 1978). Consequently, much of the work to determine the mechanism of action was conducted on CPT. The following discussion on the mode of action draws information from both the CPT and CPTH literature.

Peoples and Apostolou (1967) reported that 87% of an orally delivered dose of DRC-1339 or any of its 3 primary metabolites can be detected in the feces of starlings within 0.5 hours after dosing and >98% of the dose can be found in the feces within 2.5 hours. Giri et al. (1976) have shown that in the starling, the liver, muscle, lung and kidney retain the radio-labeled CPT for the greatest length of time ($t_{1/2}$ = 14.6 hr), and the half-life in the plasma, brain, spleen, heart, and bone marrow was 3 to 6 hrs. Current radioisotope work has supported results previously observed. In both very highly sensitive species, the red-winged blackbird (*Agelaius phoeniceus*), and in a moderately sensitive species, the dark-eyed junco, nearly all of an orally administered dose of ^{14}C-labeled CPTH was excreted within 4 hrs. For virtually all tissues except the kidney, elimination rates were the same. For both species, radioactivity levels diminished more slowly in the kidney than in any other organ or tissue. More importantly, the level of radioactivity in the kidney of the sensitive species, red-winged blackbird, remained significantly greater than background levels for the entire 24-hour test period (David Goldade, National Wildlife Research Center, Fort Collins, Colorado, personal communication).

Nephrotoxicity is generally believed to be the primary cause of death in birds except when death occurs rapidly after large doses of CPTH (Apostolou and Peoples 1970, 1971, Mull and Giri 1972, Mull et al. 1972). The early effect of CPT is believed to be irreversible necrosis of the proximal convoluted tubule in the kidney. Damage to the distal and collecting tubules is evident in later stages of intoxication, with the general disorganization of the kidney (Apostolou 1969, Borison et al. 1975). Also during later stages of intoxication, Mull et al. (1972) reported hypoglycemia, uric acid build-up in the plasma, selective decrease in protein content of kidney tissue, liver glycogen depletion, and shifts in white blood cell counts. Apostolou (1969) reported the presence of white crystals in the pericardial sack and abdominal cavity of poisoned starlings and hypothesized that the increased uric acid levels in the blood caused by CPT precipitate and crystallize in the pericardial and abdominal region of affected birds. However, these crystals were not found inside the kidney.

In less sensitive species, the mode of action of CPT is believed to be depression of the central nervous system, resulting in cardiac or respiratory arrest (Young et al. 1926, DeCino et al. 1966, Apostolou 1969, Felsenstein et al. 1974, Borison et al. 1975). Small doses of aniline can produce transient central nervous and circulatory stimulation, whereas very large doses cause circulatory depression and cardiac arrhythmias (Clark et al. 1943). Symptoms which might be the result of direct cytotoxic effect of CPT include hemoconcentration, loss of plasma proteins, and ascitic fluid in the abdomen that may be due in part to increased capillary permeability (Borison et al. 1975). Methemoglobinemia in less sensitive species is well-documented but is not generally believed to be a primary factor contributing to

death, except possibly in cats (Apostolou 1969, Westberg 1969, Mull et al. 1972, Felsenstein et al. 1974, Borison et al. 1975). Giri et al. (1976) also demonstrated that radio-labeled CPT will cross the blood-brain barrier. However, the direct effects on neurological function are unknown. Following intraperitoneal administration, CPT has been detected in brain tissue and central nervous system effects such as intense weakness, dyspnea, and complete paralysis are observed (Apostolou 1969). The central nervous system depression resulting from ingestion of CPT in less sensitive mammals and raptors is considered reversible and can be successfully treated symptomatically (Westberg 1969, Felsenstein et al. 1974).

Mull (1971) and Mull and Giri (1972) hypothesized that the kidney mitochondrial deacetylase is responsible for the difference in susceptibility to CPT between the less sensitive red-tailed hawk (*Buteo jamaicensis*) and mammals and the more sensitive chicken (*Gallus domesticus*), starling, pheasant and rock dove. The red-tailed hawk and mammals do not have kidney mitochondrial deacetylase, whereas it was present in the greatest amounts in sensitive birds. In another study, the metabolism of CPT and 2-chloro-4-acetutoluidine (CAT) was evaluated in rats and chickens (Westberg 1969). Chickens are known to have very active renal deacetylase. Rats were administered 60 times more CPT or CAT than chickens. Westberg showed that in chickens administered CPT, parent and metabolites were mainly found in the kidney. In chickens administered CAT, no parent was found in the kidneys or other tissues. Metabolites of both compounds were found in comparable ratios in the kidney. In the rat, parent and metabolite residues of CPT and CAT were found in all tissues. These results support the hypothesis that renal deacetylase has an important role in the sensitivity of species to DRC-1339 (Westberg 1969).

Schafer et al. (1977) suggested that CPT is a cumulative and chronic toxicant to birds. However, there has been some suggestion that even highly sensitive species might have some mechanism(s) for dealing with sublethal amounts of CPT (Schwab and Osborne 1966). Schwab and Osborn reported that the mechanism by which starlings detoxify or eliminate CPT operates effectively between 2-4 hr after the animal receives the toxicant (~1.2 mg CPTH offered in 2-hr intervals), but that a longer period between intubations does not greatly increase the ability of starlings to resist the toxic effects of this compound. In another test, 5 starlings each were intubated with 0, 1.0, 2.0, and 3.0 mg/kg of CPTH with propylene glycol one time and observed for 28 days. Four of the 20 test birds died (0/5 at 0 mg/kg, 0/5 at 1.0 mg/kg, 1/5 at 2.0 mg/kg, and 3/5 at 3.0 mg/kg) within 50 hours of ingestion, and no further mortality was observed during the remaining 26 days of the test (E. W. Schafer. 1970. The chronic toxicity of single sub-acute oral doses of DRC-1339 in the starling, Denver Wildlife Research Center, Denver, Colorado, USA.). However, we were unable to find any additional studies which looked at detoxification and/or elimination of CPT in sensitive bird species or that examined the threshold point at which sensitive species could survive sublethal doses of CPTH or CPT.

DISCUSSION

Previously, language used to describe the range of species sensitivity to DRC-1339 categorized all species into either sensitive or insensitive. The breakpoint between 'sensitive' and 'insensitive' is unclear and the term 'insensitive' leads the reader to believe the birds are not affected by DRC-1339. We believe terminology should be adopted that reflects the current classification scheme used by the USEPA. The USEPA classification used the following labels, based upon the inherent toxicity of the active ingredient, for toxicity to birds: 'very highly toxic' (<10 mg/kg), 'highly toxic' (10 to 50 mg/kg), 'moderately toxic' (51 to 500 mg/kg), 'slightly toxic' (501 to 2000 mg/kg), and 'practically nontoxic' (>2000 mg/kg) (Bascietto 1985). According to the USEPA's terminology, DRC-1339 is moderately toxic to even the least sensitive species.

There are many views regarding the most appropriate study design for acute toxicity testing (Lipnick et al. 1995). As early as 1948, methods were proposed for obtaining and analyzing toxicity data based on small sample sizes (Dixon and Mood 1948). This methodology, or variations of it, fell out of favor for acute toxicity testing in 1982 when the USEPA adopted standardized methodology based on 10 animals per dose level with at least 5 dose levels plus a control for birds (USEPA 1982a) and 3 dose levels and no control for rodents (USEPA 1982d). Recently, however, there has been a great deal of activity within the regulatory community to reduce the number of animals used in toxicity testing. Growing public concern for the welfare of animals is calling for reducing the number of animals tested and even eliminating animal testing all together.

In response to animal welfare concerns, the pesticide risk assessment community has begun to reevaluate the validity of generating LD_{50} estimates with small sample sizes. In 1987, the American Society for Testing and Materials (ASTM) published the toxicity testing guideline "E1163-87, Standard method for estimating acute oral toxicity in rats" (ASTM 1987). This guideline was revised 3 more times before the current version (ASTM 1998). The ASTM methodology recommends testing 1 animal per dose level every 24 hours. Depending on the survival of the animal, subsequent dose levels are increased or decreased at geometric intervals. This method is generally referred to as the "Up-and-Down Method." With slight modification, this methodology is being adopted by both national and international scientific and regulatory communities (Organisation for

Economic and Co-operation and Development[OECD] 1997, National Institute of Environmental Health Sciences [NIEHS] 2000). In 1997, the USEPA convened the Ecological Committee on FIFRA Risk Assessment (ECOFRAM) to draft guidance for the agency to replace deterministic ecological risk assessment methods with probabilistic methods. The ECOFRAM report recommends conducting definitive LD_{50} tests on only 1 species, the mallard and/or northern bobwhite. The report recommends that any further testing be conducted under the up-and-down method (USEPA 1999).

The DWRC chemical screening program usually relied on small numbers of animals to develop acute oral toxicity data and generally followed the standardized up-and-down test methodology, although sample sizes were larger. Due to limitations imposed by working with wild captured animals, much of the species data were collected opportunistically. Dose levels were generally geometrically spaced, doses were sometimes administered to more than 1 dose level at the same time, and post-dosing observation periods were almost always longer than the 2 days. Despite problems resulting from the availability of animals, the acute oral toxicity data generated on DRC-1339 by the DWRC chemical screening program breaks down as follows: 62% of all tests used 3 or more dose levels, 73% of all tests used 2 or more birds per dose level and 53% of all tests used 6 or more birds.

Multiple acute oral toxicity tests were conducted on nearly 20 species. Six species (mallard, domestic turkey (*Meleagris gallopavo*), northern bobwhite, Coturnix quail, rock dove, and starling) had at least one LD_{50} estimate based on a test designed after the USEPA guidelines or a similar design using at least 25 animals and one LD_{50} estimate based on a small number of animals. With the exception of the mallard, both LD_{50} estimates for these species were within a few milligrams per kilogram of each other. Half of the time the LD_{50} estimated from the small sample size overestimated the toxicity, and none of the changes caused a shift in the toxicity classification (i.e., very highly toxic or moderately toxic). The greatest discrepancy in LD_{50} estimates within a species was with the mallard, for which the test with the small sample size overestimated the toxicity by 82 mg/kg.

In terms of acute oral toxicity to birds, DRC-1339 has one of the largest databases of any registered pesticide. Although much of this data was collected prior to 1982, when the USEPA adopted the classical acute oral toxicity study design, and many of the LD_{50} estimates of acute oral toxicity are not as precise as many risk assessors would like, the results of most tests involving DRC-1339 are remarkably consistent. Studies demonstrate that LD_{50} estimates based on small sample sizes are a good approximation of what is observed in more rigorous classical designs (Bruce 1985, 1987, Lipnick et al. 1995). To disregard the data generated by studies conducted prior to the establishment of USEPA guidance is not only inappropriate, but also wasteful of quality data and animal life.

Most of the toxicity tests were conducted by U. S. Fish and Wildlife Service scientists prior to the USEPA adopting standardized toxicity test guidelines in the 1970s. However, many of the scientists involved in drafting the USEPA guidelines were those conducting the chemical screening work discussed above. Our objective in this paper was to compile all published and unpublished acute and chronic toxicity data so that all interested parties have access to complete and accurate data for future assessments. The depth of avian toxicity data available for DRC-1339 and the high standards utilized when the data were generated provide a unique situation for assessing the risks avian control activities control activities present to free ranging birds.

LITERATURE CITED

Agricultural Chemicals Board. 1977. DRC-1339 for bird control: the agricultural chemicals (vertebrate pest control) regulations 1977. Wellington, New Zealand.

American Cyanamid. 1966. Avian control and avicidal compounds. British Patent 1,038,526.

American Ornithologists' Union (AOU). 2000. Forty-second supplement to the American Ornithologists' Union check-list of North American birds. Auk 117:847-858.

Apostolou, A. 1969. Comparative toxicology of the avicides 3-chloro-*p*-toluidine and 2-chloro-4-acetotoluidide (sic) in birds and mammals. Dissertation, University of California, Davis, USA.

Apostolou, A., and S. A. Peoples. 1970. The development of tolerance of 3-chloro-*p*-toluidine in the rat. Proceedings of the Society for Experimental Biology and Medicine 134:577-579.

Apostolou, A., and S. A. Peoples. 1971. Toxicity of the avicide 2-chloro-4-acetotoluidide in rats: a comparison with its nonacetylated form 3-chloro-*p*-toluidine. Toxicology and Applied Pharmacology 18:517-521.

Association of American Pesticide Control Officials. 1966. Pesticide chemicals official compendium. 1966: 457-458.

American Society for Testing and Materials (ASTM). 1987. E1163-87, Standard test method for estimating acute oral toxicity in rats. Philadelphia, Pennsylvania, USA.

American Society for Testing and Materials (ASTM). 1995. E551-95, Standard test methods for developing effective bird control chemicals. Philadelphia, Pennsylvania, USA.

American Society for Testing and Materials (ASTM). 1998. E1163-98, Standard test method for estimating acute oral toxicity in rats. Philadelphia, Pennsylvania, USA.

Barger, A. E. 1974. Toxicological investigations of 2-chloro-4-acetotoluidide in starlings and quail. Thesis, University of California, Davis, USA.

Bascietto, J. 1985. Hazard Evaluation Division, standard evaluation procedure, avian single-dose oral LD_{50}. U. S. Environmental Protection Agency EPA-540/9-85-007.

Borison, H. L., S. R. Snow, D. S. Longnecker, and R. P. Smith. 1975. 3-chloro-*p*-toluidine: effects of lethal doses in rats and cats. Toxicology and Applied Pharmacology 31:403-412.

Braverman, Y. 1968. The toxicity of DRC-1339 (3-chloro-4-methylaniline hydrochloride) for the African bulbul (*Pycnonotus capensis*) as determined in laboratory experiments. Refuah Veterinarith 25(4):242-245.

Bruce, R. D. 1985. An Up-and-Down procedure for acute toxicity testing. Fundamentals of Applied Toxicology 5:151-157.

Bruce, R. D. 1987. A confirmatory study of the Up-and-Down method for acute oral toxicity testing. Fundamentals of Applied Toxicology 8:97-100.

Clark, B. B., E. J. Vanloon, and R. W. Morrissey. 1943. Acute experimental aniline intoxication. Journal of Industrial Hygiene and Toxicology 25:1-12.

Cummings, J. L., J. F. Glahn, E. A. Wilson, and J. E. Davis, jr. 2002. Potential hazards of DRC-1339 treated rice to nontarget birds when used at roost staging areas in Louisiana to reduce local populations of depredating blackbirds. International Biodeterioration and Biodegradation 49:185-188.

Cummings, J. L., D. L. York, P. A. Pipas, R. S. Stahl, and J. E. Davis. 2003. Dietary toxicity test for 2% DRC-1339 treated brown rice on nontarget avian species. *In* G. M. Linz, editor. Management of North American blackbirds. National Wildlife Research Center, Fort Collins, Colorado, USA. In Press.

DeCino, T. J., D. J. Cunningham, and E. W. Schafer. 1966. Toxicity of DRC-1339 to starlings. Journal of Wildlife Management 30:249-253.

Dixon, W. J., and A. M. Mood. 1948. A method for obtaining and analyzing sensitive data. Journal of the American Statistical Association 43:109-126.

Eisemann, J. E., G. M. Linz, and J. J. Johnston. 2001. Nontarget hazard assessment of using DRC-1339 avicide to manage blackbirds in sunflower. Pages 197-212 *in* J. J. Johnson, editor. Pesticides in wildlife. American Chemical Society Symposium Series 771.

Felsenstein, W. C., R. P. Smith, and R. E. Gosselin. 1974. Toxicological studies on the avicide 3-chloro-p-toluidine. Toxicology and Applied Pharmacology 28:110-1125.

Giri, S. N., D. H. Gribble, and S. A. Peoples. 1976. Distribution and binding of radioactivity in starlings after IV administration of 14C 3-chloro-p-toluidine. Federation Proceedings 35(3):328.

Giri, S. N., D. M. Siegel, and S. A. Peoples. 1978. Tissue distribution and binding of radioactivity in mouse after intravenous administration of [14C]-3-chloro-p-toluidine. Toxicology 11:153-65.

Heath, R. G., J. W. Spann, E. F. Hill, and J. F. Kreitzer. 1972. Comparative dietary toxicities of pesticides to birds. U. S. Fish and Wildlife Service Special Scientific Report No. 152.

Henry, J. P., M. E. Campney, and M. J. Cummings. 1964. Secondary toxicity hazard of DRC-1339. Progress report on starling control. University of California, Davis, USA.

Hill, E. W., and M. B. Camardese. 1986. Lethal dietary toxicities of environmental contaminants and pesticides to Coturnix. U. S. Fish and Wildlife Service, Fish and Wildlife Technical Report 2.

Howard, R., and A. Moore. 1991. A complete checklist of the birds of the world. Second edition. Academic Press, New York, USA.

Hubbard, D. E., R. D. Neiger, J. A. Smith, and D. C. Franke. 2003. Effects of DRC-1339 (3-chloro-4-methylaniline hydrochloride) avicide on pheasant reproduction. *In* George M. Linz, editor. Management of North American blackbirds. National Wildlife Research Center, Fort Collins, Colorado, USA. In Press.

Larson, K. H., and J. H. Dietrich. 1970. Reduction of a raven population on lambing grounds with DRC-1339. Journal of Wildlife Management 34:200-204.

Lipnick, R., J. A. Cotrouvo, R. N. Hill, R. D. Bruce, D. A. Stitzel, A. P. Walker, I. Chu, M. Goddard, L. Segal, J. A. Springer, and R. C. Meyers. 1995. Comparison of the Up-and-Down, conventional LD_{50}, and Fixed-Dose Acute Toxicity procedure. Food Chemistry and Toxicology 33:223-331.

Mull, R. L. 1971. Comparative studies of acute and subacute toxicity of 3-chloro-*p*-toluidine, studies of the effects of an acutely toxic dose in chickens on certain clinical biochemical parameters, and comparative studies of a renal aromatic N-deacetylase. Dissertation, University of California, Davis, USA.

Mull, R. L., and S. N. Giri. 1972. The role of renal aromatic n-deacetylase in selective toxicity of avicide 3-chloro-p-toluidine in birds. Biochimica et Biophysicia Acta 273:222-228.

Mull, R. L., S. N. Giri, and S. A. Peoples. 1972. Effects of an acutely toxic dose of the avicide 3-chloro-p-toluidine in chickens. Toxicology and Applied Pharmacology 22:458-464.

National Institute of Environmental Health Sciences (NIEHS). 2000. National Institute of Environmental Health Sciences, National Institute of Health, National Toxicology Program; Notice of peer review meeting on the revised Up-and-Down procedure as an alternative test method for assessing acute oral toxicity; request for comments. Federal Register 65(106):35109-35110.

Organization for Economic Cooperation and Development (OECD). 1997. Guideline for the testing of chemicals: draft proposal for a new Guideline 425. Acute oral toxicity: Up-and-Down Procedure. Organisation for Economic Co-operation and Development.

Peoples, S. A., and A. Apostolou. 1967. A comparison between the metabolism of DRC-1339 in rabbits and in starlings. Progress report on starling control. University of California, Davis, USA.

Schafer, E. W., jr., R. B. Brunton, and N. Lockyer. 1979. The chronic toxicity of single subacute doses of DRC-1339 in the starling. Technical Report DF-102.2-8. Denver Wildlife Research Center, Colorado, USA.

Schafer, E. W., jr., R. B. Brunton, D. J. Cunningham, and N. F. Lockyer. 1977. The chronic toxicity of 3-chloro-4-methyl benzamine HCl to birds. Archives of Environmental Contamination and Toxicology 6: 241-248.

Schafer, E. W., jr., W. A. Bowles, jr., and J. Hurlbut. 1983. The acute oral toxicity, repellency, and hazard potential of 998 chemicals to one or more species of wild and domestic birds. Archives of Environmental Contamination and Toxicology 12:355-382.

Shefte, N., R. L. Bruggers, and E. W. Schafer, jr. 1982. Repellency and toxicity of 3 bird control chemicals to 4 species of African grain-eating birds. Journal of Wildlife Management 46:453-457.

Schwab, R. G., and J. L. Osborne. 1966. Effects of DRC-1339 on starlings when administered as individually sublethal but progressively increasing concentrations. Progress report on starling control. University of California, Davis, USA.

Seamans, T. W., and J. L. Belant. 1999. Comparison of DRC-1339 and alpha-chloralose to reduce herring gull populations. Wildlife Society Bulletin 27(3): 729-733.

Thompson, W. R., and C. S. Weil. 1952. On the construction of tables for moving average interpolation. Biometrics 8:51-54.

Tucker, R. K. 1969. Starlicide report. Denver Wildlife Research Center, Colorado, USA.

Tucker, R. K., and D. G. Crabtree. 1970. Handbook of toxicity of pesticides to wildlife. Denver Wildlife Research Center, Bureau of Sport Fisheries and Wildlife. Resource Publication No. 84.

U. S. Department of Agriculture (USDA). 1994. Risk Assessment of wildlife damage control methods used by the USDA Animal Damage Control Program. Animal Damage Control Program, Final Environmental Impact Statement. Appendix P, Volume 3, United States Department of Agriculture, Washington, D. C. USA.

U. S. Environmental Protection Agency (USEPA). 1982a. Avian single-dose oral LD_{50} test, Guideline 71-1. Pages 33-37 *in* Pesticide assessment guidelines, subdivision E, hazard evaluation wildlife and aquatic organisms. U. S. Environmental Protection Agency PB83-153908, Washington D. C., USA.

U. S. Environmental Protection Agency (USEPA). 1982b. Avian dietary LC_{50} test, Guideline 71-2. Pages 37-43 *in* Pesticide assessment guidelines, subdivision E, hazard evaluation wildlife and aquatic organisms. U. S. Environmental Protection Agency PB83-153908, Washington D. C., USA.

U. S. Environmental Protection Agency (USEPA). 1982c. Avian reproduction test, Guideline 71-4. Pages 48-57 *in* Pesticide assessment guidelines, subdivision E, hazard evaluation wildlife and aquatic organisms. U. S. Environmental Protection Agency PB83-153908, Washington D. C, USA.

U. S. Environmental Protection Agency (USEPA). 1982d. Acute oral toxicity study, Guideline 81-1. Pages 34-39 *in* Pesticide assessment guidelines, subdivision F, hazard evaluation human and domestic animals. U. S. Environmental Protection Agency PB83-153916, Washington D. C., USA.

U. S. Environmental Protection Agency (USEPA). 1999. ECOFRAM terrestrial draft report. Ecological Committee on FIFRA Risk Assessment Methods. U. S. Environmental Protection Agency, Washington D. C. http://www.epa.gov/oppefed1/ecorisk/terreport.pdf

Weatherbee. 1968. Quarterly progress report. The Massachusetts Cooperative Wildlife Research Unit, University of Massachusetts, Amherst, USA.

Westberg, G. L. 1969. Comparative studies of the metabolism of 3-chloro-*p*-toluidine and 2-chloro-4-acetotoluidine in rats and chickens and methodology for the determination of 3-chloro-p-toluidine and metabolites in animal tissues. Thesis, University of California, Davis, USA.

Young, A. G., C. W. Muehlberger, and W. J. Welch. 1926. Toxicological studies of acute aniline poisoning. Volume 1. Experimental studies. Journal of Pharmacology and Experimental Therapeutics 27:101-123.

Appendix 1. Acute oral toxicity of DRC-1339 to birds.

Order Family Subfamily *	Species	Control group included	Total birds	Mortality / No. animals @ dose (mg/kg)	Time to death (hours)	Estimated LD_{50} (mg/kg)	95% CL (mg/kg)	Original citation
Anseriformes Anatidae	Mallard *Anas platyrhynchos*	N	6	1/3 @ 10.0 2/3 @ 31.6	<216 <48 – 96	17.8	5.62-56.2	A
		Y	60	2/10 @ 68.1 4/10 @ 100 5/10 @ 147 10/10 @ 215 10/10 @ 316	>72 – 168 >24 – 96 >24 – 120 <24 – 72 <24 – 72	100	79.4-126	B
		N	12	4na	128	102-161	C	
	Northern pintail *Anas acuta*	N	2	0/1 @ 10.0 0/1 @ 32.0	– –	>31.6	NC	A
	Blue-winged teal *Anas discors*	N	4	0/2 @ 10.0 2/2 @ 100.0	– <96	31.6	NC	A
Falconiformes Accipitridae	Northern harrier *Circus cyaneus*	N	1**	0/1 @ 100 1/1 @ 320	– 24 – 48	100 – 320	NC	A
		N	6	0/2 @ 7.5 0/3 @ 100 1/1 @ 320	– – na	<320	NC	D
	Cooper's hawk *Accipter cooperii*	N	4	0/2 @ 100.0 0/1 @ 316.0 1/1 @ 1000.0	– – <48	562	NC	A
	Red-tailed hawk *Buteo jamaicensis*	N	1	1 @ 320.0	24 – 48	<320	NC	E
	Golden eagle *Aquila chrysaetos*	N	1	0/1 @ 100.0	–	>100	NC	F
Falconidae	American kestrel *Falco sparverius*	N	2	0/1 @ 100.0 0/1 @ 320.0	–	>320	NC	A
Galliformes Cracidae	Chachalaca *Ortalis vetula*	N	3	0/1 @ 10.0 0/1 @ 18.0 1/1 @ 100.0	– – 46	42.1	NC	F
Phasianidae Phasianinae	Chicken *Gallus domesticus*	Y	50	0/10 @ 3.62 0/10 @ 5.55 4/10 @ 8.32 10/10 @ 12.11	na na na na	6.5-7.4	NC	H
		Y	50	6/10 @ 13.6 8/10 @ 19.0 10/10 @ 23.5 10/10 @ 28.3	na na na na	<13.7	NC	I
		na	75	7/25 @ 3.0 33/40 @ 6.0 10/10 @ 9.0	72 24 24	3.0-6.0	NC	J
		na	40	14/20 @ 6.0 10/10 @ 9.0 10/10 @ 15.0	na	<10.0	NC	HH
	Ring-necked pheasant *Phasianus colchicus*	N	20	0/2 @ 3.16 0/4 @ 5.62 3/6 @ 10.0 4/4 @ 17.8 2/2 @ 31.6 2/2 @ 100.0	– – 48 – 108 24 – 48 28 – 53 8 – 12	10.0	7.20-13.18	F
		na	8	nana	10.0	NC	A	
Meleagridinae	Domestic turkey *Meleagris gallopavo*	N	6	0/2 @ 3.2 1/2 @ 5.6 2/2 @ 10.0	– 50 – 65 18 – 49	5.6	NC	A
		Y	50	3/10 @ 7.42 4/10 @ 9.18 6/10 @ 11.58 7/10 @ 14.65	na na na na	10.26	NC	K

Appendix 1. Continued

Order Family Subfamily *	Species	Control group included	Total birds	Mortality / No. animals @ dose (mg/kg)	Time to death (hours)	Estimated LD_{50} (mg/kg)	95% CL (mg/kg)	Original citation
Meleagridinae	Domestic turkey *Meleagris gallopavo*	Y	50	9/10 @ 5.4 9/10 @ 6.8 10/10 @ 8.5 10/10 @ 10.4	na na na na	<9.0	NC	L
Odontophoridae	California quail *Callipepla californica*	N	1	1/1 @ 10.0	9	<10	NC	F
	Northern bobwhite *Colinus virginianus*	N	4	0/1 @ 3.2 1/1 @ 5.6 2/2 @ 10.0	– 50 – 65 24 – 23	4.2	NC	F
		Y	70	0/10 @ 0.681 0/10 @ 1.00 0/10 @ 1.47 5/10 @ 2.15 4/10 @ 3.16 9/10 @ 10.0	– – – 96 – 216 72 – 96 24 – 72	2.6	2.1-3.3	M
	Coturnix quail *Coturnix coturnix*	N	82	4/20 @ 1.78 10/20 @ 2.37 16/20 @ 3.16 20/20 @ 4.21 2/2 @ 5.62	72 – 96 43 – 93 43 – 93 24 – 72 26	2.4	2.1-2.7	F
		N	1	1/1 @ 10.0	na	<10.0	NC	A
Charadriiformes Laridae	Herring gull *Larus argentatus*	N	24	0/5 @ 0.75 0/5 @ 1.5 0/4 @ 3.75 4/4 @ 7.5 4/4 @ 15.0 4/4 @ 30.0	– – 41 – 72 48 – <60 24 – <48 24 – <72	1.5 - 3.75	NC	O
Charadriiformes Laridae	Herring gull *Larus argentatus*	N	56	0/7 @ 0.4 0/7 @ 0.8 0/7 @ 1.5 2/7 @ 2.9 7/7 @ 5.8 4/7 @ 10.6 7/7 @ 21.2 7/7 @ 42.2	– – – 54 – 165 45 – 199 43 – 52 20 – 48 22 – 54	4.6	3.0-7.2	P
Columbiformes Columbidae	Rock dove *Columba livia*	N	4	0/1 @ 5.6 1/2 @ 17.7 1/1 @ 56	– 77 – 92 48	17.7	NC	A
		N	8	0/1 @ 5.6 0/2 @ 10.0 2/4 @ 18.0 1/1 @ 56.0	– – 71 – 92 48	18	NC	Q
		Y	25	0/5 @ 5.0 1/5 @ 10.0 4/5 @ 20.0 4/5 @ 40.0	na na na na	10-20	NC	R
	Mourning dove *Zenaida macroura*	N	17	0/1 @ 1.8 1/2 @ 3.2 3/4 @ 5.6 4/4 @ 10.0 2/2 @ 18.0 2/2 @ 56.0 2/2 @ 100.0	– 2 – 24 2 – 48 8 – 48 2 – 24 2 – 24 2 – 24	3.2	1.8-5.6	S
		na	5	nana	5.6-10	NC	A	
	Common ground dove *Columbina passerina*	N	2	0/1 @ 3.2 1/1 @ 5.6	– 31 – 50	4.2	NC	F

Appendix 1. Continued

Order Family Subfamily *	Species	Control group included	Total birds	Mortality / No. animals @ dose (mg/kg)	Time to death (hours)	Estimated LD_{50} (mg/kg)	95% CL (mg/kg)	Original citation
Columbiformes Columbidae	White-winged dove *Zenaida asiatica*	N	10	0/2 @ 3.2 2/2 @ 5.6 2/2 @ 10.0 2/2 @ 18.0 2/2 @ 32.0	– 71 – 95 54 – 71 25 – 49 25 – 49	4.2	NC	F
	White-tipped dove *Leptotila verreauxi*	N	1	0/1 @ 5.6	–	>5.6	NC	F
Psittaciformes Psittacidae	Budgerigar *Melopsittacus undulatus*	N	8	0/2 @ 5.6 0/2 @ 32.0 0/2 @ 188.0 2/2 @ 316.0	– – – 56 – 163	242	NC	F
Strigiformes Tytonidae	Barn owl *Tyto alba*	N	9	0/2 @ 1.78 1/2 @ 3.16 1/2 @ 5.6 2/2 @ 10.0 1/1 @ 31.6	– 54 – 96 54 – 96 30 – 51 30 – 48	4.2	1.9-9.5	F
Passeriformes Alaudidae	Horned lark *Eremophila alpestris*	Y	60	3/10 @ 101.3 3/10 @ 177.2 6/10 @ 310.2 8/10 @ 542.8 9/10 @ 949.8	<72 <72 <72 – 96 <24 <24	232.0	NC	T
Pycnonotidae	African bulbul *Pycnonotus capensis*	N	16	0/4 @ 4.0 3/4 @ 8.0 4/4 @ 16.0 4/4 @ 32.0	– < 24 – < 48 >48 >24	6.7	6.2-7.3	U
Mimidae	Brown thrasher *Toxostoma rufum*	N	1	0/1 @ 3.2	–	>3.2	NC	F
	Curve-billed thrasher *Toxostoma curvirostre*	N	3	1/2 @ 3.2 1/1 @ 10.0	31 – 46 3 – 18	3.2	NC	F
Turdidae	American robin *Turdus migratorius*	N	6	0/2 @ 1.8 1/2 @ 3.2 2/2 @ 5.6	– 30 – 48 30 – 48	3.2	NC	F
Emberizidae	White-crowned sparrow *Zonotrichia leucophrys*	N	2	0/1 @ 100.0 0/1 @ 320.0	– –	>320	NC	F
	Dark-eyed junco *Junco hyemalis*	Y	60	2/10 @ 100.0 4/10 @ 175.0 10/10 @ 306.3 10/10 @ 535.9 10/10 @ 937.9	<24 – <48 <24 – <48 <24 – <96 <24 – <48 <24 – <48	162	121-290	V
	American tree sparrow *Spizella arborea*	Y	50	6/10 @ 4.0 9/10 @ 8.0 10/10 @ 16.0 10/10 @ 32.0	<24 – < 36 h <48 – <240 h <48 – < 144 h <48 – < 96 h	3.5	0.0-5.1	W
		Y	60	9/10 @ 25.0 7/10 @ 50.0 6/10 @ 100.0 10/10 @ 200.0 10/10 @ 400.0	<24 – 48 h <24 h <24 h <24 h <24 h	<25	NC	X
Cardinalidae	Northern cardinal *Cardinalis cardinalis*	Y	7	2/2 @ 3.16 2/2 @ 10.0 1/1 @ 31.6	27 – 47 1 – 16 6 – 22	<3.2	NC	Y
Icteridae	Western meadowlark *Sturnella neglecta*	Y	60	0/10 @ 0.51 0/10 @ 1.07 4/10 @ 2.24 7/10 @ 4.70 7/10 @ 9.87	– – <48 – <72 <48 – <72 <48 – <72	4.01	NC	Z
	Red-winged blackbird *Agelaius phoeniceus*	N	10	1/2 @ 0.56 0/2 @ 1.0 0/2 @ 1.78 2/2 @ 3.16 2/2 @ 5.6	192 – – 96 53 – 62	2.4	NC	A

Appendix 1. Continued

Order Family Subfamily *	Species	Control group included	Total birds	Mortality / No. animals @ dose (mg/kg)	Time to death (hours)	Estimated LD_{50} (mg/kg)	95% CL (mg/kg)	Original citation
Icteridae	Red-winged blackbird *Agelaius phoeniceus*	na	12	1/4 @ 2.5 4/4 @ 8.0 4/4 @ 14.0	<67 <96 <44	<8.0	NC	HH
		na	2	2/2 @ 3.16	na	<3.16	NC	HH
	Tri-colored blackbird *Agelaius tricolor*	N	12	0/4 @ 1.78 3/4 @ 3.16 4/4 @ 5.62	– 7 – 74 24 – 48	2.74	2.1-3.7	F
	Boat-tailed grackle *Quiscalus major*	N	8	2/2 @ 1.0 2/2 @ 3.2 2/2 @ 5.6 2/2 @ 10.0	49 – 60 27 – 43 27 – 43 21 – 27	<1.0	NC	F
		N	4	1/2 @ 1.0 2/2 @ 1.8	81 – 96 26 – 42	1.0	NC	AA
	Common grackle *Quiscalus quiscula*	N	6	1/2 @ 1.0 2/2 @ 3.2 2/2 @ 10.0	60 – 72 33 – 56 3 – 16	1.0	NC	F
	Bronzed cowbird *Molothrus aeneus*	N	10	0/2 @ 1.0 1/2 @ 3.2 2/4 @ 5.6 1/2 @ 10.0	– 31 – 50 3 – 18 26	5.62	NC	F
Fringillidae	Linnet *Acanthis cannabina*	N	4	0/2 @ 16.0 0/2 @ 32.0	–	>32	NC	U
	Cassin's finch *Carpodacus cassinii*	N	1	0/1 @ 100.0	–	>100	NC	F
	House finch *Carpodacus mexicanus*	N	8	0/2 @ 25.0 0/2 @ 56.0 0/2 @ 112.0 0/2 @ 225	– – – –	>225	NC	F
Passeridae	House sparrow *Passer domesticus*	N	3	0/1 @ 100.0 0/1 @ 320.0 1/1 @ 448.0	– – 25 – 40 h	375	NC	A
Ploceidae	Golden sparrow	N	na	nana	316	178 -562	BB	
	Auripasser luteus	N	na	nana	287	173 - 480	BB	
	Masked weaver *Ploceus taeniopterus*	N	na	nana	>316	NC	BB	
	Village weaver *Ploceus cucullatus*	N	na	nana	>316	NC	BB	
	Red-billed quelea *Quelea quelea*	N	8	0/2 @ 17.8 1/2 @ 31.6 2/2 @ 56.2 2/2 @ 100.0	– 48 48 24 – 48	31.6	17.8 - 56.2 56.2	BB
	Red bishop	N	na	nana	237	NC	BB	
	Euplectes orix	N	na	nana	215	167 - 278	BB	
Sturnidae	European starling *Sturnus vulgaris*	N	34	0/4 @ 1.0 0/3 @ 1.5 2/4 @ 3.2 7/7 @ 5.0 4/4 @ 10.0 10/10 @ 15 2/2 @ 100.0	– – 27 – 32 h 35 – 38 h 12 – 35 h 10 – 32 h 3 – 17 h	3.2	NC	NC
		N	30	1/6 @ 2.37 2/12 @ 3.16 4/6 @ 4.21 6/6 @ 5.62	49 h 48 – 85 h 28 – 100 h 25 – 41 h	3.8	3.1 - 4.6	A
		N	16	0/4 @ 1.0 4/4 @ 1.78 4/4 @ 3.16 4/4 @ 5.62	– 24 – 48 h 24 h 24 h	1.33	NC	DD

Appendix 1. Continued

Order Family Subfamily *	Species	Control group included	Total birds	Mortality / No. animals @ dose (mg/kg)	Time to death (hours)	Estimated LD_{50} (mg/kg)	95% CL (mg/kg)	Original citation
Corvidae	Blue jay *Cyanocitta cristata*	N	2	1/1 @ 10.0 1/1 @ 100.0	4 – 21 h 4 – 21 h	<10	NC	A
	Western scrub jay *Aphelocoma californica*	N	7	0/1 @ 0.1 0/1 @ 1.0 1/2 @ 1.8 2/2 @ 3.2 1/1 @ 10.0	– – 50 – 96 h 33 – 48 h 7 – 72 hr	1.8	1.0 - 3.2	F
	Green jay *Cyanocorax yncas*	N	2	0/1 @ 3.2 1/1 @ 10.0	– 24 h	5.62	NC	F
	Black-billed magpie *Pica pica*	N	4	0/1 @ 5.6 2/2 @ 17.7 1/1 @ 56.0	– 5 – 46 h 20 h	10	NC	A
	Rook *Corvus frugilegus*	na	13	na 3.0	NC	EE		
	American crow *Corvus brachyrhynchos*	N	5	0/1 @ 1.0 1/1 @ 1.8 1/1 @ 3.2 1/1 @ 5.6 1/1 @ 10.0	– 60 – 92 h 49 – 64 h 32 – 46 h 26 – 40 h	1.33	NC	A
	Common raven *Corvus corax*	N	16	0/2 @ 1.8 1/3 @ 3.2 0/3 @ 5.6 1/2 @ 10.0 2/3 @ 18.0 2/3 @ 32.0	– 35 h – 47 h 29 – 45 h 22 – 48	13	5 - 39	FF
		Y	8	0/1 @ 1.1 0/1 @ 1.7 1/1 @ 2.6 0/1 @ 3.9 1/1 @ 5.9 1/1 @ 8.9 1/1 @ 13.3 1/1 @ 20.0	– – <74 h – <44 h <46 h <46 h <29 h	2.9	NC	GG

* Taxonomic classification of North American species used AOU 2000, all others followed Howard and Moore 1991.
* * Only one northern harrier was tested at 100 mg/kg. Two weeks after administering the first dose the same bird was dosed at a rate of 320 mg/kg.
na Data not available

A DeCino et al. 1966; *B* D. Fletcher and C. Pedersen. 1991. Compound DRC-1339: 21-day acute oral LD_{50} study in mallard ducks: Lab Project No. 89 DD 71, Bio-Life Associates; *C* Tucker 1969; *D* Henry et al. 1964; *E* A. Zajanc. 1963. DRC-1339 toxicity to hawks, Denver Wildlife Research Center, Colorado, U.S.A.; *F* Schafer et al. 1983; *G* American Association of Pesticide Control Officials 1966; *H* R. D. Grant. 1967. S. R. 60 – Toxicity studies on starlicide: experiment 3, Ralston Purina; *I* R. D. Grant. 1967. S. R. 60 – Toxicity studies on starlicide: Experiment 4, Ralston Purina; *J* American Cyanamid. 1962. Toxicology of compound 47676, American Cyanamid; *K* R. D. Grant. 1967. S. R. 60 – Toxicity studies on starlicide: Experiment 5, Ralston Purina; *L* R. D. Grant. 1967. S. R. 60 – Toxicity studies on starlicide: experiment 6, Ralston Purina; *M* D. Fletcher, and C. Pedersen. 1991. Compound DRC-1339: 21-day acute oral LD_{50} study in bobwhite quail: Lab Project No. 89 QD 135, Bio-Life Associates; *O* Weatherbee 1968; *P* Seamans and Belant 1999; *Q* D. J. Cunningham and E. W. Schafer, Denver Wildlife Research Center, unpublished data; *R* Mull 1971; *S* D. West and T. L. Clark, Denver Wildlife Research Center, unpublished data; *T* R. W. Sayre. 2001. DRC-1339: an acute oral toxicity study with the horned lark (*Eremophila alpestris*), Genesis Laboratories, Wellington, Colorado, U.S.A.; *U* Braverman 1968; *V* R. W. Sayre. 2001. DRC-1339: an acute oral toxicity study with the dark-eyed junco (*Junco hymenalis*), Genesis Laboratories, Wellington, Colorado, U.S.A.; *W* J. Mach. 2001. DRC-1339: an acute oral toxicity study with the American tree sparrow (*Spizella arborea*), Genesis Laboratories, Wellington, Colorado, U.S.A.; *X* J. Borchert. 2001. DRC-1339: an acute oral toxicity study with the American tree sparrow (*Spizella arborea*), Genesis Laboratories, Wellington, Colorado, U.S.A. *Y* USDA 1994; *Z* J. Borchert. 2001. DRC-1339: an acute oral toxicity study with the western meadowlark (*Sturnella neglecta*), Genesis Laboratories, Wellington, Colorado, U.S.A.; *AA* D. West and R. Brunton, Denver Wildlife Research Center, unpublished data; *BB* Shefte et al. 1982; *CC* D. J. Cunningham and T. J. Decino, Denver Wildlife Research Center, unpublished data; *DD* Denver Wildlife Research Center, unpublished data; *EE* Agricultural Chemicals Board 1977; *FF* Larson and Dietrich 1970; *GG* P. J. Savarie and C. E. Knittle. 1991. Acute oral approximate lethal dose (ALD) of compound DRC-1339 to common ravens (*Corvus corax*), Denver Wildlife Research Center, Colorado, U.S.A; HH American Cyanamid 1966.

Appendix 2. Acute dietary toxicity of DRC-1339 to birds.

Species	Age (days)	Diet	Exposure / observation (Days)	Control group	Number of birds	Mortality / No. animals @ dose dose (PPM)	Estimated LC50 in ppm (95% CL)	NOEL	Reference
Mallard *Anas platyrhynchos*	6	Homogenous mixture in pelleted lab diet	5 / 7	Y	110	0/10 @ 156.0 1/10 @ 312.0 9/10 @ 625.0 9/10 @ 1250.0 10/10 @ 2500.0 10/10 @ 5000.0	322 (232.8 – 423.7)	156	*A*
Coturnix quail *Coturnix coturnix*	Adult	Homogenous mixture in pelleted lab diet	28 / 4	Y	60	0/12 @ 3.2 0/12 @ 10 12/12 @ 32 12/12 @ 100	18	10	*B*
	14 [a]	Homogenous mixture in pelleted lab diet	5 / 3	Y	78	1/13 @ 12.0 [a] 9/13 @ 28.0	22 [a] (19 – 27)	<12.0	*C*
Northern bobwhite *Colinus virginianus*	13	Homogenous mixture in pelleted lab diet	5 / 11	Y	110	2/10 @ 9.75 2/10 @ 19.5 9/10 @ 39.0 9/10 @ 78.0 10/10 @ 156.0	14.1 (8.8 – 21.0)	<9.75	*D*
	Adult	1/3 corn, sorghum, and pelleted lab diet diluted with 2% treated diet at 1:6, 1:69, 1:699 and 1:6999	120 / -	Y	22	2/4 @ 2.9 1/4 @ 29 6/6 @ 286 6/6 @ 2860	<2.9	<2.9	*B*
Ring-necked pheasant *Phasianus colchicus*	Adult	Cracked corn diluted with 2% treated corn at 1:6 and 1:69	24 / -	Y	12	4/4 @ 286 .0 4/4 @ 2,860	<286	<286	*B*
European starling *Sturnus vulgaris*	Adult	Homogenous mixture in pelleted lab diet	125 / -	Y	48	4/4 @ 1.0 4/4 @ 2.5 4/4 @ 5.0 4/4 @ 10.0 4/4 @ 10.0 4/4 @ 20.0 4/4 @ 40.0	30-day = 4.7 90-day = 1.0	<1.0	*B*
Rock dove	Adult	Homogenous mixture in	30 / -	N	4	2/4 @ 25.0	<25	<25	*B*
Columba livia		lab diet	60 / -	N	2	2/2 @ 100.0	<100	<100	
Savannah sparrow *Passerculus sandwichensis*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	1 hr each day for 5 days / 3 day observation period	N	35	0/35 @ 714.0	<714	<714	*E*
		2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	12 hr each day for 5 days / 3 day observation period	N	19	0/19 @ 714.0	<714	<714	*E*
	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	0/10 @ 769 ppm	<769	<769	*G*
Song sparrow *Melospiza melodia*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	1 hr each day for 5 days / 3 day observation period	N	3	0/3 @ 714.0	<714	<714	*E*
Chipping sparrow *Spizella passerina*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	1 hr each day for 5 days / 3 day observation period	N	3	0/3 @ 714.0	<714	<714	*E*
White-crowned sparrow *Zonotrichia leucophrys*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	12 hr each day for 5 days / 3 day observation period	N	8	0/8 @ 714.0	<714	<714	*E*
Field sparrow *Spizella pussila*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:27 with untreated brown rice	12 hr each day for 5 days / 3 day observation period	N	3	0/3 @ 714.0	<714	<714	*E*
African bulbul *Pycnonotus capensis*	Wild Caught	Bread crumbs treated at a rate of 0.72 mg DRC-1339 / gram bread	*Ad libitum* for 2 days	N	9	9/9 @ 720.0	<720	<720	*F*
Linnet *Carduelis cannabina*	Wild Caught	Bread crumbs treated at a rate of 0.72 mg DRC-1339 / gram bread	*Ad libitum* for 2 days	N	7	0/7 @ 720.0	<720	<720	*F*

Appendix 2. Continued

Species	Age (days)	Diet	Exposure / observation (Days)	Control group	Number of birds	Mortality / No. animals @ dose dose (PPM)	Estimated LC50 in ppm (95% CL)	NOEL	Refer-ence
Canada goose *Branta canadensis*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	0/10 @ 769 ppm	<769	<769	*G*
Snow goose *Chen caerulescens*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	0/10 @ 769 ppm	<769	<769	*G*
American tree sparrow *Spizella arborea*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	9/10 @ 769 ppm	<769	<769	*G*
Western meadowlark *Sturnella neglecta*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	9/10 @ 769 ppm	<769	<769	*G*
Mourning dove *Zenaida macroura*	Wild Caught	2% DRC-1339 treated brown rice diluted 1:25 with untreated brown rice	*Ad libitum* for 5 days	Y	20	8/9 @ 769 ppm	<769	<769	*G*

A C. Pedersen and C. Lesar. 1993. Compound DRC-1339 98% Concentrate (Starlicide): 12-day acute dietary LC_{50} study in mallard ducklings: Lab Project No. 90 DC 151, Bio-Life Associates, Neillsville, Wisconsin, USA; *B* Schafer et al. 1977; *C* Heath et al. 1972; *D* C. Pedersen and C. Lesar. 1993. Compound DRC-1339 98% Concentrate (Starlicide): 12-day acute dietary LC_{50} study in bobwhite quail: Lab Project No. 90 DC 155, Bio-Life Associates, Neillsville, Wisconsin, USA; *E* Cummings et al. 2002; *F* Braverman 1968; *G* Cummings et al. 2003

[a] Data presented in Hill and Camardese 1986

Appendix 3. Reproductive toxicity of DRC-1339 to birds.

Species	Exposure period (days)	No. of birds (pairs)	Dose (PPM in the diet)	Reported reproductive effects	Reproductive NOEL	Reference
Coturnix quail *Coturnix coturnix*	28 4	30	0, 3.2, 10, 32, 100	3.2 ppm – Increase in the percent of broken eggs during handling 10 ppm – Increase in the percent of broken eggs during handling, increased egg production, decreased number of live chicks	<10	*A*
Northern bobwhite *Colinus virginianus*	120 –	11	0, 2.9, 29, 286, 2860	Inconclusive results for reproductive effects because of the small sample size.	NC	*A*
Ring-necked pheasant *Phasianus colchicus*	3 doses administered by oral intubation a 2 day intervals	36 F 12 M	0, 2 mg/dose, 4 mg/dose	The only statistically significant difference was in reduced brood sizes attributed to effects on males. This effect was greatest at the high (4 mg/dose) treatment group. While not statistically significant, negative trends were also noted for both males and females in clutch size and in male fertility and percent hatchability attributed to the male.	2 mg/bird	*B*
Rock dove *Columba livia*	60	2	25.0	Because only a single dose level was tested, firm determination of effects was impossible, however, it did appear that DRC-1339 caused lower fertility and nestling survival.	NOEL	*A*

A Schafer et al. 1977; *B* Hubbard et al. 2003