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BIRD CONTROL CHEMICALS—NATURE, MODES OF ACTION, AND TOXICITY

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INTRODUCTION

Bird control chemicals represent many diverse basic chemical structures, particularly when one considers the limited number of compounds that have been, or are being, used to control birds. This diversity is a direct result of the sources from which most of these chemicals have been derived: human medications, rodenticides, and insecticides. In the 1960s and 1970s, most of the effort in testing new bird control chemicals was expended in finding compounds that were specifically effective on the many species of pest birds. In the 1980s the effort was to develop data to maintain registered chemicals. Because of these factors, currently used bird control chemicals represent an interesting mixture of the old and the new.

This chapter will include discussions of bird control chemicals that have widespread use throughout the world plus all bird control chemicals currently registered by the Environmental Protection Agency for use in the U.S. This chapter is organized into five main sections based on the primary use of the chemical. Within each section, the use, mode of action, and the toxic effects (acute, chronic, secondary, and reproductive) of each bird control chemical will be discussed briefly by related groups (organophosphates, etc.). In those instances where a bird control chemical is also a widely used pesticide, references will be provided only in relation to the use of that chemical in bird control. As an additional aid to users, a tabular listing of the acute avian and mammalian toxicity of each chemical or group of chemicals is presented by toxicity category and closely related species or family groupings.

References will be limited to recent reviews or pertinent individual articles when no general review is available and will be used only in the discussions of individual chemicals or groups of chemicals. Published and available unpublished toxic effect data for most chemicals used in bird control are limited since many compounds were developed for use prior to 1970, when data requirements were much less strict than they are today. Much of these data are now being gathered as the re-registration of "old" pesticides accelerates.

TOXICANTS

Chemicals have been used to kill birds causing, or suspected of causing, damage to agricultural crops, urban structures, and/or other property or commodities for well over 300 years. Formulations containing arsenic, antimony, phosphorus, and botanical extracts were the earliest used bird control chemicals. Some are still used today. Toxic chemicals developed during World Wars I and II were also used occasionally to kill birds. Because most of these naturals were toxic to all animal species, most of the commonly used avicides were also highly toxic to mammals. With the advent of the pesticide era in the late 1940s and the synthesis and subsequent evaluation of large numbers of chemicals on many animal species, a number of chemicals were found that were selectively toxic to birds and relatively nontoxic to mammals and other organisms. Some of these selective chemicals were developed and are still in use today.

In the mid to late 1960s, major effort was made to find and develop avicides that were not only selectively toxic to birds as a group, but also selectively toxic to specific pest bird species. Although a few chemicals were found with these attributes, their selectivity actually limited their usefulness primarily because of the regulatory climate in the U.S. High registration costs due to stringent environment regulations for avicides have made it impractical to develop selective toxicants for use on specific avian pests. Recent research and development programs designed to find new avicides or avian control chemicals have returned to broad-spectrum, less selective compounds that have other major uses. In the last 10 years little effort has been put into finding new avicides. Instead, most effort has been put into gathering data for existing pesticides so that they can continue to be available for use.

The following is a brief description of avicides that are being, or have been extensively, used throughout the world.

ORGANOPHOSPHATES

A number of organophosphate insecticides including fenthion, *O*-dimethyl *O*-(3-methyl-4-methylthio)phenyl phosphorothioate; mevinphos, methyl 3-[(dimethoxy-phosphinyl)oxy]-2-butenoate; and parathion, *O,O*-diethyl *O*-(4-nitrophenyl)-phosphorothioate, have been used in treated baits, dermal contact sprays, treated water, and wicked perches for bird control purposes.[42,55,76,88] The chemistry and toxicology of these insecticides are discussed elsewhere in this handbook series, but there appears to be little difference in the mode of action and toxicity levels between birds and mammals.[36] Because organophosphates are, in general, irreversible inhibitors of acetylcholinesterase, their toxic effects tend to accumulate even if the chemical itself may not.[61,89] The potential for secondary poisoning (predators consuming poisoned prey species) with organophosphates is moderate, depending upon the acute or chronic toxicity of the pesticide to the predatory species and the speed of metabolism or elimination and the time of death in the prey species.[27,56,63,87] Adverse reproductive effects in birds have been documented, but may be caused primarily by the toxic effects of these chemicals.[22,49,51]

CHLORINATED HYDROCARBONS

Endrin. (1a$^{\alpha}$,2,2a,3$^{\alpha}$,6$^{\alpha}$,6a,7,7a$^{\alpha}$)-3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-2,7:3,6-dimethanonaphth(2,3-b)oxirene, was at one time the most widely used chlorinated hydrocarbon avicide in the U.S. and throughout the world; however, its use is now restricted. It is still used in baits and occasionally in wicked perches.[42,50] Endrin is an insecticide. A detailed description of its chemistry and toxicology are discussed elsewhere in this handbook series. There appears to be little difference in the toxicity of endrin between bird and mammal species.[36] Chlorinated hydrocarbons are nerve toxicants (central nervous system [CNS] depressants or stimulants) and because of their high solubility in body fats, are accumulated and can be released in lethal amounts under conditions of stress.[12,19,31] Since endrin accumulates and is quite persistent, the potential for secondary poisoning is great with this material, especially in those predatory or scavenger species at the top of food chains.[21,63,80] Endrin has also been implicated in reproductive failure in birds.[59,77]

METALLIC SALTS

The main chemical in this group is thallium, a chemical that has been used to prepare toxic baits for rodents and birds. In mammals, thallium works at the cellular level and resembles arsenic in its toxic effects; it inhibits many enzyme systems, reduces tissue respiration, and causes severe gastrointestinal distress.[19] The mode of action of thallium in birds appears to be very similar to that in mammals. Poisoning symptoms are varied and require analysis to verify causal agent as thallium.[19] The most notable poisoning symptoms are depilation in mammals and feather loss in birds. Thallium is readily stored in most body tissues, but is slowly excreted and thus has considerable potential for causing secondary poisoning in predatory or scavenger species.[13,60] Reproductive effects have not been demonstrated.

ALKALOIDS

Strychnine (strychnidin-10-one) alkaloid is perhaps the most widely known and used of the chemicals in this group. It and strychnine sulfate are widely used as rodenticides or avicides, primarily on baits.[50,52,60] The chemistry and toxicology of strychnine are discussed elsewhere in this handbook, but in birds they are similar to mammals, where they cause CNS stimulation.[19] Although strychnine is not accumulated and is rapidly excreted, the material still poses a low to moderate probability of causing secondary poisoning; its rapid toxic action can result in large amounts of unabsorbed strychnine in the gut of killed prey species.[1,32,57,63]

Nicotine, (*S*)-3-(1-methyl-2-pyrrolidinyl)pyridine, and nicotine sulfate are two other highly toxic alkaloids that have been used as bird toxicants and repellents.[64] They are extremely fast acting and have little potential for chronic toxicity. Reproductive effects have not been investigated in birds.

ORGANOMETALLIC SALTS

Sodium fluoroacetate (1080) and fluoroacetamide (1081) are well-known vertebrate pesticides.[4,7,60] These are widely used on baits to control birds. Because the primary use of these two chemicals is as rodenticides, their chemistry and toxicology are discussed elsewhere in this handbook series. Both compounds are metabolized to fluorocitrate and interfere with the Krebs cycle (citric acid metabolism) resulting in reduced energy production at the cellular level,[11,39,62] thus causing severe CNS stimulation. Both chemicals are distributed throughout the body and may accumulate since they are slowly excreted. The distribution and accumulation of these compounds would indicate a moderate possibility of secondary poisoning in predatory or scavenger species. Reproductive effects in birds have not been investigated.

ANILINE DERIVATIVES

One chemical has been developed and registered for use as an avicide based on its differential toxicity between bird and mammal species and its selectivity to some pest birds. This compound, coded DRC-1339 (3-chloro-4-methylbenzenamine hydrochloride, Starlicide®*), was developed as a blackbird/starling toxicant in the mid 1960s.[20] It is now used against other blackbird species, corvids, and pigeons.[6,29,35,38] The chemical is unique because of its high toxicity to most pest birds and low to moderate toxicity to most predatory birds and almost all mammalian species.[20] Although the mode of action of this material is not well understood, it appears to cause death primarily by nephrotoxicity in susceptible species and by CNS depression in nonsusceptible species.[63,86] Some attempt has been made to relate the susceptibility/nonsusceptibility pattern to the presence or absence of certain enzyme systems; however, only insufficient data are available to verify the relationship.[2]

DRC-1339 is a chronic toxicant in susceptible bird species,[73] but not in other species since it is rapidly metabolized and excreted in both groups, and it is apparently not accumulated. The chronic toxicity observed appears to relate to irreversible kidney damage caused by the chemical during its short stay in the body of sensitive species.[2] Because most predatory or scavenger vertebrates are nonsusceptible, and the chemical is rapidly metabolized and excreted, greatly ingested DRC-1339 poses little or no risk of secondary poisoning.[63] Reproductive effects in birds are reversible and are related to the toxic effects of the chemical itself.[73]

The free base of DRC-1339, known as CPT, 3-chloro-4-methyl benzenamine, and a metabolic product known as CAT, *N*-(3-chloro-4-methylphenyl)acetamide, are also being considered for possible development as avicides due to different physical-chemical properties which may make them more suitable for specific uses, such as dermal toxicants.[3,23,40] The

* The use of trade names does not imply endorsement of commercial products by the U.S. Government.

secondary hazard potential and reproductive effects of these materials are similar to DRC-1339.[16,63]

REPELLENTS

Chemical repellents or aversive agents have been used for over a century to prevent or reduce the likelihood of birds damaging agricultural crops and structures of various types. Repellent chemicals represent the use of behavior modification as a form of bird control to reduce damage without directly affecting depredating populations. Lethal control methods, on the other hand, attempt to reduce populations and may or may not reduce the amount or distribution of damage.

Repellency or aversion in birds are both complicated behavioral responses that can be caused by a large number of stimuli with a variety of results. Because they are behavioral responses, they are difficult to measure or quantify in the laboratory or field since many other unrelated stimuli or environmental factors can also modify responses. The problem of determining the effectiveness of repellents, as opposed to the relative ease of measuring the effects of most toxic chemicals, resulted for many years in emphasis on lethal control methods. In the last two decades, however, a better understanding of avian physiology and the development of reliable methods of measuring avian behavioral response have resulted in an increased emphasis on developing repellent or aversive chemicals to control bird damage.

Repellents or aversive agents may be categorized as follows: tactile (modification of surfaces), taste (modification of flavors or odors), physiological (illness-induced aversion), and other (primarily chemical-caused behavioral changes). The assignment of chemicals to different behavioral categories is based on experience instead of scientific evidence since conclusive data are generally not available.

TACTILE

Hydrocarbons

This group of chemicals or mixtures of chemicals, which include mineral oil, polybutenes, polyisobutenes, etc., are derived from petroleum or coal and are usually used to discourage birds from alighting or roosting on structures and trees.[30] Formulations containing these chemicals modify the perching surface so that it becomes slippery or sticky, confusing a bird's tactile senses or physically preventing perching. Although none of these chemicals or mixtures are considered to be directly toxic,[79] secondary effects are death by exposure or starvation when excessive feather contamination interferes with thermoregulatory ability or flight. Secondary poisoning hazards and effects on reproduction are undefined.

TASTE

Alum-Based Materials

Aluminum potassium/ammonium sulfate synergized with sucrose octa-acetate and/or other materials has been used in many areas of the world in formulations known as CURB and RETA.[9,25] The combination of these two materials produces a product that is very bitter and highly astringent to the human senses. Alum is used as a food additive and is not toxic to mammalian or avian species in moderate doses. In birds these formulations cause a taste response that results in aversion. Secondary hazards and reproductive effects in birds have not been evaluated.

Anthranilates

DMA (*N,N*-dimethyl anthranilate) and MA (*N*-methyl anthranilate) are naturally occur-grapes or oranges. Birds find both of these offensive in solutions and feed, and they are being investigated for use as livestock food additives and turf treatments.[45] Although both are present in a variety of foods, the toxicology of these anthranilates is not well known. It is unlikely that either material would present secondary hazards or reproductive effects in birds.

Coal Tar

Coal tar is a mixture of many organic compounds, principally aromatic and aliphatic hydrocarbons. It often contains small amounts of many carcinogenic, teratogenic, or mutagenic materials.[79] Although its use for bird control has been limited to seed treatments,[17,33] little is known of the fate of many of its constituents in the soil or residues in plants grown from treated seed. Because of the variety of compounds contained in coal tar, the toxicity of this mixture is also not well documented. The mode of action of coal tar in birds is related to taste and/or odor. Secondary poisoning hazards and reproductive effects are not known in birds.

Cupric Oxalate

Cupric oxalate is used primarily as a seed treatment to prevent bird damage to sprouting crops.[33,46] Oxalates are rapidly absorbed from the gastrointestinal tract and are moderately toxic to birds and mammals.[8,46] In the body, oxalates combine with calcium to form calcium oxalate which, in turn, stimulates the CNS. Death can be caused directly by CNS stimulation, by renal obstruction with oxalate crystals, or by a combination of both effects. Cupric oxalate is a bitter compound that birds detect through taste. The chemical has a low probability of causing secondary hazards, unless massive amounts of oxalate salts remain in the body of the prey species. Reproductive effects in birds are not defined.

Fungicides

There are two widely used fungicides that have also been used as bird repellents: captan, 3a,4,7,7a-tetrahydro-2(trichloromethylthio)-1H-isoindole-1,3(2H)-dione, and thiram, tetramethylthioperoxydicarbonic diamide.[26] These pesticides are used as seed treatments to repel birds (and protect against fungi) and have been used as bird repellent foliar sprays on ripening agricultural crops with occasional success.[47-53] The toxicity and chemistry of these chemicals are discussed elsewhere in this handbook series; however, both act as CNS depressants at high exposure levels and at lower levels are repellents by some undefined taste mechanism. Neither chemical appears to be accumulated in birds; because of their low to moderate acute and chronic toxicity, captan and thiram present little probability of secondary poisoning.[60] Both compounds have been implicated in reproductive disorders, particularly captan, perhaps due to its close structural relationship to thalidomide.[24,81]

Quinones

p-Quinone (2,5-cyclohexadine-1,4-dione) and anthraquinone (9,10-anthracenedione)have been used as bird repellents on seeds and as foliar sprays for ripening agricultural crops.[43] These quinones are related to the earliest fungicides, and some are strong irritants of mucous membranes.[12] Birds find these materials distasteful, and the occasional repellency attributed to these materials is probably not irritation. Massive amounts of these chemicals may result in death due to generalized CNS depression. Effects on reproduction or potential secondary hazards have not been studied.

PHYSIOLOGICAL

Lindane

Lindane, (1 alpha,2 alpha,3,4 alpha,5 alpha,6)-1,2,3,4,5,6-hexachlorocyclohexane, and chemistry and toxicology are discussed elsewhere in this handbook. Lindane is a CNS stimulant in acutely toxic doses[19] and can also cause degenerative changes in the liver and kidneys if exposure occurs over longer periods. Because lindane is accumulated in the fat of birds and mammals,[31] it must be considered as having a moderate secondary poisoning hazard potential. Lindane has also been suspected of causing reproductive dysfunction in some bird species.

Methiocarb

Methiocarb, 3,5-dimethyl-4-(methylthio)phenyl methylcarbamate, Mesurol®, is a carbamate insecticide and bird repellent.[14,33,83] A detailed discussion of the chemistry and toxicology of carbamates is contained elsewhere in this handbook. Carbamates, as organophosphates, inhibit acetylcholinesterase. The effects of carbamates are rapidly reversible.[19] Methiocarb does not appear to accumulate in body tissues and this, in addition to its reversible effect on acetylcholinesterase, greatly reduces the probability of chronic intoxication.[74]

Illness-induced aversion caused by methiocarb is probably responsible for its repellency to birds.[56] Birds can detect this effect and associate it with the taste or some other sensory effect.[11] This mode of action has been described in mammalian species, and in birds it appears to be very strong and is recognized for long periods of time.[71] Reproductive effects of methiocarb have been demonstrated in birds; they appear to be nutritional in nature and due to the reduction in food consumption caused by the chemical, not by direct effects of the chemical.[74]

Trimethacarb

Trimethacarb, 3,4,5-trimethylphenyl methylcarbamate, is another carbamate insecticide that is useful as a bird repellent.[10] Its activity is similar to that of methiocarb although treatment rates with trimethacarb are from two to five times greater than methiocarb. The mode of action is similar to methiocarb. Chronic intoxication and reproductive effects have not been well studied; however, these effects are expected to be similar to methiocarb.

U-12171

This chemical, 2-methyl-1-(1-oxo-2,2-diphenyl)butyl pyrrolidine, was used as a bird repellent on seed crops, and its effects were apparently caused by irritation of mucous membranes.[28] It is not in current use. U-12171 is not highly toxic by acute modes of administration, and although the toxicology and mode of action are not well defined, it probably is a CNS depressant. U-12171 does not appear to accumulate in bird tissues and this, combined with its low mammalian toxicity, indicates a minimal secondary hazard. Reproductive effects have not been reported.

OTHER

4-Aminopyridine

This compound, trade named Avitrol®, is highly toxic to all vertebrates.[68] In mammals it produces symptoms typical of CNS stimulants, with initial effects noted in 10 to 15 min and death occurring up to 4 h later. Occasionally the convulsive stages of intoxication are accompanied by audible vocalizations caused by involuntary contractions of the diaphragm. In many gregarious species the vocalizations of intoxicated birds are pronounced and frighten nonintoxicated birds from the treated area. This effect (area repellency) is used to reduce damage caused by many species of birds with minimum mortality on the target species.[5,42,44,88] 4-Aminopyridine has been shown to be noncumulative, is rapidly metabolized by birds, and thus has not shown any secondary hazards when used at recommended application rates.[63,66,69] Because of its rapid lethal effects, however, some hazards may occur from predatory species consuming unabsorbed chemical in the GI tract of affected or dead birds. Reproductive

Naphthalene

This chemical is used in seed treatments and as a fumigant.[17] Although it is generally considered as nontoxic, massive amounts can cause mortality by stimulating the CNS. Repeated exposure to low levels of airborne naphthalene can result in blood dyscrasias and cataracts.[12] Naphthalene has a pungent odor and may affect some species of birds that have highly developed olfactory senses. Problems with secondary hazards and reproduction have not been described.

SOPORIFICS

Soporifics have been used in research to bait and capture large numbers of birds for banding purposes and also for capturing nuisance birds for removal from areas where they conflict with man. In some countries which prohibit the use of toxic chemicals, soporifics offer the only practical chemical removal method. Soporifics have also been used to induce a form of area repellency in some gregarious bird species since these species often associate a location where they ingested chemicals with an unpleasant physiological effect. The effectiveness of soporifics is extremely dose dependent and requires frequent adjustment of treatment levels or dilution ratios to maintain peak efficacy depending on species, location, and environmental conditions. In addition, the induction of soporific action normally takes from 15 to 30 min, which often allows sufficient time for affected birds to move considerable distances from the treatment site where they may die from the effects of the chemical, exposure, or predation.

α-CHLORALOSE

α-Chloralose is a condensation product of glucose and chloral hydrate. It is a CNS depressant that has hypnotic effects at less than lethal levels and has been used to immobilize birds so that they can be collected and removed.[48,65] Although α-chloralose does not accumulate in bird tissues, it has been implicated in liver and kidney disorders following repeated administration. Because the chemical is slowly metabolized, some secondary hazards or reproductive effects may occur.[37]

TRIBROMOETHANOL

This chemical is a sedative/hypnotic used for the same purpose as α-chloralose.[65] Tribromoethanol (2,2,2-tribromoethanol) causes cyanosis, respiratory and circulatory disorders, and is toxic to the kidneys and liver upon acute or chronic administration.[19] It is more rapidly metabolized than α-chloralose; however, some secondary hazards to predatory or scavenger species are still possible. Reproductive effects are not defined.

METHIOCARB

This carbamate insecticide, previously discussed, is also an effective soporific for many species of birds and has been used occasionally for capturing birds for banding purposes. The main advantage of methiocarb is that for many bird species it requires far less chemical to induce the soporific action.[65] As a soporific, the safety margin between the effective and lethal doses (ED_{50}/LD_{50}) is often fairly narrow, thus requiring the use of complicated baiting techniques.

REPRODUCTIVE INHIBITORS

Reproductive inhibition has been proposed for over three decades as a potential method for reducing bird populations and then maintaining them at low levels to reduce bird/man conflicts. Many individuals and organizations have been involved in this effort, both in the U.S. and abroad. However, the complexity of finding and using reproductive inhibitors effectively, plus the difficulty in mitigating potential environmental and human effects, has thus far precluded their development except for application to unique urban problems.

AZACOSTEROL

Azacosterol, 17[(3-dimethylamino)propyl] methylamino androst-5en-3-ol hydrochloride, Ornitrol®, interferes with cholesterol synthesis, thus reducing or preventing the formulation of viable eggs in females.[75] Azacosterol is relatively nontoxic to mammals, but it has many side effects often associated with hormonal compounds. The use of azacosterol as a chemosterilant requires the ingestion of daily doses for 10 to 15 d in order to reach peak efficacy.[24,75] Although it is not known whether sufficient amounts accumulate in body tissue to cause secondary poisoning, it probably is of minor importance since the use of the product generally does not result in the death of treated birds. Azacosterol use can occasionally result in myotonia (a degenerative muscle disorder) in treated birds, which can be lethal.

TEM

TEM, 2,4,6-tris(1-azirdinyl)-1,3,5-triazine, is an insecticide and cancer therapeutic agent that belongs to a group of chemicals known as alkylating agents. It has been used to control avian reproduction,[18,72] but is highly toxic and is extremely destructive to rapidly growing cells, such as those encountered in cancerous and reproductive tissues. Because of its highly toxic characteristics at the cellular level, TEM also causes chromosomal abnormalities and has been implicated in causing teratogenic or mutagenic effects.[12] The secondary hazards of this compound have not been investigated.

OTHER

A number of other chemicals have been evaluated for their ability to produce responses in birds that might be useful in reducing bird/man conflicts. Of all the chemicals, only one has been widely used in bird control.

PA-14

This surfactant has been applied to winter starling/blackbird roosts in the U.S. when temperature and moisture conditions are suitable.[34] Although relatively nontoxic, it is used as a toxic spray in aqueous solutions that interferes with the insulating qualities of bird's feathers; death by exposure results.[41] PA-14 is only slightly toxic to mammals although it can cause eye and skin irritations.[63] It has the advantage of being biodegradable and presents little hazard to predatory or scavenger species.[63]

TABLE 1
The Acute Oral Toxicity of Various Bird Control Chemicals to Birds and Mammals

Common name or trade name	Mammals[a]			Birds[a]									
	Mice and rats	Dogs and cats	Primates	Ducks and geese	Hawks and eagles	Quail and chickens	Doves and pigeons	Crows and jays	Starlings	Blackbirds	Sparrows and finches	CAS Registry number
Fenthion	3[b]	—	3	1	1	2	1	1	1	1	1	[55-38-9]
Mevinphos	1	—	1	1	—	1	1	—	1	1	1	[7786-34-7]
Parathion (methyl)	1, 2	1	1	1	—	1	1	—	1	1	1	[56-38-2]
Endrin	1, 2	1	1	1	1	1	1	—	1	1	1	[72-20-8]
Thallium SO_4	2	2	1	2	—	2	2	2	2	—	—	[7446-18-6]
Strychnine	1	1	2	1	1	2	1	—	1	1	1	[57-24-9]
Compound 1080	1	1	1	1	1	1	1	1	—	1	1	[62-74-8]
DRC-1339	3	3	—	2	3	2	2	1	1	1	3	[7745-89-3]
Mineral oil, etc.	4	—	4	—	—	—	—	—	4	—	—	[8012-95-1]
Captan	4	—	4	>2	—	>2	—	>2	>2	>2	>2	[133-06-2]
Thiram	3	3	—	3	—	3	—	—	—	3	>2	[137-26-8]
Coal tar	3	3	—	—	—	—	—	—	—	—	—	[8007-45-2]
Cupric oxalate	—	—	—	—	—	—	4	—	—	>2	>2	[814-91-5]
Alum	—	—	—	—	—	—	4	—	—	4	—	[10043-01-3]
p-Quinone	3	—	2	—	—	—	—	—	—	—	3	[106-51-4]
Anthraquinone	4	—	—	—	—	—	—	—	—	>2	>2	[84-65-1]
Lindane	2	2	3	4	—	2	3	3	2	2	2	[58-89-9]
Methiocarb	2	3	—	2	—	2	2	1	2	1	1	[2032-65-7]
Trimethacarb	3	—	—	2	—	2	3	—	>2	2	—	[2686-99-9]
U-12171	4	—	—	—	—	3	—	>2	3	2	>2	[61164-09-8]
4-Aminopyridine	2	1	1	1	1	1	1	1	1	1	1	[504-24-5]
Naphthalene	4	3	3	—	—	—	—	—	—	—	—	[91-20-3]
α-Chloralose	2	3	3	2	—	2	3	2	2	2	2	[15879-73-3]
Tribromoethanol	3	3	—	3	—	3	3	3	3	3	3	[75-80-9]
Azacosterol	3	—	—	—	—	3	3	—	—	3	—	[1249-84-9]
TEM	1	1	—	—	—	3	—	—	1	1	—	[51-18-3]
PA-14	4	4	—	—	4	—	—	—	4	3	—	[68131-40-8]

[a] Toxicity categories assigned as follows: 1 = 0—10 mg/kg, 2 = 11—100 mg/kg, 3 = 101—1000 mg/kg, 4 = >1001 mg/kg.
[b] In addition to sources listed in the text of this chapter, data were obtained from References 54, 67, 78, 84, and 85.

REFERENCES

1. **Anthony, R. M., Lindsey, G. D., and Evans, J.,** Hazards to golden-mantled ground squirrels and associated secondary hazard potential from strychnine for forest pocket gophers. *Proc. Vertebr. Pest Conf.*, 11:25, 1984.
2. **Apostolou, A.,** Comparative Toxicology of the Avicides 3-chloro-*p*-toluidine and 2-chloro-4-acetotoluidine in Birds and Mammals. Ph.D. thesis. University of California, Davis, 1969.
3. **Areson, C. W.,** Pest bird control with avicide BCF-7000—Sun Oil Refinery Project, Tulsa, Oklahoma, *Proc. Vertebr. Pest Conf.*, 12:307, 1986.
4. **Aulerica, R. J., Ringer, R. K., and Safronoff, J.,** Primary and secondary toxicity of warfarin, sodium monofluoroacetate and methyl parathion in mink, *Arch. Environ. Contam. Toxicol.*, 16:357, 1987.
5. **Besser, J. F.,** 4-Aminopyridine for protecting crops from birds—a current review, *Proc. Vertebr. Pest Conf.*, 7:11, 1976.
6. **Boyd, F. L. and Hall, D. L.,** Use of DRC-1339 to control crows in three roosts in Kentucky and Arkansas, *Proc. Eastern Wildl. Damage Control Conf.*, 3:3, 1987.
7. **Braverman, Y.,** Experiments on direct and secondary poisoning by fluoroacetamide in wildlife and domestic carnivores, *J. Wildl. Dis.*, 15:319, 1979.
8. **Brooks, V. J.,** *Poisons*. Robert Kreiger Publishing, Huntington, NY, 304, 1975.
9. **Bruggers, R. L.,** Evaluating CURB as a crop repellent to West African bird pests, in Vertebrate Pest Control and Management Materials, ASTM STP-680, Beck, J. R., Ed., 188, 1979.
10. **Bruggers, R. L., Sultana, P., Brooks, J. F., Fiedler, L. A., Rimpel, M., Manikowski, S., Sauthaiah, N., and Okuno, I.,** Preliminary investigations of the effectiveness of trimethacarb as a bird repellent in developing countries, *Proc. Vertebr. Pest Conf.*, 11:192, 1984.
11. **Bullard, R. W., Bruggers, R. L., Kilburn, S. R., and Fielder, L. A.,** Sensory-cue enhancement of the bird repellency of Methiocarb, *Crop Prot.*, 2:387, 1983.
12. **Casarett, L. J. and Doull, J., Eds.,** *Toxicology—The Basic Science of Poisons*. Macmillan, New York, 1975.
13. **Clausen, B. and Karlog, O.,** Thallium loading in owls and other birds of prey in Denmark, *Nord. Veterinaermed.*, 29:227, 1977.
14. **Crase, F. T. and DeHaven, R. W.,** Methiocarb: its current status as a bird repellent, *Proc. Vertebr. Pest Conf.*, 7:46, 1976.
15. **Crosier, W. F., Nash, A., and Crosier, D. C.,** Dry nonphytotoxic bird and insect repellent, *Proc. Assoc. Off. Seed Anal.*, 60:206, 1970.
16. **Cunningham, D. J., Schafer, E. W., Jr., and McConnel, L. K.,** DRC-1339 and DRC-2698 residues in starlings: preliminary evaluation of their effects on secondary hazard potential, *Proc. Bird Control Seminar*, 8:31, 1979.
17. **Dambach, C. A. and Leedy, P. L.,** Ohio studies with repellent materials with notes on damage to corn by pheasants and other wildlife, *J. Wildl. Manage.*, 12:392, 1948.
18. **Dasgupta, P. and Bhattacharyya, S. F.,** Triethylenemelamine induced suppression of the activity of male reproductive organs of the red-vented bulbul, *Indian J. Exp. Biol.*, 25:664, 1987.
19. **Deichmann, W. B. and Gerarde, H. W.,** *Toxicology of Drugs and Chemicals*, Academic Press, New York, 1969.
20. **DeCino, T. J., Cunningham, D. J., and Schafer, E. W., Jr.,** Toxicity of DRC-1339 to starlings, *J. Wildl. Manage.*, 30:249, 1966.
21. **DeWitt, J. B.,** Chronic toxicity to quail and pheasants of some chlorinated insecticides, *J. Agric. Food Chem.*, 4:863, 1956.
22. **DiModugno, G., Albano Annicchino, G., Perrone, C., and Renna, P.,** Acute poisoning by phosphate-esters in laying hens, *Acta Med. Vet.*, 19:137, 1973.
23. **Douville de Franssu, P., Gramet, P., Grolleau, G., and Sach, A.,** Aerial treatments against starling roosts with chloro-para-toludin (CPT): results of eight years of experiments, *Proc. Vertebr. Pest Conf.*, 12:273, 1986.
24. **Elder, W. H.,** Chemical inhibitors of ovulation in the pigeon, *J. Wildl. Manage.*, 28:556, 1964.
25. **Ewing, K., Crabb, A. C., Martin, L. R., and Moituso, R.,** Preliminary laboratory and field trials of CURB, a possible avian repellent, *Proc. Bird Control Seminar*, 7:239, 1976.
26. **Fitzwater, W. D.,** Control of animal pests. II, *Am. Nurseryman*, 104:14, 1956.
27. **Fleming, W. J., DeChacin, H., Pattee, O. H., and Lamont, T. G.,** Parathion accumulation in cricket frogs and its effect on American kestrels, *J. Toxicol. Environ. Health*, 10:921, 1982.
28. **Frank, F. R., Schafer, E. W., Jr., and Guarino, J. L.,** Laboratory and field studies with an avian repellent for sprouting seeds, *Proc. Bird Control Seminar*, 5:86, 1970.
29. **Glahn, J. F.,** Use of starlicide to reduce starling damage at livestock feeding operations, *Proc. Great Plains Wildlife Damage Control Workshop*, 5:273, 1981.

30. Hayden, K., Entanglements and sticky repellents, *Proc. Bird Control Seminar*, 4:140, 1968.
31. Hayes, W. J., *Clinical Handbook on Economic Poisons*, Publication 476 (rev.), Public Health Service, U.S. Department of Health, Education and Welfare, Washington, D.C., 1963.
32. Hegdal, P. L. and Gatz, T. A., Hazards to wildlife associated with underground strychnine baiting for pocket gophers, *Proc. Vertebr. Pest Conf.*, 7:258, 1976.
33. Heisterberg, J. F., Bird repellent seed corn treatment: efficacy evaluations and current registration status, *Proc. Eastern Wildl. Damage Cont. Conf.*, 1:255, 1983.
34. Heisterberg, J. F. and Stickley, A. R., Jr., Controlling blackbirds and starlings at winter roosts, *Proc. Eastern Wildl. Damage Control Conf.*, 3:177, 1987.
35. Hobbs, J. and Leon, F. G., Great-tailed grackle predation on south Texas citrus, *Proc. Eastern Wildl. Damage Control Conf.*, 3:143, 1987.
36. Hudson, R. H., Haegele, M. A., and Tucker, R. K., Acute oral and perentaneus toxicity of pesticides to mallards: correlations with mammalian toxicity data, *Toxicol. Appl. Pharmacol.*, 47:451, 1979.
37. Knapp, M. and Russel, H. A., Danger to birds of prey from the use of chloralose as a control agent for sea gulls. Detection of chloralose poisoning in buzzards, *Dtsch. Tieraerztl. Wochenschr.*, 80:573, 1973.
38. Knittle, C. E., Guarino, J. L., Nelson, P. C., DeHaven, R. W., and Twedt, D. J., Baiting blackbird and starling congregating areas in Kentucky and Tennessee, *Proc. Vertebr. Pest Conf.*, 9:31, 1980.
39. Kun, E., Monofluoroacetic acid (compound 1080), its pharmacology and toxicology, *Proc. Vertebr. Pest Conf.*, 10:34, 1982.
40. Lefebvre, P. W., Holler, N. R., Matteson, R. E., Schafer, E. W., and Cunningham, D. J., Developmental states of *N*-(3-chloro-4-methylphenyl)acetamide as a candidate blackbird/starling roost toxicant, *Proc. Bird Control Seminar*, 8:65, 1981.
41. Lefebvre, P. W. and Seubert, J. L., Surfactants as blackbird stressing agents, *Proc. Vertebr. Pest Conf.*, 4:156, 1970.
42. Martin, C. M. and Martin, L. R., Pigeon control: an integrated approach, *Proc. Vertebr. Pest Conf.*, 10:190, 1982.
43. Martin, H., Ed., *Pesticide Manual*, 3rd ed., British Crop Protection Council, London, 535, 1972.
44. Martin, L. R. and Jarvis, W. T., Avitrol-treated bait for protection of grapes from house finch damage, *Proc. Vertebr. Pest Conf.*, 9:17, 1980.
45. Mason, J. R., Arzt, A. H., and Reidinger, R. F., Jr., Evaluation of dimethyl anthranilate as a nontoxic starling repellent for feedlot settings, *Proc. Eastern Wildl. Damage Control Conf.*, 1:259, 1983.
46. McWilliams, E., Seed-Treating Compositions for Repelling Birds and Rodents, U.S. Patent 2,900,303, 1959.
47. Metzer, R. and Royall, W. C., Jr., Field tests of three chemicals as bird repellents on mature grain sorghum, *Tex. Agric. Exp. Stn. Bull.*, MP-524, 1961.
48. Mitchell, R. T., A Review of the Use of alpha-Chloralose for Capturing and Controlling Birds, U.S. Department of the Interior, Fish Wildl. Serv. Spec. Rep., 1976.
49. Muller, H. D. and Lochman, D. C., Fecundity and progeny growth following subacute insecticide ingestion by the mallard, *Poult. Sci.*, 51:239, 1972.
50. Narang, D. D. and Bindra, O. S., Studies on the poison-baiting of the house sparrow, *Plant Prot. Bull. (India)*, 23:29, 1973.
51. Neill, D. D., Muller, H. D., and Schutze, J. V., Pesticide effects on the fecundity of the grey partridge, *Bull. Environ. Contam. Toxicol.*, 6:546, 1971.
52. Ochs, P., Strychnine, *Proc. Bird Control Seminar*, 7:108, 1976.
53. Parodi, P. C. and Racznski, M., Two chemical bird repellents on ripe wheat, *Agric. Tec.*, 31:104, 1971.
54. Pimentel, D., Ecological Effects of Pesticides on Nontarget Species, U.S. Executive Office of President, Office of Science and Technology, Washington, D.C., 1971.
55. Pope, G. G. and Ward, P., Effects of small applications of an organophosphorous poison, fenthion, on the waver-bird, *Quelea quelea*, *Pestic. Sci.*, 3, 1972.
56. Powell, G. V. N., DeWeese, L. R., and Lamont, T. G., A field evaluation of frogs as a potential source of secondary organophosphorus insecticide poisoning, *Can. J. Zool.*, 60:2233, 1982.
57. Redig, P. T., Stowe, C. M., Arendt, T. D., and Duncan, D. H., Relay toxicity of strychnine in raptors in relation to a pigeon eradication program, *Vet. Hum. Toxicol.*, 24:335, 1982.
58. Rogers, J. G., Jr., Responses of caged red-winged blackbirds to two types of repellents, *J. Wildl. Manage.*, 38:418, 1974.
59. Roylance, K. J., Jergensen, C. D., Booth, G. M., and Carter, M. W., Effects of dietary endrin on reproduction of mallard ducks, *Arch. Environ. Contam. Toxicol.*, 14:705, 1985.
60. Rudd, R. L. and Genelly, R. E., Pesticides: their use and toxicity in relation to wildlife, *Calif. Dep. Fish Game Fish Bull.*, No. 7, 1956.
61. Saint-Andre, G. D. and Douville de Franssu, P., Effect of the insecticide treatments of cereals on young partridges, *Def. Ves.*, 36:64, 1982.
62. Savarie, P. J., Toxic characteristics of fluorocitrate, the toxic metabolite of compound 1080, *Proc. Vertebr.*

63. Schafer, E. W., Jr., Potential primary and secondary hazards of avicides. *Proc. Vertebr. Pest Conf.*, 11:217, 1984.
64. Schafer, E. W., Jr. and Brunton, R. B., Chemicals as bird repellents: two promising agents, *J. Wildl. Manage.*, 35:569, 1971.
65. Schafer, E. W., Jr. and Cunningham, D. J., An Evaluation of 148 Compounds as Avian Immobilizing Agents, Fish and Wildlife Service, U.S. Department of the Interior, Washington, D.C., Spec. Sci. Rep. Wildl. No. 150, 1972.
66. Schafer, E. W., Jr. and Marking, L. L., Long-term effects of 4-amino-pyridine exposure to birds and fish, *J. Wildl. Manage.*, 39:807, 1975.
67. Schafer, E. W., Jr., Bowles, W. A., Jr., and Hurlbut, J., The acute oral toxicity, repellency and hazard potential of 998 chemicals to one or more species of wild and domestic birds, *Arch. Environ. Contam. Toxicol.*, 12:355, 1983.
68. Schafer, E. W., Jr., Brunton, R. B., and Cunningham, D. J., A summary of the acute toxicity of 4-aminopyridine to birds and mammals, *Toxicol. Appl. Pharmacol.*, 26:532, 1973.
69. Schafer, E. W., Jr., Brunton, R. B., and Lockyer, N. F., Hazards to animals feeding on blackbirds killed with 4-aminopyridine baits, *J. Wildl. Manage.*, 38:424, 1974.
70. Schafer, E. W., Brunton, R. B., and Lockyer, N. F., The effects of subacute and chronic exposure to 4-aminopyridine on reproduction in Coturnix quail, *Bull. Environ. Contam. Toxicol.*, 13:758, 1975.
71. Schafer, E. W., Jr., Brunton, R. B., and Lockyer, N. F., Learned aversion in wild birds: a method for testing comparative acute repellency, in Test Methods for Vertebrate Pest Control and Management Materials, ASTM STP-625, Jackson, W. B. and Marsh, R. E., Eds., American Society for Testing and Materials, Philadelphia, 186, 1977.
72. Schafer, E. W., Jr., Guarino, J. L., and Brunton, R. B., Use of male Coturnix quail in the laboratory development of avian chemosterilants, in Test Methods for Vertebrate Pest Control and Management Materials, ASTM STP-625, Jackson, W. B. and Marsh, R. E., Eds., American Society for Testing and Materials, Philadelphia, 225, 1977.
73. Schafer, E. W., Jr., Brunton, R. B., Cunningham, D. J., and Lockyer, N. F., The chronic toxicity of 3-chloro-4-methyl benzamine HCl to birds, *Arch. Environ. Contam. Toxicol.*, 6:241, 1977.
74. Schafer, E. W., Jr., Brunton, R. B., Lockyer, N. F., and Cunningham, D. J., The chronic toxicity of methiocarb to grackles, doves, quail and reproductive effects in quail, *Bull. Environ. Contam. Toxicol.*, 4:641, 1975.
75. Shortmeyer, J. L. and Beckwith, S. L., Chemical control of pigeon reproduction, *Trans. North Am. Wildl. Conf.*, 35:44, 1970.
76. Sindhu, A. S. and Simwat, G. S., Control of house-crow through poison baiting, *J. Res. Punjab Agric. Univ.*, 10:216, 1973.
77. Spann, J. W., Heinz, G. H., and Hulse, C. S., Reproduction and health of mallards fed endrin, *Environ. Toxicol. Chem.*, 5:755, 1986.
78. Spector, W. S., Ed., *Handbook of Toxicology*, Vols. 1, 3, 4, W. B. Saunders, Philadelphia, 1956.
79. Stecher, P. G., Ed., *The Merck Index*, 8th ed., Merck, Rahway, NJ, 1968.
80. Stickel, W. H., Reichol, W. L., and Hugles, D. L., Endrin in birds: lethal residues and secondary poisoning, *Dev. Toxicol. Environ. Sci.*, 4:397, 1979.
81. Swanson, M. H., Waibel, P. E., Helbacha, N. V., and Johnson, E. L., Shell egg quality as affected by arasan in the diet, *Poult. Sci.*, 35:92, 1956.
82. Sweet, D. V., Ed., Registry of Toxic Effects of Chemical Substances, U.S. Department of Health, Education and Welfare, Washington, D.C., 1987.
83. Tobin, M. E. and Dolbeer, R. A., Status of mesurol as a bird repellent for cherries and other fruit crops, *Proc. Eastern Wildl. Damage Control Conf.*, 3:149, 1987.
84. Tucker, R. K. and Crabtree, D. G., *Handbook of Toxicology of Pesticides to Wildlife*, Publ. No. 84, Bureau of Sport Fishing and Wildlife Resources, U.S. Department of the Interior, Washington, D.C., 1970.
85. von Rumker, R. F., Pesticide Manual, II. Basic Information on Thirty-Five Pesticide Chemicals, Agency for International Development, U.S. Department of State, Washington, D.C., 1972.
86. Westberg, G. L., 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, M.S. thesis, University of California, Davis, 1974.
87. White, D. H., King, K. A., Mitchell, C. A., Hill, E. F., and Lament, T. G., Parathion causes secondary poisoning in a laughing gull breeding colony, *Bull. Environ. Contam. Toxicol.*, 23:281, 1979.
88. Will, T. J., Air Force problems with birds in hangars, *Proc. Eastern Wildl. Damage Control Conf.*, 2:104, 1985.
89. Zinkl, J. G., Jessup, D. A., Bischoff, A. I., Lew, F. E., and Wheeldom, E. B., Fenthion poisoning of wading birds, *J. Wildl. Dis.*, 17:117, 1981.