Rev Environ Contam Toxicol 170:13–74 © Springer-Verlag 2001

Pesticide Acute Toxicity Reference Values for Birds

Pierre Mineau, Alain Baril, Brian T. Collins, Jason Duffe,
Gerhard Joerman, and Robert Luttik

Contents

I. Introduction 13
II. Data Selection 15
A. Data Acquisition and Appraisal 15
B. Selection and Processing of Toxicity Data 16
C. Scaling of Toxicity Data to Body Weight 18
D. Modification of the Distribution Approach to Incorporate Body-Weight Scaling 19
E. Choice of an Appropriate Percentile in the Acute Toxicity Distribution 20
F. Choice of the Appropriate Bird Weights to Model 21
G. Derivation of Extrapolation Factors 22
H. Procedure for Pesticides Having Low Acute Toxicity 25
III. Results and Discussion 71
Acknowledgments 71
References 72

I. Introduction

Avian risk assessment of pesticides depends for the most part on two laboratory-derived measures of lethality. First, the median lethal dose (LD_{50}), a statistically derived single oral dose of a compound that will cause 50% mortality of the test population, and second, the median lethal concentration (LC_{50}), which similarly derives the concentration of a substance in the diet that is expected to lead to 50% mortality of the test population. Mineau et al. (1994) have argued against the continued use of the LC_{50} endpoint in avian risk assessment of pesticides. The test as currently designed was found to provide unreliable results, in part because of the difficulty of properly determining exposure during the test. The LC_{50} test, conducted on very young birds, is greatly influenced also by the exact age and condition of the test population. Also, the correlation of LC_{50} values among test species is weak, thus casting further doubt on the value of the endpoints and limiting our ability to extrapolate from test species to wild bird spe-

Communicated by George W. Ware.

P. Mineau (✉), A. Baril, B.T. Collins, J. Duffe
National Wildlife Research Centre, Canadian Wildlife Service, Environment Canada, Hull, Québec, Canada, K1A OH3.

G. Joerman
Biologische Bundesanstalt für Land-und Forstwirtschaft, Braunschweig, Germany.

R. Luttik
RIVM, 3720 BA Bilthoven, The Netherlands.

cies. Finally, comparison of test results with field evidence suggests that lab-derived LC_{50}s are poor predictors of risk. Until the LC_{50} test is redesigned to address these weaknesses, avian risk assessment will depend almost entirely on the results of the LD_{50} test.

Avian risk is difficult to estimate in an absolute sense from laboratory-derived data. Field studies are generally needed to provide "ground truthing" of a risk model and, to date, a number of such field studies have been carried out and can be used to "calibrate" laboratory-derived predictions of risk based on acute endpoints. Laboratory data are most useful in providing a comparative assessment of the risk posed by different pesticides. Such comparative assessments have also proved useful in the various measurement systems designed to assess the environmental consequences of choosing different agrochemicals or agricultural management systems (Benbrook et al. 1996).

When carrying out comparative risk assessments for pesticides, it is essential to use the most unbiased data possible. Pesticides are customarily tested against no more than 1 to 3 bird species, yet there are an estimated 10,000 species in the world. More than 800 species occur in Canada and the United States alone. In this review, we present acute toxicity values that can be used as reference values in pesticide risk assessments. These values are only useful for protecting birds from pesticides if matched by adequate measures of exposure. Also, they only address acute lethal toxicity and not reproductive or chronic health effects or even sublethal effects that may give rise to delayed mortality or a reduction in biological fitness. Different strategies have been used over the years to compare the toxicity of different pesticides to birds. (1) Restricting among-chemical comparisons to a commonly tested group of species: This strategy quickly runs into data gaps and leads to an arbitrary ranking of relative toxicity depending on the species chosen. Test species can be inconsistent in their relative sensitivity rankings among pesticides (Tucker and Haegele 1971). (2) Several species as phylogenetically close as possible to a species of interest are used: Unfortunately, toxicological susceptibility does not always follow phylogenetic lines (Schafer and Brunton 1979; Mineau 1991; Joermann 1991; Baril et al. 1994), and it is notoriously difficult to predict which species are most at risk from a given pesticide treatment. (3) Finally, using the lowest value available from all species tested: This approach, however, introduces a systematic bias related to the amount of test data available and reported for each pesticide.

Baril et al. (1994) and then Luttik and Aldenberg (1995, 1997) suggested that a distribution-based method should be employed for birds much as had been proposed for soil and aquatic organisms (Stephan and Rogers 1985; Kooijman 1987; Van Straalen and Denneman 1989). A distribution-based approach uses the pesticide-specific data available to define the shape of the distribution through the estimation of a mean and variance for the distribution. Fitting toxicity data to distributions has been criticized, most recently by Newman et al. (2000). However, their main criticism concerns the pooling of toxicity data for very different phylogenetic groups and the resulting lack of fit to commonly used distributions. This result would be expected, for instance, when pooling

the response of both algae and aquatic invertebrates to a herbicide. We have found that both the log-logistic and log-normal distributions are adequate when dealing with the toxicity of pesticides to birds. The alternative proposed by Newman and colleagues is to use bootstrapping (distribution-free resampling of the data) to arrive at an effect threshold. The main disadvantage of this technique is that any biases inherent in the initial data, a likely problem if few data are available, will be preserved and emphasized. We therefore opted for a distribution-based method. However, two modifications of this technique were necessary: (1) introducing a scaling factor for body weight to improve cross-species comparisons of toxicological susceptibility (Mineau et al. 1996); and (2) developing a strategy to consider chemicals for which there are insufficient data from which to derive a distribution. Slightly different approaches were described by Baril et al. (1994) and by Luttik and Aldenberg (1995) to meet this second objective. We present here the relative merits of both these approaches, and provide what we believe to be the most scientifically defensible reference values that can be used for assessing the *relative* acute risk of different pesticides to birds.

II. Data Selection

A. Data Acquisition and Appraisal

Data acquisition procedures were modified slightly from those described in Baril et al. (1994) and Mineau et al. (1996). Under the auspices of the OECD (Organisation for Economic Co-operation and Development) and following the recommendations of a 1994 workshop on avian toxicity testing (SETAC 1996), the Canadian Wildlife Service's existing database of LD_{50} values was expanded with the assistance of several collaborators worldwide. A recent (Brian J. Montague 30 April 98 pers. comm.) version of the U.S. EPA 'one liner' database was obtained and amalgamated with our existing database. Between 1996 and 1997, various data were also obtained from Germany (Federal Biological Research Centre for Agriculture and Forestry), the Netherlands (National Institute of Public Health and the Environment), France (Institut National de la Recherche Agronomique), and the United Kingdom (Pesticide Disclosure Documents from the Pesticide Safety Directorate). Many of those data consisted of studies sponsored by pesticide manufacturers in support of the registration of their pest control products. The confidentiality afforded to these data varies greatly between countries. At one extreme (Canada), all data endpoints (e.g., LD_{50} values) are considered to be proprietary and confidential unless specifically marked for public release by the manufacturer; at the other extreme (U.S.), endpoints are freely available and complete LD_{50} studies can be requested through "Freedom of Information Act" provisions. Some jurisdictions make endpoints available for a fee, either in hard copy form (United Kingdom) or through a dial-up database (France). Furthermore, several companies release data endpoints in summary form (e.g., Material Safety Data Sheets) and these data are picked up by public sources such as the British Crop Protection Council's *Pesticide Manual* (see

following). Because of this confusion, we decided that no species-specific data would be released nor could any be back-calculated from the information presented here.

Known sources of data from the open literature were also searched. These sources included existing compendia of avian acute toxicity data assembled by governmental agencies in the U.S. and elsewhere (Schafer et al. 1983; Hudson et al. 1984; Grolleau and Caritez 1986; Smith 1987), as well as scientific publications containing one or a few values. An exhaustive search of the literature was carried out by means of the Terretox database of the U.S. government as well as the commercially available Medline and Biological Abstracts databases. A final source of data consisted of various editions of the *Pesticide Manual* (the 4th, 9th, and 11th editions; the latter one containing most of the avian data). Before accepting the data from these editions of the *Pesticide Manual*, a sample was checked against our existing database. Although the data presented in the *Pesticide Manual* (Tomlin 1997) were often biased toward species of lesser sensitivity, the data themselves were almost invariably accurate (a calculated accuracy rate of 99% for 108 data points for which the original data source was already available to us). The 11th edition of the *Pesticide Manual* was also used to indicate which pesticides are currently being commercialized worldwide. All data were carefully vetted for errors and duplicates and, where possible, checked to the original source.

B. Selection and Processing of Toxicity Data

The distribution approach to handling interspecies differences in sensitivity to chemicals requires that a single value be available for each pesticide-species combination. In many cases, however, more than one value was available for any combination. It was therefore necessary to establish criteria that provided a uniform process for the selection of values. The criteria were chosen so as to minimize bias and variability introduced by the formulation of the pesticide, the age of the birds, and numerous other factors. Our data selection criteria were modified to agree with those used by Luttik and Aldenberg (1995, 1997) following several rounds of consultation. This method explains some of the small discrepancies between the values reported here and the few that were presented in Mineau et al. (1996). The criteria were as follows.

1. Only Data for Adult-Sized Birds Were Used (typically >1 month for passerine and gallinaceous birds; >3 months for waterfowl). In some cases, age was unspecified but the data, often generated for pesticide submissions, were assumed to refer to adults as specified in current and former EPA protocols. Tests on passerine species were generally carried out on wild-caught individuals which, we assumed, had fledged at that point. The notable exception was the domestic chicken, for which it is customary to test young chicks or pullets. Values for domestic fowl were therefore excluded unless age was specified.

2. Studies of formulated products or of technical products with very low percentages of active ingredient were not used. We did not correct for the percentage of active ingredient found in the technical grade of the pesticide.
3. If more than one LD_{50} value was available for a species and a given pesticide, a geometric mean value was calculated. No one study was given preference over another.
4. If there were multiple LD_{50} values for a certain species and a given pesticide, and one of those values was a "greater than" (>) or "lower than" (<) value, this value was not used if it lay inside the range of the other available values. However, this value was used as a point estimate (the < or > having been removed) when it lay outside the range of other available values for that species and pesticide.
5. If, in a set of available LD_{50}s for a given pesticide, a particular species only had a greater or lower than value, this value was not used if it lay within the range of values available for the other species, but it was used as a point estimate (the < or > having been removed) if it were outside the range of values available for the other species.
6. Where the majority of available species LD_{50}s were greater than a certain value, such as is often the case with nontoxic pesticides where limit values are given (e.g., all species >2000 mg/kg), the data were not fitted to a distribution regardless of how many such values were available. Instead, an extrapolation factor approach was employed, as described next.
7. When separate values were given for each sex, the geometric mean of the two values was calculated.
8. When the value given by a single source was a range, the geometric mean of the range was calculated. This criterion applied mainly to the studies reported by Schafer and coauthors (1983) in which the ranges given correspond to values obtained from separate studies (Ed Shafer, personal communication).
9. When compendia of values were published by any given laboratory and where there were discrepancies between different editions or publications, the most recently published value was accepted. This choice assumes that previous errors were corrected by the laboratory in question.

Unfortunately, we were not able to take into account the method of dosing (e.g., by gavage needle or gelatin capsule) nor were we able to account for the use of vehicles or diluents (e.g., corn oil), this information seldom being available. We recognize this is an important source of variation as is the differential propensity of different bird species to regurgitate (Hart and Thompson 1995). Also, we were unable to ensure that the technical pesticide material was identical from test to test. The data span several decades, and it is likely that the level of purity and proportion of degradation products and contaminants changed over the years and across different manufacturers. Some pesticides are known to be racemic mixtures and may have been marketed first as the mixture and later as the active isomer. Often, this is reflected by the fact that there are several CAS numbers available for any one pesticide (Tomlin 1997). We cannot be certain

that all toxicity tests reported here are specific to the CAS number given for the pesticide in question, nor can we venture a guess as to the contribution of this factor to the overall within-chemical variance in toxic response.

As with any such compendium, cholinesterase-inhibiting pesticides are well represented (at least in having higher numbers of species tested per pesticide) because of their relatively high toxicity to birds and the fact that they account for the majority of wildlife poisoning incidents. Because of our desire to develop methods that are representative of all classes of pesticides, we carried out some analyses (at least initially) on cholinesterase inhibitors separately from other pest control products. The data for cholinesterase inhibitors are therefore presented separately in this review (see tables 2 and 3). The database thus compiled for cholinesterase inhibitors consists of 147 pesticides and 837 acceptable LD_{50} determinations. For noncholinesterase inhibitors, we were able to compile 1601 acceptable LD_{50} values for 733 pesticides.

C. Scaling of Toxicity Data to Body Weight

It is customary to extrapolate between species on the basis of acute toxicity measurements expressed in mg/kg body weight, yet Mineau et al. (1996) showed that for a group of 36 pesticides chosen for the high number of LD_{50} data points available, the appropriate scaling factor in birds (with toxicity in mg/animal regressed against body weight) is usually > 1 and can be as high as 1.55. These authors showed that, when fitting a distribution to LD_{50} data expressed as mg/kg body weight (i.e., forcing the data to a slope of 1), the resulting distribution overestimated LD_{50} values for small-bodied birds and resulted in wider confidence intervals for the usual distribution-based toxicity benchmarks, e.g., the 5% and 95% bounds of the distribution. For the present analysis, and for all pesticides with $n \geq 4$, ln LD_{50} values (in mg/kg rather than mg/animal) were regressed against ln weight in grams. Mean species weights were obtained from Dunning (1993). As described by Mineau et al. (1996), the slope or "scaling factor" for the majority of pesticides is positive [corresponding to a slope greater than 1 in Mineau et al. (1996) when toxicity values were expressed as mg/animal]. For the 130 pesticides with $n \geq 4$, the regressions were positive in 99 cases and the overall mean slope was 0.239; this was slightly more extreme than the value of 1.15 (corresponding to 0.15 when expressed on the basis of mg/kg) reported by Mineau et al. for a subset of 36 pesticides. A similar proportion of slopes was positive for cholinesterase inhibitors (54/68) than for other pesticides combined (45/62). As determined by an F-test, 14 pesticides of the 130 had a slope significantly different from 0 at the $p < 0.05$ probability level (11 of which were positive). Allowing the p to rise to 0.1, a total of 30 slopes were significantly different from null, 24 of them positive. As argued by Mineau et al. (1996), failure to achieve statistical significance in a majority of the slopes does not remove the biological significance of the finding. Several slopes may miss being significantly different from 0 either because of inadequate sample size, or because they are only slightly different from 0, or a combination of both. The fact that the large majority are greater than 0 indicates a

phenomenon that is biologically significant. Therefore, even for pesticides for which statistical significance is not achieved, the observed slope should be regarded as a better estimate of the true value rather than assuming the slope is 0. Not using a scaling factor when susceptibility does scale to weight would result in potentially serious underprotection at one end (usually the small one) of avian size ranges. On the other hand, scaling toxicity data to a completely spurious slope factor might mislead. Fortunately, inspection of the data revealed that many of the very extreme slopes measured, both positive and negative, were in fact significant, at least at the $p < 0.1$ level, thus lessening the concern that we may be fitting data to spurious slopes.

The reason for avian acute toxicity values scaling to weight raised to the value of 1.2 or even slightly higher on average is unclear. In mammals, the common wisdom is that toxicity tends to scale to 0.67 or 0.75 (reviewed in Mineau et al. 1996) although a recent reassessment of acute toxicity data in mammals and birds (Sample and Arenal 1999) calculated an average scaling factor of 0.94 for mammals and confirmed an average of 1.2 in birds. It was suggested (Fischer and Hancock 1997) that these scaling factors may be a consequence of taxonomic differences. Songbirds (order Passeriformes) constitute the majority of the small-bodied species in the database, and they may be more susceptible toxicologically. A simpler, and more compelling possibility, is that small birds in any taxonomic group are less able to withstand the rigors of the physiological disruption brought about by acute dosing, especially reduced food intake. Regardless of the reason, the end result is the same: the use of the appropriate scaling factor results in the least estimation error for the toxicity of a pesticide to a bird of a given weight and in reduced variance in the distribution of LD_{50} values. One, however, needs to exercise caution in estimating LD_{50} values for very large or very small bird species, or birds from taxonomic groups that are poorly represented in the data set. For example, as reviewed by Mineau et al. (1999) there is some evidence that hawk and owl species (orders Falconiformes and Strigiformes) are more sensitive, at least to cholinesterase inhibitors, than other birds of similar body weight.

D. Modification of the Distribution Approach to Incorporate Body-Weight Scaling

Until now the best method available to derive a set level of protection with a given level of certainty based on the distribution of toxicity data was that developed by Aldenberg and Slob (1993). These authors modified existing methods (Kooijman 1987; Van Straalen and Denneman 1989; Wagner and Lokke 1991), which aimed to determine environmental concentrations or doses of chemicals that were protective of 95% of the species in the wild. The modifications consisted of deriving extrapolation constants, K_n, that account for the uncertainty in the estimates of the distribution parameters when dealing with small sets of laboratory-derived toxicity data. The extrapolation constants are determined such that a one-sided left confidence limit L for $\log(HD_5)$ (for *H*azardous *D*ose at the 5% tail of the distribution) is given by

$$L = \bar{y}_n - [K_n * S_n] \quad (1)$$

where $\bar{y}_n$ and S_n are mean and standard deviation, respectively, of a sample log (LD_{50}) test data of size n.

This approach does not, however, incorporate body weight as a covariate. Mineau et al. (1996) were able to describe the relationship between the LD_{50} and body weight using the equation

$$y_i = \beta_0 + \beta_1 x_i + e_i \quad (2)$$

where, $y_i = \log(LD_{50})$, $x_i = \log(Weight)$, β_0 and β_1 denote the intercept and slope of the regression line, and e_i denotes the random deviation of the data from the model.

The distributional method as described by Aldenberg and Slob (1993) does not incorporate a body weight covariate and requires an estimate of the mean and the standard deviation or variance. The equivalent terms can be defined for a model with a covariate, but in this case one must choose a value for x_0 (the log of the weight of the bird that one wants to protect). The estimators of these two quantities with and without a covariate are compared in Appendix 1. For the Aldenberg and Slob approach, the precision of the estimates only depends on n whereas for the covariate approach it depends on n and another term that reflects the precision of the predicted LD_{50} at the designated weight. The predicted LD_{50} becomes less precise as one moves away from the average of the x_i. To compensate for this, a value for the extrapolation constant K must be developed separately for each data set and designated weight of bird to be protected; this is done through a simulation in the manner of Aldenberg and Slob (1993).

E. Choice of an Appropriate Percentile in the Acute Toxicity Distribution

Working with a distribution allows one to set a desired percentile, or a threshold LD_{50} value sufficiently protective for an arbitrarily chosen proportion of the entire population of bird species. For risk assessment purposes, it is customary to choose a value in the left tail, e.g., at the 1% or 5% tail of the distribution. This custom was born of convenience and practicality and has no scientific basis. Some may take issue with the fact that 5% or even 1% of the species inhabiting the exposed ecosystem can be summarily "written off." Choosing a percentile does not mean that this percentage of species will necessarily be impacted. The final level of protection afforded to birds will depend on the interplay of all the components of the risk assessment and regulatory scheme. For comparative risk assessment, using an LD_{50} value representative of the left tail of the distribution is preferable to using a measure of central tendency (median, arithmetic mean or geometric mean) because the latter parameters do not take into account information regarding the variance of the distribution. For the purpose of this exercise, the 5th percentile of the log-logistic distribution of species LD_{50}s was determined (the point on the tail of the log-logistic distribu-

tion that excludes 5% of the lower LD_{50} values). It is useful to also remember that we are fitting LD_{50} values to a distribution; these are not no-effect or minimal-effect concentrations. At the predicted threshold, half the exposed individuals from a species at the 5% tail of susceptibility are expected to die. Risk assessors may wish to apply another factor to cover intraspecific differences in susceptibility. Typically, this would be done through consideration of the probit slope of the dose–mortality relationship.

Having arbitrarily fixed the protection level at the 5th percentile of the species distribution, (termed HD_5 (*H*azardous *D*ose 5%) by Aldenberg and colleagues as well as in this review, or TLD_5 (*T*hreshold *L*ethal *D*ose 5%) by Baril and colleagues), we still need to fix the level of certainty we wish to attach to the determination of this value. As argued by Aldenberg and Slob (1993) and confirmed by Baril et al. (1994), median estimates of the HD_5 (calculated with a 50% probability of overestimation) may not be sufficiently protective, especially where rare or valuable focal species of unknown susceptibility must be protected. In other words, far fewer than 95% of bird species may actually be protected. However, thresholds that account for a higher (90% or 95% are commonly used) certainty that the estimate of the 5th percentile is not overestimated are extremely conservative (likely overprotective), especially when sample sizes are small. Our intent here was to present threshold values that would allow for the "fairest" comparison possible between pesticides having data sets of vastly different size and quality. Indeed, one of our goals was to permit comparison of older pesticides (often with large data sets) with that of newer products (with typically few data) without allowing sample size to have an overwhelming influence on the result. We opted therefore to report median threshold values (the 5% tail of the distribution calculated with 50% probability of overestimation), recognizing that some of these values carry with them a very high risk of underprotection, which may render them unsuitable for product by product risk assessment. Of course, if probabilistic risk assessments are to be carried out, one may wish to enter the entire estimated distribution of LD_{50} values rather than an arbitrary 5% threshold.

F. Choice of the Appropriate Bird Weights to Model

Because of the nature of regression, the real advantage of using the new distribution model that incorporates body weight as a covariate is predicting the sensitivity of birds having body weights that deviate from the tested average. For chemicals for which the regression between body weight and toxicity is highly statistically significant, the confidence in the estimated HD_5(50%) for birds of any chosen weight is high. For those chemicals for which the slope is different from zero but not statistically significant, we opted to apply the covariate as well. Using a distribution model without a covariate can lead to the erroneous underestimation of the sensitivity of birds at either extreme of the weight axis if the scaling relationship is real. Because our intent was to provide reference values that are sufficiently protective of most birds regardless of size, we assumed that the fitted scaling relationship was biologically real in all cases.

To generate a single LD_{50} value protective of birds in general regardless of their weight, we first calculated HD_5 values for birds of 20, 100, 200, or 1000 g. Those weights were chosen based on typical bird weights recorded from casualties in pesticide field studies carried out in North America, primarily the U.S. (CWS unpublished analysis). Although this weight range does not encompass all bird species, it does account for the vast majority. The reference value reported in this review is the lesser of the 5% threshold values calculated for these four body weights. Most often, this was the value determined for birds of 20 g.

G. Derivation of Extrapolation Factors

As proposed by Luttik and Aldenberg (1997), we decided that a minimum of four LD_{50} values were needed for determining the mean and standard deviation parameters of the distribution. For pesticides with fewer data points, a different approach is needed because the data are insufficient to fit to a distribution without the parameters being estimated with unusually large errors. We must therefore predict the fifth percentile of the distribution through extrapolation from the small data set using some predetermined factor or set of factors. Luttik and Aldenberg (1995) presented one approach to derive such extrapolation factors.[1] Their method assumes the following: (1) the mean of the logarithm of the available toxicity data is the best estimate of the mean of the distribution; (2) the standard deviation is equal to a "generic" standard deviation that is calculated from the pooled historical data sets for a large number of chemicals tested on many species; and (3) species sensitivities are random across chemicals. Thus, Luttik and Aldenberg determined that, if a single test species is available, an extrapolation factor of 5.7 should be applied to the LD_{50} (unadjusted for body weight scaling) to obtain the median estimated HD_5 (to be indicated as $HD'_5(50\%)$). This factor stays constant regardless of N, the number of species for which test data are available.

There is, however, a serious impediment to the use of such a strategy for regulatory or comparative purposes. Data available for any given pesticide (especially if the data are limited to one or a few species) are not necessarily a random sample. As discussed earlier, we have found that only a few data points are typically released, and these data may be biased to put a product in the best light possible regarding its toxicity to nontarget species. Also, species commonly used for testing (e.g., the mallard duck and northern bobwhite) tend to be at the "insensitive" side of the distribution already. We believe that to adopt the strategy of a single "universal" extrapolation factor would be a strong incentive to biased reporting. Several authors have found that species tend to differ

[1]The word extrapolation factor is used here in place of the frequently used safety factor or assessment factor. In contrast to the latter, which often are arbitrarily set at 10 or 100 to reflect a potentially error-prone extrapolation, the extrapolation factors presented here are based on sound empirical data reflecting variability in interspecies susceptibility to chemicals.

in their sensitivity to pesticides in a predictable manner; some species are, on average, more sensitive than others to pesticides (Baril et al. 1994; Joermann 1991; Schafer and Brunton 1979). To make use of these known relationships, Baril and colleagues proposed that extrapolation factors should be tailored to the actual species for which data are available. For example, a different extrapolation factor would be applied to a single mallard LD_{50} value than to a northern bobwhite or Japanese quail LD_{50}. A simulation exercise (Baril and Mineau 1996; this is an abstract only; data not published) showed that to ignore sensitivity relationships in favor of a single (universal) extrapolation factor resulted in more estimation errors.

We therefore opted to generate species-specific extrapolation factors from our available data set. The calculated $HD_5(50\%)$ values for all pesticides with *N* greater or equal to 6 were used to derive extrapolation factors. All computed $HD_5(50\%)$ values were used regardless of the significance of the regression statistics. As outlined earlier, the smaller of the HD_5 values computed for weights ranging between 20 and 1000 g was retained as our reference value, and those reference values were used to calculate species- and pesticide-specific extrapolation factors. A sample size of 6 or more ensured that both the parameters of the distribution and the slope of the regression between body weight and LD_{50} were relatively well characterized. Thus, the extrapolation factor specific to a particular species or combination of test species is simply the ratios of the computed $HD_5(50\%)$ to the LD_{50}s of the test species (or geometric mean of LD_{50} values in the case of a combination of species), averaged over all chemicals in the database.

We propose that these extrapolation factors be used to estimate $HD_5(50\%)$ values ($HD_5(50\%)$) where *N*, the number of species tested is, 1–3. Two different methods of combining the two or three available LD_{50} values were tried: taking the smallest value, and taking the geometric mean of the values. Deriving extrapolation factors from the geometric means of available LD_{50}s was found to lead to less estimation error (data not shown). The geometric mean was then retained as the best way to combine two or three available data points to compute extrapolation factors. We computed extrapolation factors for most of the commonly tested species or combinations of those species (Table 1). Other factors computed for more rarely-tested species were derived as needed but are not given here because of the smaller sample sizes used in their derivation.

The use of an extrapolation factor introduces another potentially significant source of error in the estimation of the $HD_5(50\%)$; this is the error resulting from an individual species' varying sensitivity relative to the population 5% tail. Whereas some species appear to be reasonably "well behaved" by showing a degree of sensitivity relative to the population tail that is consistent across chemicals (red-winged blackbird, red-billed quelea, Japanese quail), other species tended to move extensively within the sensitivity distributions established for each pesticide (chicken, mallard, European starling). For the latter species, sometimes they were very sensitive and sometimes they were very insensitive relative to the 5% percentile. The extrapolation factors were therefore ranked

Table 1. Extrapolation factors ordered by increasing coefficients of variation.

	n	Extrapolation factor	Approximate C.V.	95th percentile	5th percentile
Red-winged blackbird	67.00	3.95	2.32	10.62	1.47
Red-billed quelea	22.00	3.63	2.68	10.92	1.20
Bobwhite quail and Japanese quail	36.00	8.05	3.18	27.97	2.32
Bobwhite quail and Japanese quail and mallard duck	32.00	8.94	3.64	34.85	2.29
Japanese quail	61.00	10.36	4.11	44.96	2.39
Japanese quail and mallard duck and house sparrow	46.00	8.37	4.26	37.51	1.87
Japanese quail and mallard duck	56.00	10.41	5.48	58.93	1.84
European starling and red-winged blackbird	57.00	5.63	5.57	32.37	0.98
Bobwhite quail and mallard duck	40.00	9.61	6.10	60.12	1.54
Bobwhite quail	42.00	8.61	7.19	63.08	1.17
Ring-necked pheasant	66.00	9.41	7.42	71.05	1.25
European starling	59.00	11.82	7.60	91.32	1.53
Mallard duck	67.00	10.38	10.89	114.00	0.95
Chicken	37.00	19.75	13.82	274.31	1.42

Approx. C.V. = (95th percentile − 5th percentile)/extrapolation factor.
95th percentile = extrapolation factor + 1.645 * SD.
5th percentile = extrapolation factor − 1.645 * SD.

on the basis of their approximate coefficient of variation, the lowest coefficient being indicative of the lowest likelihood of making a large estimation error. Given the possibility of applying more than one extrapolation factor, we chose the one with the lowest approximate coefficient of variation. For example, although an extrapolation factor based on the geometric mean of several species is usually more "stable" and therefore less prone to serious error than a factor based on a single species, it can be seen from Table 1 that extrapolating the $HD'_5(50\%)$ from a single Japanese quail LD_{50} value results in less error, on average, than extrapolating from a combination of bobwhite and mallard data. Nevertheless, using an extrapolation factor is clearly a "second-best" alternative to curve-fitting LD_{50} data and deriving an actual HD_5. In the example just given, testing two species such as the northern bobwhite and mallard increases the probability that unexpected chance variations in susceptibility will be uncovered.

We believe that the approach of using reference values based on species-specific extrapolation factors represents the most unbiased attempt to date to compare the toxicity of pesticides for which many data points are available with those about which we know very little. Because cholinesterase-inhibiting pesticides represent a large group of chemicals with a uniform mode of toxic action, they were analyzed separately from other pesticides, and specific extrapolation factors were derived for that group of compounds. However, when the comparison was made between those compounds and a sample of noncholinesterase inhibitors, we found that the computed mean extrapolation factors were not significantly different (not shown) and a single set of factors for all pesticides in the sample was therefore generated (see Table 1).

H. Procedure for Pesticides Having Low Acute Toxicity

In the case of pesticides of lower toxicity, limit values are often provided; e.g., $LD_{50} > 2000$ mg/kg. Ideally, one would like to take into consideration the condition of the test birds and any mortality at the limit dose. In trying to set a value that is protective of 95% of bird species, it matters whether birds at the limit dose were moribund, with possibly some mortality being seen already, or whether there were no visible signs of toxicity in any of the individuals tested. Unfortunately, this information was not uniformly available. The following compromise procedure was therefore developed. (1) If, for any pesticide data set, a toxicity data point with an exact value existed (rather than a limit), this data point was used with the relevant species-specific extrapolation factor where possible. (2) Otherwise, the relevant species-specific extrapolation factors were applied separately to each available data point (treated as point estimates, ignoring the > symbol) and the *highest* resulting HD'_5 value was retained. Even then, it is clear that the resulting HD'_5 is probably an underestimate and that the pesticide is likely less toxic than shown. However, given that the HD'_5 thus calculated is already very high, this underestimation is unimportant in the context of a relative risk assessment. The acute toxicity of these pesticides is not likely to be a concern.

Table 2. Reference LD_{50} values for Cholinesterase-inhibiting pesticides ordered alphabetically by common chemical name.

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
Acephate	30560-19-1	7	146.00	0.1809	4.7716	0.66	18.52	—	E
AKTON™	1757-18-2	2	1037.50	na	na	na	18.99	1	U
Aldicarb	116-06-3	10	2.82	0.2955	–0.6559	0.12	0.43	—	E
Allyxycarb	6392-46-7	2	12.42	na	na	na	3.37	1	S
Aminocarb	2032-59-9	4	46.20	–0.3618	6.0268	0.33	6.59	—	S
Azamethiphos	35575-96-3	2	39.30	na	na	na	3.98	2	E
Azinphos-ethyl	2642-71-9	1	—	na	na	na	1.53	1	E
Azinphos-methyl	86-50-0	7	44.69	0.7806	–0.6793	0.00	2.28	—	E
Bendiocarb	22781-23-3	4	16.24	–0.9475	8.3724	0.37	0.72	—	E
Benfuracarb	82560-54-1	1	—	na	na	na	4.23	1	E
BOMYL™	122-10-1	2	5.36	na	na	na	0.25	1	U
Bromophos	2104-96-3	1	—	na	na	na	491.14	1	S
Bromophos-ethyl	4824-78-6	5	300.00	0.8503	0.805	0.01	12.88	—	E
Bufencarb	8065-36-9	8	32.95	0.1165	2.7226	0.71	3.09	—	S
Butocarboxim	34681-10-2	1	—	na	na	na	6.17	1	E
Butonate	126-22-7	3	158.00	na	na	na	40.00	1	S
Butoxycarboxim	34681-23-7	1	—	na	na	na	18.58	1	E
Cadusafos	95465-99-9	2	123.05	na	na	na	6.33	2	E
Carbanolate	671-04-5	12	4.22	0.1412	0.8936	0.53	0.75	—	S
Carbaryl	63-25-2	7	1870.50	0.8026	2.5147	0.06	30.05	—	E
Carbofuran	1563-66-2	18	1.65	0.0423	0.257	0.82	0.21	—	E
Carbophenothion	786-19-6	9	56.80	0.4054	1.431	0.12	2.00	—	S
Carbosulfan	55285-14-8	2	51.00	na	na	na	9.52	1	E

Also tabled are the CAS registration numbers, the number of species values available, the median LD_{50}, the slope, intercept and *p* value of the LD_{50} *weight regression, the calculated or estimated HD_5(50%) and, where used, the number of species from which an extrapolation factor was developed (see Table 1). The status follows the nomenclature of the *Pesticide Manual*, 11th Ed.; E, in use; S, superseded; U, unknown.

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
Chlorethoxyfos	54593-83-8	1	—	na	na	na	3.25	1	E
Chlorfenvinphos	470-90-6	15	23.70	0.3635	1.8073	0.10	2.73	—	E
Chlormephos	24934-91-6	3	100.00	na	na	na	25.10	1	E
Chlorphoxim	14816-20-7	2	100.00	na	na	na	11.61	1	S
Chlorpyrifos	2921-88-2	18	27.36	0.226	2.0941	0.09	3.76	—	E
Chlorpyrifos methyl	5598-13-0	2	845.00	na	na	na	25.32	1	E
Chlorthion	500-28-7	3	280.00	na	na	na	70.89	1	S
Cloethocarb (Bas 2631)	51487-69-5	1	—	na	na	na	0.43	1	S
Coumaphos	56-72-4	12	6.78	0.2179	0.7579	0.36	0.69	—	E
Crotoxyphos	7700-17-6	2	423.10	na	na	na	14.23	1	S
Crufomate	299-86-5	2	182.50	na	na	na	25.32	1	S
Cyanophos	2636-26-2	1	—	na	na	na	0.83	1	E
Demeton	8065-48-3	13	7.67	0.2357	0.6881	0.15	1.04	—	S
Demeton-*S*-methyl	867-27-6	7	49.00	0.1396	3.0132	0.47	7.24	—	E
Demeton-*S*-methylsulphon	17040-19-6	2	50.06	na	na	na	8.14	1	S
Dimidafos	1754-58-1	2	44.15	na	na	na	3.37	1	S
Diazinon	333-41-5	14	5.25	–0.2608	3.5883	0.29	0.59	—	E
Dicapthon	2463-84-5	1	—	na	na	na	4.13	1	S
Dichlofenthion	97-17-6	7	75.00	0.2685	3.327	0.57	7.54	—	S
Dichlorvos (DDVP)	62-73-7	11	14.75	0.0493	2.2876	0.61	5.18	—	E
Dicrotophos	141-66-2	15	2.83	0.1787	0.3645	0.32	0.42	—	E
Diethofencarb	87130-20-9	2	2250.00	na	na	na	234.13	2	E
Dimethoate	60-51-5	10	29.50	0.1773	2.5296	0.37	5.78	—	E
Dimetilan	644-64-4	4	27.20	0.1601	2.8008	0.83	0.92	—	S
Dioxacarb	6988-21-2	5	115.00	0.7849	0.4173	0.09	3.36	—	S
Dioxathion	78-34-2	2	258.50	na	na	na	25.50	1	S
Disulfoton	298-04-4	7	11.90	0.2019	1.2104	0.60	0.81	—	E

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
EPN	2104-64-5	14	6.43	0.3624	0.604	0.33	0.53	—	E
Ethamphos (ethamfen-phos, ethamfenthion)		2	7.93	na	na	na	0.78	2	U
Ethiofencarb	29973-13-5	3	196.00	na	na	na	14.96	1	E
Ethion (diethion)	563-12-2	5	127.80	0.9169	–0.1551	0.18	1.06	—	E
Ethoprop	13194-48-4	9	7.50	0.1086	1.3764	0.40	2.41	—	E
Etrimfos	38260-54-7	1	—	na	na	na	23.65	1	E
Famphur	52-85-7	3	2.70	na	na	na	0.45	1	E
Fenamiphos	22224-92-6	5	1.10	–0.0863	0.5444	0.66	0.43	—	E
Fenchlorphos	299-84-3	4	487.42	0.6983	2.1557	0.15	12.23	—	S
Fenitrothion	122-14-5	12	63.43	0.2707	3.0869	0.39	3.37	—	E
Fenobucarb	3766-81-2	1	—	na	na	na	31.12	1	E
Fensulfothion	115-90-2	14	0.73	0.2903	–1.8278	0.05	0.13	—	S
Fenthion	55-38-9	23	5.62	0.2581	0.4784	0.07	0.87	—	E
Fonofos	944-22-9	10	23.50	0.3442	1.293	0.07	3.86	—	E
Formetanate	22259-30-9	4	31.75	–0.515	6.2418	0.06	8.77	—	E
Fospirate	5598-52-7	2	34.75	na	na	na	3.37	1	S
Fosthiazate	98886-44-3	2	15.00	na	na	na	1.47	2	E
Furathiocarb	65907-30-4	1	—	na	na	na	2.41	1	E
Heptenophos	23560-59-0	2	52.74	na	na	na	3.04	1	E
Isazofos	42509-80-8	3	11.10	na	na	na	0.51	2	E
Isocarbophos	24353-61-5	5	1.00	0.254	–1.1291	0.148	0.26	—	U
Isofenphos	25311-71-1	6	10.96	0.0994	2.7255	0.86	0.44	—	E
Isoprocarb	2631-40-5	1	—	na	na	na	14.23	1	E
Leptophos	21609-90-5	5	268.84	1.2259	–1.5553	0.41	0.09	—	S
Malathion	121-75-5	8	466.50	0.0323	6.0138	0.85	139.10	—	E
Mephosfolan	950-10-7	1	—	na	na	na	0.14	1	E

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
Methacrifos	62610-77-9	1	—	na	na	na	11.20	1	E
Methamidophos	10265-92-6	3	15.82	na	na	na	1.70	2	E
Methidathion	950-37-8	7	34.64	na	na	na	3.53	1	E
Methiocarb	2032-65-7	33	7.50	0.4708	0.0308	0.00	1.06	—	E
Methocrotophos	25601-84-7	2	3.12	na	na	na	0.25	1	S
Methomyl	16752-77-5	13	23.69	0.0852	2.7336	0.50	8.46	—	E
Methyl parathion	298-00-0	10	10.81	0.2021	1.3254	0.27	2.13	—	E
Methyl trithion	953-17-3	1	—	na	na	na	4.51	1	S
Mevinphos	7786-34-7	13	3.80	0.0254	0.9409	0.88	0.70	—	E
Mexacarbate	315-18-4	16	5.64	−0.2586	3.2429	0.03	1.39	—	S
Mobam	10793-30-1	8	255.00	0.2555	4.1803	0.34	30.31	—	S
Monocrotophos	6923-22-4	23	2.51	−0.0312	1.0218	0.79	0.42	—	E
Naled	300-76-5	7	64.90	na	na	na	1.72	1	E
Omethoate	1113-02-6	2	28.52	na	na	na	4.14	1	E
Oxamyl	23135-22-0	3	4.18	na	na	na	0.78	2	E
Oxydemeton-methyl	301-12-2	11	53.90	−0.0452	4.1453	0.82	13.96	—	E
Parathion	56-38-2	19	5.62	0.0797	1.2228	0.76	0.40	—	E
Phenthoate	2597-03-7	2	259.00	na	na	na	23.17	1	E
Phorate	298-02-2	8	7.06	0.1817	0.4833	0.65	0.34	—	E
Phosalone	2310-17-0	1	—	na	na	na	106.27	1	E
Phosfolan	947-02-4	7	2.37	0.1034	0.8054	0.62	0.69	—	S
Phosmet	732-11-6	5	435.80	1.1854	−1.5394	0.06	1.24	—	E
Phosphamidon	297-99-4	15	4.24	0.1528	0.7174	0.32	1.08	—	E
Phoxim	14816-18-3	12	32.21	0.6057	0.1756	0.01	1.71	—	E
Pirimicarb	23103-98-2	8	20.52	0.1118	2.4285	0.50	6.78	—	E
Pirimiphos-ethyl	23505-41-1	2	6.00	na	na	na	1.90	1	E

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
Pirimiphos-methyl	29232-93-7	2	470.00	na	na	na	13.51	1	E
Promecarb	2631-37-0	4	13.50	1.3541	−2.6021	0.15	0.94	—	E
Propaphos	7292-16-2	1	—	na	na	na	0.18	1	E
Propetamphos	31218-83-4	3	78.00	na	na	na	7.09	1	E
Propoxur	114-26-1	23	11.76	0.344	0.8344	0.02	1.31	—	E
Prothiofos	34643-46-4	1	—	na	na	na	13.65	1	E
Prothoate (trimethoate)	2275-18-5	2	55.95	na	na	na	5.52	1	S
Pyridaphention	119-12-0	1	—	na	na	na	7.94	1	E
Pyrolan	87-47-8	1	—	na	na	na	3.27	1	S
Quinalphos	13593-03-8	2	20.65	na	na	na	0.42	1	E
Schradan	152-16-9	3	19.00	na	na	na	2.02	1	S
Sulfotep	3689-24-5	2	150.00	na	na	na	50.63	1	E
Sulprofos	35400-43-2	5	47.00	−0.0883	4.8854	0.89	6.85	—	E
Tebupirimfos	96182-53-5	1	—	na	na	na	2.36	1	E
Temephos	3383-96-8	14	65.60	0.3163	2.6217	0.10	8.68	—	E
Terbufos	13071-79-9	5	9.48	1.0277	−1.5328	0.32	0.16	—	E
Tetrachlorvinphos	961-11-5	3	4750.00	na	na	na	25.32	1	E
Thiocarboxime	29118-87-4	5	12.00	−0.4141	5.2618	0.08	5.04	—	S
Thiodicarb	59669-26-0	1	—	na	na	na	234.96	1	E
Thiofanox	39196-18-4	3	1.20	na	na	na	0.12	1	E
Thiometon	640-15-3	2	61.75	na	na	na	5.07	1	E
Thionazin	297-97-2	8	2.77	−0.2254	2.2454	0.07	1.02	—	S
Triazamate	112143-82-5	1	—	na	na	na	0.93	1	E
Triazophos	24017-47-8	5	9.47	0.1991	1.0113	0.55	1.68	—	E
Trichlorfon	52-68-6	12	60.73	0.3189	2.4757	0.06	13.36	—	E
Trichloronat	327-98-0	10	18.50	0.4069	0.7989	0.30	0.73	—	S

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	$HD_5(50\%)$	#_EF	Status
Trimethacarb (Landrin™)	12407-86-2	8	69.00	–0.1382	5.0938	0.56	16.28	—	E
Vamidothion	2275-23-2	1	—	na	na	na	3.72	1	E
Xylylcarb	2425-10-7	1	—	na	na	na	6.20	1	E
Numbered Experimental Products: Probably Never Marketed									
2-Propargyloxyphenyl *N*-methylcarbamate (HERCULES 9699)	3279-46-7	2	45.00	na	na	na	11.39	1	
3-(2-Butyl)-phenyl *N*-methyl carbamate *N*-benzenesulfoate (RE-11775)	25474-41-3	2	57.90	na	na	na	1.23	1	
3,4,5-Trimethylphenyl methylcarbamate (Landrin™ isomer 1)	2686-99-9	1	—	na	na	na	4.50	1	
3,5-Diisopropylphenyl *N*-methylcarbamate (HRS 1422)	330-64-3	2	55.00	na	na	na	2.53	1	
3,5 Xylyl *N*-methylcarbamate	2655-14-3	1	—	na	na	na	19.61	1	
3-Propargyloxyphenyl *N*-methylcarbamate (HERCULES 8717)	3692-90-8	2	40.48	na	na	na	3.80	1	

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status
Diethyl 5-methylpyrazol-3yl phosphate (Pyrazoxon)	108-34-9	1	—	na	na	na	3.38	1	
m-Isopropylphenyl *N*-methylcarbamate (HERCULES 5727)	64-00-6	2	11.31	na	na	na	1.42	1	
O,*O*-Diethyl naphtalene-1,8-dicarboximido-oxyphosphonothioate (BAY22408)	2668-92-0	2	261.86	na	na	na	6.00	1	
O,*O*-Dimethyl *O*-(3,5-dimethyl-4-methylthio-phenyl)phosphoro-thioate (Bayer 37342)		1	—	na	na	na	3.64	1	
O,*O*-Dimethyl *O*-(4-methyl-mercaptophenyl) phosphate (GC-6506)	3254-63-5	2	0.90	na	na	na	0.07	1	
O-Ethyl *S*-*p*-tolyl ethyl phosphonodithioate (BAY 38156)	333-43-7	2	3.34	na	na	na	0.43	1	
Phenol, 3-(1-methyl-ethyl)-4-(methylthio)-methyl carbamate (ACD 7029)		7	13.30	0.0329	2.6034	0.94	1.20	—	

Table 2. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	$HD_5(50\%)$	#_EF	Status
Phosphonamidothioic acid, *p*-ethyl-*O*-[3-methyl-4-(methylthio)-phenyl]ester (BAY HOL 0574)		9	5.62	–0.2266	2.5104	0.41	0.51	—	
Phosphoramidic acid, ethyl-,2,4-dichloro-phenyl ester (DOWCO 161)		9	13.30	0.0151	2.8043	0.30	4.33	—	
Phosphorothioic acid, *O*-(3-bromo-5,7-dimethyl-pyrazolo[1,5-a]-pirimidin-2-yl)*O*,*O*-diethyl ester (BAY 75546)	7682-90-8	7	4.22	0.3415	0.035	0.00	0.91	—	
Insufficient Product Data									
Dimethylvinphos	2274-67-1	—							E
Isoxathion	18854-01-8	—							E
Mecarbam	2595-54-2	—							E
Metolcarb	1129-41-5	—							E
Profenofos	41198-08-7	—							E
Pyraclofos	77458-01-6	—							E
Dialifos	10311-84-9	2	752.55						S
Formothion	2540-82-1	2	238.85						E
Pirimiphos-methyl	29232-93-7	1	—						E

Table 3. Reference LD_{50} values for pesticides that do not inhibit cholinesterase; the values are ordered by principal target pest and alphabetically by common chemical name.

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Chemicals Primarily Active Against Insects and other Invertebrates										
2-(Octylthio)ethanol	3547-33-9	2	2250.00	—	—	—	234.13	2	E	Insecticide
Abamectin	71751-41-2	2	1042.30	—	—	—	42.80	2	E	Acaricide
Acequinocyl (AKD-2023)	57960-19-7	2	2000.00	—	—	—	193.05	1	E	Acaricide
Acetampirid	135410-20-7	1	—	—	—	—	20.91	1	E	Insecticide
Acetates of Z/E 8-dodecenyl and Z 8-dodecenol	28079-04-1 (Z 8-dodecenyl)	1	—	—	—	—	232.29	1	E	Insect pheromone
Acrinathrin	101007-06-1	2	1625.00	—	—	—	156.09	2	E	Acaricide insecticide
Aldrin	309-00-2	12	19.83	0.44	0.80	0.15	1.15	—	S	Insecticide
Allethrin	584-79-2	1	—	—	—	—	192.68	1	E	Insecticide
Alpha-Cypermethrin	67375-30-8	1	—	—	—	—	9633.91	1	E	Insecticide
Amitraz	33089-61-1	1	—	—	—	—	41.83	1	E	Insecticide acaricide
Azadirachtin	992-20-1	1	—	—	—	—	261.32	1	U	Miticide
Azocyclotin	41083-11-8	1	—	—	—	—	17.42	1	E	Acaricide
Bensultap	17606-31-4	4	192.00	1.35	−2.11	0.23	0.41	—	E	Insecticide
Benzene Hexachloride	608-73-1	1	—	—	—	—	12.54	1	E	Insecticide
Benzyl benzoate	120-51-4	1	—	—	—	—	232.29	1	U	Miticide
Beta-Cyfluthrin	68359-37-5	4	—	—	—	—	—		E	Insecticide
Bifenazate (D2341)	149877-41-8	1	—	—	—	—	132.64	1	E	Acaricide
Bifenthrin	82657-04-3	2	1975.00	—	—	—	204.71	2	E	Insecticide

Also tabled are the CAS registration numbers, the number of species values available, the median LD_{50}, the slope, intercept and *p* value of the LD_{50}*weight regression, the calculated or estimated HD_5(50%) and, where used, the number of species from which an extrapolation factor was developed (see Table 1). The status follows the nomenclature of the *Pesticide Manual*, 11th Ed.; E, in use; S, superseded; U, unknown.

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Binapacryl	485-31-4	2	717.50	—	—	—	—	—	S	Acaricide
Bioallethrin (Depallethrin)	548-79-2	1	—	—	—	—	235.77	1	E	Insecticide
Bioallethron S-cyclopentenyl isomer	28434-00-6	3	5000.00	—	—	—	520.29	2	E	Insecticide
Bioethanomethrin (RU-11-679)	22431-62-5	1	—	—	—	—	—		U	Insecticide
Bioresmethrin	28434-01-7	1	—	—	—	—	506.33	1	E	Insecticide
Bromopropylate	18181-80-1	2	2255.00	—	—	—	193.05	1	E	Acaricide
BT	68038-71-1	1	—	—	—	—	481.70	1	U	Insecticide
Buprofezin	69327-76-0	3	2000.00	—	—	—	680.40	2	E	Insecticide
Butoxypolypropylene glycol	9003-13-8	1	—	—	—	—	261.32	1	S	Insecticide
Calcium polysulfide	1344-81-6	1	—	—	—	—	65.04	1	E	Insecticide
Calcium tetrathiocarbamate	81510-83-0	1	—	—	—	—	137.05	1	U	Insecticide
CGA 50 439	61676-87-7	1	—	—	—	—	78.09	1	E	Acaricide, ixodicide
Chlordane	57-74-9	4	62.28	1.00	−1.63	0.44	0.09	—	E	Insecticide
Chlordecone	143-50-0	2	220.33	—	—	—	26.42	1	S	Insecticide, fungicide
Chlorfenapyr	122453-73-0	2	8.30	—	—	—	0.56	1	E	Insecticide, acaricide
Chlorfluazuron	71422-67-8	1	—	—	—	—	241.81	1	E	Insecticide
Chlorofenizon	80-33-1	1	—	—	—	—	444.02	1	S	Acaricide
Citronella oil	8000-29-1	1	—	—	—	—	261.32	1	E	Insecticide
Clofentezine	74115-24-5	2	5250.00	—	—	—	493.59	2	E	Acaricide
Codiemone	33956-49-9	1	—	—	—	—	249.71	1	E	Insect pheromone

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Copper salts of fatty acids & rosin acids	9007-39-0	1	—	—	—	—	209.06	1	U	Insecticide
Cryolite	15096-52-3	1	—	—	—	—	249.71	1	E	Insecticide
Cycloprothrin	63935-38-6	2	3500.00	—	—	—	482.63	1	E	Insecticide
Cyfluthrin	68359-37-5	4	—	—	—	—	485.44	1	E	Insecticide
Cyhalothrin	68085-85-8	1	—	—	—	—	481.70	1	E	Insecticide
Cyhexatin	13121-70-5	1	—	—	—	—	57.43	1	E	Acaricide
Cypermethrin	52315-07-8	3	10000.00	—	—	—	579.15	1	E	Insecticide
Cyromazine	66215-27-8	4	2061.50	–0.13	8.25	0.63	604.60	—	E	Insect growth regulator
DDT	50-29-3	5	1334.00	0.36	5.12	0.37	122.90	—	E	Insecticide
Deltamethrin	52918-63-5	5	1000.00	—	—	—	97.09	1	E	Insecticide
Diafenthiuron	80060-09-9	2	1500.00	—	—	—	156.09	2	E	Insecticide, acaricide
Dicofol	115-32-2	3	680.99	—	—	—	72.37	1	E	Acaricide
Dieldrin	60-57-1	16	35.15	0.08	3.02	0.71	4.15	—	S	Insecticide
Dienochlor	2227-17-0	2	3087.95	—	—	—	243.97	2	E	Insecticide
Diflubenzuron	35367-38-5	3	5000.00	—	—	—	952.56	1	E	Insecticide
Dinitro-O-cresol	534-52-1	2	23.00	—	—	—	2.22	1	U	Insecticide
Dipropyl isocinchomeronate	136-45-8	1	—	—	—	—	156.79	1	U	Insecticide
DUOMEEN T-E-9 (N-tallow-trimethylene diamines)		2	1019.00	—	—	—	37.83	1	U	Mosquito control agent
Endosulfan	115-29-7	6	52.42	0.34	2.23	0.17	9.53	—	E	Insecticide
Endrin	72-20-8	11	1.78	0.03	0.59	0.83	0.75	—	S	Insecticide
Esfenvalerate	66230-04-4	2	1478.51	—	—	—	131.24	2	E	Insecticide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Etofenprox	80844-07-1	1	—	—	—	—	192.68	1	E	Insecticide
Etoxazole	153233-91-1	1	—	—	—	—	192.68	1	E	Acaricide
Farnesol	4602-84-0	2	2150.00	—	—	—	223.73	2	E	Miticide
Fenazaquin	120928-09-8	2	1873.50	—	—	—	194.51	2	E	Acaricide
Fenbutatin oxide	13356-08-6	5	—	—	—	—	291.52	1	E	Acaricide
Fenothiocarb	62850-32-2	2	1471.54	—	—	—	142.91	2	E	Acaricide
Fenoxycarb	79127-80-3	1	—	—	—	—	675.68	1	E	Insecticide
Fenpyroximate	111812-58-9	2	2000.00	—	—	—	208.12	2	E	Acaricide
Fenvalerate	51630-58-1	2	5447.36	—	—	—	321.77	2	E	Insecticide
Fipronil	120068-37-3	7	39.19	–0.37	7.22	0.65	1.47	—	E	Insecticide
Fluazuron	86811-58-7	2	2000.00	—	—	—	208.12	2	E	Ixodicide
Flubenzimine	37893-02-0	1	—	—	—	—	431.67	1	S	Acaricide
Flucycloxuron	94050-52-9	1	—	—	—	—	192.68	1	E	Acaricide, insecticide
Flucythrinate	70124-77-5	2	2645.00	—	—	—	274.88	2	E	Insecticide
Flufenoxuron	101463-69-8	1	—	—	—	—	232.29	1	E	Insecticide
Fluvalinate	69409-94-5	1	—	—	—	—	291.52	1	E	Insecticide
Gossyplure (Hexadecadienyl acetate)	53042-79-8	1	—	—	—	—	963.39	1	E	Insect pheromone
Halfenprox	111872-58-3	1	—	—	—	—	218.82	1	E	Acaricide
Heptachlor	76-44-8	7	125.00	–0.09	5.37	0.89	3.47	—	E	Insecticide
Hexaflumuron	86479-06-3	2	2000.00	—	—	—	208.12	2	E	Insecticide
Hexythiazox	78587-05-0	2	3620.27	—	—	—	482.63	1	E	Acaricide
Hydramethylnon	67485-29-4	2	2169.00	—	—	—	222.90	2	E	Insecticide
Imazethabenz-methyl	81405-85-8	2	2150.00	—	—	—	223.73	2	E	Insecticide
Imidacloprid	105827-78-9	7	35.36	–0.06	3.90	0.79	8.43	—	U	Insecticide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Isobenzan	297-78-9	7	3.16	0.41	–0.90	0.12	0.43	—	S	Insecticide
Isolan	119-38-0	1	—	—	—	—	6.99	1	S	Insecticide
Isomate-M	28079-84-1	1	—	—	—	—	232.29	1	U	Pheromone
Lambda-Cyhalothrin	91465-08-6	1	—	—	—	—	428.14	1	E	Insecticide
Limonene	138-86-3	1	—	—	—	—	232.29	1	U	Insecticide
Lindane	58-89-9	11	90.83	0.42	2.86	0.14	10.50	—	E	Insecticide
Lufenuron	103055-07-8	2	2000.00	—	—	—	208.12	2	E	Insecticide, acaricide
Methoprene	40596-69-8	1	—	—	—	—	192.68	1	E	Insect growth regulator
Methoxychlor	72-43-5	4	—	—	—	—	291.52	1	E	Insecticide
Methyl chloroform	71-55-6	1	—	—	—	—	291.52	1	U	Insecticide
Methyl nonyl ketone	112-12-9	2	2250.00	—	—	—	234.13	2	U	Insecticide
Muscalure	27519-02-4	1	—	—	—	—	232.29	1	E	Insect pheromone
N,*N*-Diethyl-*M*-Toluamide	134-62-3	1	—	—	—	—	159.70	1	U	Insecticide
Napthalene	91-20-3	1	—	—	—	—	312.43	1	S	Insecticide
Neurolidol	7212-44-4	2	2150.00	—	—	—	223.73	2	E	Miticide
Nicotine	54-11-5	5	247.40	1.40	–1.89	0.06	1.04	—	E	Insecticide
Nicotine sulfate	65-30-5	10	75.00	0.37	2.82	0.19	6.94	—	U	Insecticide
Nitenpyram	120738-89-8	2	1687.00	—	—	—	165.48	2	E	Insecticide
Novaluron	116714-46-6	1	—	—	—	—	192.68	1	E	Insecticide
Paradichlorobenzene	106-46-7	1	—	—	—	—	186.76	1	U	Insecticide
Permethrin	52645-53-1	5	—	—	—	—	3127.53	1	E	Insecticide
Phenol		2	310.20	—	—	—	—	—	U	Insecticide
Phenothrin [(1R)-*trans*-isomer]	26002-80-2	1	—	—	—	—	291.52	1	E	Insecticide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Piperonyl butoxide	51-03-6	1	—	—	—	—	261.32	1	E	Insecticide
POE Isooctadecanol	52292-17-8	1	—	—	—	—	192.68	1	U	Insecticide
Polybutene	9003-29-6	1	—	—	—	—	249.71	1	U	Insecticide
Polychlorocamphanes		2	53.00	—	—	—	—	—	U	Insecticide
Potassium salt of oleic acid	143-18-0	1	—	—	—	—	246.38	1	U	Insecticide
Potassium salts of fatty acids	10124-65-9	1	—	—	—	—	291.52	1	U	Insecticide
Prallethrin	23031-36-9	2	1085.50	—	—	—	112.60	2	E	Insecticide
Pymetrozine	123312-89-0	2	2000.00	—	—	—	208.12	2	E	Insecticide
Pyrethrin	8003-34-7	1	—	—	—	—	963.39	1	E	Insecticide
Pyridaben	96489-71-3	3	2250.00	—	—	—	279.50	2	E	Acaricide, insecticide
Pyrimidifen	105779-78-0	1	—	—	—	—	42.87	1	E	Acaricide, insecticide
Pyriproxyfen	95737-68-1	2	2000.00	—	—	—	208.12	2	E	Insecticide
Resmethrin	10453-86-8	4	—	—	—	—	60.32	1	E	Insecticide
Rotenone	83-79-4	1	—	—	—	—	211.95	1	E	Insecticide
Ryanodine	15662-33-6	6	2.37	0.06	0.85	0.91	0.59	—	S	Insecticide
SD-16898		4	6.77	–0.23	3.30	0.36	3.14	—	U	Insecticide, acaricide
Silafluofen	105024-66-6	2	2000.00	—	—	—	193.05	1	E	Insecticide
Sodium cyanide	143-33-9	6	8.99	–0.08	2.64	0.77	2.13	—	E	Insecticide, acaricide
Sulcofuron-sodium	3567-25-7	2	1558.00	—	—	—	149.96	2	E	Insecticide
Sulfluramid	4151-50-2	1	—	—	—	—	16.96	1	E	Insecticide
SZI-121	162320-67-4	1	—	—	—	—	193.05	1	E	Acaricide
Tau-Fluvalinate	102851-06-9	1	—	—	—	—	291.52	1	E	Insecticide, acaricide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
TDE	72-54-8	1	—	—	—	—	41.02	1	S	Insecticide, mosquito larvicide and adulticide
Tebufenozide	112410-23-8	1	—	—	—	—	249.71	1	E	Insecticide
Tebufenpyrad	119168-77-3	2	2000.00	—	—	—	208.12	2	E	Acaricide
Teflubenzuron	83121-18-0	2	2125.00	—	—	—	220.74	2	E	Insecticide
Tefluthrin	79538-32-2	3	734.00	—	—	—	178.63	2	E	Insecticide
TEPA	545-55-1	7	29.90	–0.24	4.71	0.26	4.45	—	U	Insecticide, chemo-sterilant
Tetradifon	116-29-0	4	—	—	—	—	580.72	1	E	Acaricide
Tetramethrin	7696-12-0	1	—	—	—	—	276.01	1	E	Insecticide
Thiocyclam	31895-21-3	1	—	—	—	—	333.01	1	E	Insecticide
Tobacco dust	8037-19-2	1	—	—	—	—	249.71	1	U	Insecticide
Toxaphene	8001-35-2	11	70.70	–0.32	6.26	0.21	10.40	—	S	Insecticide
Tralomethrin	66841-25-6	1	—	—	—	—	291.52	1	E	Insecticide
Transfluthrin	118712-89-3	1	—	—	—	—	—		E	Insecticide
Tridec-4-en-1-yl acetate	65954-19-0	2	2060.66	—	—	—	214.34	2	E	Insecticide
Triflumuron	64628-44-0	2	2780.50	—	—	—	208.05	2	E	Insecticide
Z-11-Hexadecanol	53939-28-9	1	—	—	—	—	232.29	1	U	Insecticide
ZXI 8901	160791-64-0	1	—	—	—	—	32.53	1	E	Insecticide
Chemicals Primarily Active Against Bacteria and Algae or Applied as Fumigants										
1,2-Benzenedicarbox-aldehyde	643-79-8	1	—	—	—	—	71.10	1	U	Bactericide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
1,3-dibromo-5,5-dimethylhydantoin (DBDMH)	77-48-5	1	—	—	—	—	291.52	1	U	Bactericide
2-(Hydroxymethyl) amino)ethanol	34375-28-5	1	—	—	—	—	202.44	1	U	Bactericide
2-Benzyl-4-chlorophenol	120-32-1	1	—	—	—	—	291.52	1	U	Bactericide
4,4-Dimethyloxazolidine	51200-87-4	2	905.00	—	—	—	91.84	2	U	Bactericide
4-Chloro-3,5-xylenol	88-04-0	1	—	—	—	—	276.01	1	U	Bactericide
Acrolein	107-02-8	2	14.06	—	—	—	1.37	2	E	Herbicide, fungicide, microbicide
ADBAC	68424-85-1	2	810.04	—	—	—	49.61	2	U	Bactericide
Alkyl amine hydrochloride	91745-52-7	1	—	—	—	—	114.87	1	U	Bactericide
Alkyl amino-3-aminopropane	61791-64-8	1	—	—	—	—	8.56	1	U	Bactericide
Alkyl trimethyl ammonium chloride	61789-18-2	1	—	—	—	—	62.95	1	U	Bactericide
Azadioxabicyclooctane	59720-42-2	1	—	—	—	—	241.81	1	U	Bactericide
BCDMH	16079-88-2	1	—	—	—	—	187.84	1	U	Bactericide
Benzisothiazolin-3-one	2634-33-5	1	—	—	—	—	71.66	1	U	Bactericide
BHAP (Bromohydroxyacetophenone)	2491-38-5	1	—	—	—	—	76.89	1	U	Bactericide
Bioban P-1487	2224-44-4	1	—	—	—	—	96.34	1	U	Bactericide
Bis(bromoacetoxy)-2-butene	20679-58-7	1	—	—	—	—	18.88	1	U	Bactericide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Bis(trichloromethyl) sulfone	3064-70-8	1	—	—	—	—	216.76	1	U	Bactericide
Boric acid	10043-35-3	1	—	—	—	—	291.52	1	U	Pesticide
Bromonitrostyrene	7166-19-0	1	—	—	—	—	48.17	1	U	Bactericide
Bronopol	52-51-7	1	—	—	—	—	49.04	1	E	Bactericide
Busan 77	31512-74-0	1	—	—	—	—	47.88	1	U	Bactericide
Calcium hypochlorite	7778-54-3	2	803.50	—	—	—	41.32	2	U	Algicide
Chlorhexidine diacetate	56-95-1	1	—	—	—	—	233.80	1	U	Bactericide
Chromic acid	7738-94-5	1	—	—	—	—	19.05	1	U	Preservative
Copper sulfate (basic)	1332-14-5	1	—	—	—	—	47.12	1	U	Antifoulant
Copper sulfate pentahydrate	7758-99-8	1	—	—	—	—	43.89	1	E	Algicide
Copper triethanolamine	82027-59-6	1	—	—	—	—	192.68	1	U	Bactericide
Cosan 145	97553-90-7	1	—	—	—	—	156.79	1	U	Preservative
Cuprous thiocyanate	1111-67-7	1	—	—	—	—	232.29	1	E	Bactericide
Dazomet	533-74-4	3	383.50	—	—	—	53.33	1	E	Fumigant
DBNPA	10222-01-2	2	220.43	—	—	—	22.91	2	U	Bactericide
DCDIC	138-93-2	1	—	—	—	—	309.34	1	U	Bactericide
DCDMH (1,3-Dichloro-5,5-dimethylhydantoin)	118-52-5	1	—	—	—	—	291.52	1	U	Bactericide
DDAC	7173-51-5	1	—	—	—	—	12.62	1	U	Bactericide
Dichloropropene/methylisothiocyanate	542-75-6, 556-61-6	1	—	—	—	—	36.80	1		Fumigant, fungicide, nematicide
Diiodomethyl *p*-tolyl sulfone	20018-09-1	1	—	—	—	—	291.52	1	U	Preservative
Dimethoxane	828-00-2	1	—	—	—	—	184.09	1	U	Bactericide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Dioctyl dimethyl ammonium chloride	5538-94-5	1	—	—	—	—	20.35	1	U	Algicide
Dithio-3-one,4,5-dichloro	1192-52-5	1	—	—	—	—	28.69	1	U	Bactericide
Dowicil	4080-31-3	2	1795.00	—	—	—	183.10	2	U	Bactericide
DTEA	36362-09-1	1	—	—	—	—	216.76	1	U	Bactericide
Erioglaucine/tartrazine	3844-45-9	2	2250.00	—	—	—	234.13	2	U	Algicide
Formaldehyde	50-00-0	1	—	—	—	—	91.75	1	E	Fungicide, bactericide
Glutaraldehyde	111-30-8	1	—	—	—	—	167.89	1	U	Bactericide
Grotan	4719-04-4	1	—	—	—	—	176.54	1	U	Bactericide
Guanidine (dodine free base)	112-65-2	2	1391.87	—	—	—	141.62	2	E	Bactericide
Hydroxypropyl methane thiosulfonate	30388-01-3	1	—	—	—	—	45.66	1	U	Bactericide
Iodine	7553-56-2	1	—	—	—	—	232.29	1	U	Bactericide
Iodine complex	11096-42-7	1	—	—	—	—	197.44	1	U	Bactericide
Irgarol	28159-98-0	1	—	—	—	—	261.32	1	U	Bactericide
Isobardac	138698-36-9	1	—	—	—	—	3.95	1	U	Bactericide
Isocyanuric acid	108-80-5	1	—	—	—	—	184.49	1	U	Bactericide
Lithium hypochlorite	13840-33-0	1	—	—	—	—	54.62	1	U	Bactericide
Metaldehyde	108-62-3	3	196.00	—	—	—	16.93	1	E	Molluscicide
Methyl bromide	74-83-9	1	—	—	—	—	8.48	1	E	Soil sterilant, fumigant
Methyl isocyanate	556-61-6	1	—	—	—	—	13.10	1	E	Fungicide, nematicide, fumigant

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Methylisothiazolinone (Acticide 14)	26172-55-4	1	—	—	—	—	7.91	1	U	Bactericide
Metronidazole	443-48-1	1	—	—	—	—	481.70	1	U	Bactericide
Mineral oil (including parafin oil)	8012-95-1	1	—	—	—	—	261.32	1	U	Bactericide
MTI	82633-79-2	1	—	—	—	—	17.65	1	U	Preservative
Nemagon	96-12-8	2	111.40	—	—	—	16.58	1	S	Nematicide
Nicosamide-olamine	1420-04-8	3	—	—	—	—	232.29	1	E	Molluscicide
Nitrapyrin	1929-82-4	1	—	—	—	—	260.89	1	E	Bactericide, nitrification inhibitor
OBPA (DID 47)	58-36-6	2	5050.00	—	—	—	963.39	1	U	Bactericide
Octhilinone	26530-20-1	1	—	—	—	—	55.50	1	E	Bactericide
Oxazolidine E	7747-35-5	1	—	—	—	—	116.14	1	U	Bactericide
Parachlorometacresol	59-50-7	1	—	—	—	—	178.86	1	U	Bactericide
PHMB	32289-58-0	1	—	—	—	—	241.81	1	E	Bactericide
PNMDC/DCDMC	137-41-7	1	—	—	—	—	114.86	1	U	Bactericide
Potassium azide	12136-44-6	3	20.80	—	—	—	1.60	1	U	MISC
Potassium bromide	7758-02-3	1	—	—	—	—	290.36	1	U	Bactericide
Potassium dimethylthiocarbamate	128-03-0	1	—	—	—	—	145.76	1	U	Bactericide
Pyrazole	85264-33-1	1	—	—	—	—	88.15	1	U	Bactericide
SDDC	128-04-1	1	—	—	—	—	115.10	1	U	Bactericide
Silver	7440-22-4	1	—	—	—	—	261.32	1	U	Bactericide
Sodium 2-mercaptobenzothiolate	2492-26-4	1	—	—	—	—	249.71	1	U	Bactericide
Sodium 2-phenylphenate	132-27-4	1	—	—	—	—	116.14	1	U	Bactericide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Sodium bromide	7647-15-6	2	2200.00	—	—	—	228.87	2	U	Bactericide
Sodium chlorite	7758-19-2	2	792.86	—	—	—	79.64	2	U	Bactericide
Sodium dichloro-S-tri-azinetrione	2893-78-9	2	1954.68	—	—	—	203.36	2	U	Bactericide
Sodium dichloroisocyan-uratedihydrate	51580-86-0	1	—	—	—	—	206.27	1	U	Bactericide
Sodium dodecylbenzene-sulfonate	25155-30-0	1	—	—	—	—	157.49	1	U	Bactericide
Sodium hypochlorite	7681-52-9	2	2710.14	—	—	—	272.16	2	U	Bactericide
Sodium omadine	15922-78-8	2	194.49	—	—	—	17.20	2	U	Bactericide
Streptomycin	3810-74-0	1	—	—	—	—	232.29	1	E	Bactericide
TBT methacrylate	26354-18-7	1	—	—	—	—	192.68	1	U	Antifoulant
TCMTB	21564-17-0	1	—	—	—	—	76.75	1	U	Bactericide
Tetraglycine hydroperi-odide	7097-60-1	1	—	—	—	—	29.04	1	U	Bactericide
THPS	55566-30-8	1	—	—	—	—	29.58	1	U	Bactericide
Tributyltin methacrylate	2155-70-6	1	—	—	—	—	81.07	1	U	Bactericide
Trichloro-s-triazinetrione	87-90-1	2	1480.87	—	—	—	146.48	2	U	Bactericide
Trichloromelamine	7673-09-8	1	—	—	—	—	246.38	1	U	Bactericide
Triclosan	3380-34-5	2	1487.50	—	—	—	138.59	2	U	Bactericide
Triethylhexahydro-s-triazine	7779-27-3	2	472.52	—	—	—	47.49	2	U	Preservative
Trimethoxysilyl quats	27668-52-6	1	—	—	—	—	153.18	1	U	Bactericide
Zinc naphthenate	12001-85-3	1	—	—	—	—	261.32	1	U	Preservative
Zinc oxide	1314-13-2	1	—	—	—	—	65.74	1	U	Preservative

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Chemicals Primarily Active Against Fungi										
2-Phenylphenol	132-27-4	1	—	—	—	—	116.14	1	E	Fungicide
3-Iodo-2-propynyl butyl-carbamate	55406-53-6	1	—	—	—	—	99.00	1	U	Fungicide
Anilazine	101-05-3	5	2000.00	0.19	6.73	0.21	614.90	—	S	Fungicide
Azaconazole	60207-31-0	2	731.00	—	—	—	48.26	1	E	Fungicide
Azoxystrobin	131860-33-8	1	—	—	—	—	232.29	1	E	Fungicide
Barium metaborate	13701-59-2	1	—	—	—	—	145.64	1	U	Fungicide
Benalaxyl	71626-11-4	2	6850.00	—	—	—	819.31	2	E	Fungicide
Benomyl	17804-35-2	3	100.00	—	—	—	25.32	1	E	Fungicide
Bis tributlytin oxide	56-35-9	1	—	—	—	—	68.80	1	S	Fungicide
Bitertanol	55179-31-2	3	2000.00	—	—	—	420.74	1	E	Fungicide
Bromuconazol	116255-48-2	2	2150.00	—	—	—	223.73	2	E	Fungicide
Bupirimate	41483-43-6	2	3873.50	—	—	—	482.63	1	E	Fungicide
Captafol	2425-06-1	1	—	—	—	—	291.52	1	E	Fungicide
Captan	133-06-2	3	100.00	—	—	—	25.32	1	E	Fungicide
Carbendazim	10605-21-7	2	4681.99	—	—	—	491.11	2	E	Fungicide
Carboxin	5234-68-4	5	2000.00	1.64	−1.95	0.04	3.44	—	E	Fungicide
Ceresan M	517-16-8	1	—	—	—	—	33.48	1	S	Fungicide
Chinomethionat (oxythio-quinox)	2439-01-2	3	500.00	—	—	—	126.58	1	E	Acaricide, fungicide
Chloroneb	2675-77-6	1	—	—	—	—	481.70	1	S	Fungicide
Chlorothalonil	1897-45-6	1	—	—	—	—	193.05	1	E	Fungicide
Chlozolinate	84332-86-5	3	4500.00	—	—	—	790.55	2	E	Fungicide
Copper hydroxide	20427-59-2	3	3400.00	—	—	—	219.11	2	E	Fungicide
Copper napthenate	1338-02-9	1	—	—	—	—	261.32	1	E	Fungicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Copper oxychloride	1332-40-7	1	—	—	—	—	45.95	1	E	Fungicide
Cuprobame	7076-63-3	1	—	—	—	—	—		S	Fungicide
Cuprous oxide	1317-39-1	2	406.00	—	—	—	33.16	1	E	Fungicide
Cycloheximide	66-81-9	3	9.38	—	—	—	1.85	2	S	Fungicide
Cymoxanil	57966-95-7	2	2250.00	—	—	—	234.13	2	E	Fungicide
Cyproconazole	113096-99-4	1	—	—	—	—	14.22	1	E	Fungicide
Cyprodinil	121552-61-2	2	2000.00	—	—	—	208.12	2	E	Fungicide
Debacarb/carbendazim	62732-91-6	1	—	—	—	—	96.34	1	E	Fungicide
Dichlofluanid	1085-98-9	2	5000.00	—	—	—	482.63	1	E	Fungicide
Dichlone	117-80-6	1	—	—	—	—	192.68	1	S	Fungicide
Dichloropropene	542-75-6	1	—	—	—	—	17.65	1	E	Fungicide
Dichlobutrazol	75736-33-3	1	—	—	—	—	928.81	1	E	Fungicide
Dicloran	99-30-9	3	900.00	—	—	—	139.61	2	E	Fungicide
Diethofencarb	87130-20-9	2	2250.00	—	—	—	234.13	2	E	Fungicide
Difenoconazol	119446-68-3	1	—	—	—	—	207.13	1	E	Fungicide
Diflumetorim	130339-07-0	2	1430.00	—	—	—	85.04	1	E	Fungicide
Dimethirimol	5221-53-4	1	—	—	—	—	202.53	1	E	Fungicide
Dimethomorph	110488-70-5	2	2000.00	—	—	—	208.12	2	E	Fungicide
Diniconazole	83657-24-3	2	1745.10	—	—	—	179.64	2	E	Fungicide
Dinobuton	973-21-7	1	—	—	—	—	7.59	1	E	Acaricide, fungicide
Dinocap	39300-45-3	1	—	—	—	—	249.71	1	E	Fungicide, acaricide
Dithianon	3347-22-6	6	294.50	0.50	2.66	0.51	5.29	—	E	Fungicide
DMDM hydantoin	6440-58-0	1	—	—	—	—	141.62	1	U	Fungicide
Dodine (doguadine)	2439-10-3	1	—	—	—	—	110.02	1	E	Fungicide
Edifenphos	17109-49-8	1	—	—	—	—	75.14	1	E	Fungicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Epoxiconazol	106325-08-0	1	—	—	—	—	232.29	1	E	Fungicide
Ethirimol	23947-60-6	1	—	—	—	—	202.53	1	E	Fungicide
Etridiazole	2593-15-9	1	—	—	—	—	65.04	1	E	Fungicide
Fenaminosulf	140-56-7	3	17.80	—	—	—	4.52	1	S	Fungicide
Fenarimol	60168-88-9	2	632.46	—	—	—	65.81	2	E	Fungicide
Fenbuconazol	114369-43-6	2	2174.72	—	—	—	270.13	2	E	Fungicide
Fenfuram	24691-80-3	1	—	—	—	—	0.69	1	E	Fungicide
Fenpiclonil	74738-17-3	2	1305.00	—	—	—	52.13	2	E	Fungicide
Fenpropidin	67306-00-7	1	—	—	—	—	39.21	1	E	Fungicide
Fenpropimorph	67306-03-0	3	3949.68	—	—	—	419.73	1	E	Fungicide
Fentin acetate	900-95-8	4	107.00	0.38	2.90	0.05	38.25	—	E	Fungicide
Fentin hydroxide	76-87-9	3	76.07	—	—	—	7.39	2	E	Fungicide
Ferimzone	89269-64-7	1	—	—	—	—	94.14	1	E	Fungicide
Fluazinam	79622-59-6	2	2986.00	—	—	—	284.34	2	E	Fungicide
Fludioxonil	131341-86-1	2	2000.00	—	—	—	208.12	2	E	Fungicide
Fluquinconazole	136426-54-5	2	2000.00	—	—	—	208.12	2	E	Fungicide
Flusilazole	85509-19-9	1	—	—	—	—	153.18	1	E	Fungicide
Flusulfamide	106917-52-6	1	—	—	—	—	7.67	1	E	Fungicide
Flutolanil	66332-96-5	2	2000.00	—	—	—	208.12	2	E	Fungicide
Flutriafol	76674-21-0	2	2808.00	—	—	—	481.70	1	E	Fungicide
Folpet	133-07-3	2	1405.78	—	—	—	118.28	2	E	Fungicide
Fosetyl-aluminium	39148-24-8	2	6498.50	—	—	—	785.42	2	E	Fungicide
Fuberidazole	3878-19-1	2	424.28	—	—	—	47.78	1	E	Fungicide
Furalaxyl	57646-30-7	1	—	—	—	—	579.15	1	E	Fungicide
Guazatine	13516-27-3	3	216.00	—	—	—	41.99	1	E	Fungicide
Guazatine (triacetate)	57520-17-9	3	120.00	—	—	—	32.65	1	U	Fungicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Hexaconazole	79983-71-4	1	—	—	—	—	391.14	1	E	Fungicide
Hymexazol	10004-44-1	3	1479.00	—	—	—	175.77	2	E	Fungicide
Imazalil	35554-44-0	3	2000.00	—	—	—	49.23	1	E	Fungicide
Imibenconazole	86598-92-7	2	2250.00	—	—	—	234.13	2	E	Fungicide
Iminoctadine triacetate	39202-40-9	1	—	—	—	—	94.89	1	E	Fungicide
Iprodione	36734-19-7	1	—	—	—	—	158.40	1	E	Fungicide
Isoprothiolane	50512-35-1	1	—	—	—	—	428.29	1	E	Fungicide
Kasugamycin	6980-18-3	1	—	—	—	—	386.10	1	E	Fungicide, bactericide
Lignasan BLP	52316-55-9	1	—	—	—	—	447.01	1	U	Fungicide
Mancozeb	8018-01-7	3	6861.49	—	—	—	710.95	1	E	Fungicide
Maneb	12427-38-2	4	—	—	—	—	345.34	1	E	Fungicide
Mepanipyrim	110235-47-7	2	2250.00	—	—	—	234.13	2	E	Fungicide
Mepronil	55814-41-0	2	2000.00	—	—	—	208.12	2	E	Fungicide
Mercuric chloride	7487-94-7	1	—	—	—	—	4.10	1	E	Fungicide
Metalaxyl	57837-19-1	1	—	—	—	—	89.09	1	E	Fungicide
Metalaxyl-M	70630-17-0	1	—	—	—	—	137.03	1	E	Fungicide
Metconazole	125116-23-6	1	—	—	—	—	91.75	1	E	Fungicide
Methylmercury dicyandiamide	502-39-6	2	35.00	—	—	—	5.11	1	S	Fungicide
Metiram	9006-42-2	1	—	—	—	—	249.71	1	E	Fungicide
Myclobutanil	88671-89-0	1	—	—	—	—	59.23	1	E	Fungicide
Nabam	142-59-6	3	2120.00	—	—	—	204.63	1	E	Fungicide
Nuarimol	63284-71-9	1	—	—	—	—	73.46	1	E	Fungicide
Ofurace	58810-48-3	1	—	—	—	—	—		E	Fungicide
Oxadixyl	77732-09-3	3	2000.00	—	—	—	149.07	2	E	Fungicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Oxine-copper	10380-28-6	3	618.00	—	—	—	115.69	2	E	Fungicide
Oxytetracycline	79-57-2	1	—	—	—	—	232.29	1	S	Fungicide
Paranitrophenol	100-02-7	1	—	—	—	—	67.02	1	U	Fungicide
Pefurazoate	101903-30-4	2	3300.00	—	—	—	229.73	1	E	Fungicide
Penconazole	66246-88-6	3	2424.00	—	—	—	193.41	2	E	Fungicide
Pencycuron	66063-05-6	3	2000.00	—	—	—	277.77	2	E	Fungicide
Pentachlorophenol (PCP)	87-86-5	3	504.00	—	—	—	50.79	2	U	Insecticide, fungicide, herbicide
Phenylmercuric acetate (PMA)	62-38-4	4	145.86	2.19	−9.43	0.16	0.01	—	E	Fungicide
Prochloraz	67747-09-5	3	707.00	—	—	—	74.20	2	E	Fungicide
Prochloraz-manganese		1	—	—	—	—	202.31	1	U	Fungicide
Procymidone	32809-16-8	2	5300.00	—	—	—	637.07	1	E	Fungicide
Propamocarb	24579-73-5	2	2910.00	—	—	—	321.72	1	E	Fungicide
Propiconazole	60207-90-1	4	2667.50	0.33	5.69	0.29	296.80	—	E	Fungicide
Propineb	12071-83-9	2	3000.00	—	—	—	482.63	1	E	Fungicide
Pyrazophos	13457-18-6	2	295.53	—	—	—	26.53	1	E	Fungicide
Pyrifenox	88283-41-4	2	2000.00	—	—	—	208.12	2	E	Fungicide
Pyrimethanil	53112-28-0	2	2000.00	—	—	—	208.12	2	E	Fungicide
Pyrithione	1121-30-8	2	126.93	—	—	—	25.32	1	S	Fungicide
Quintozene	82-68-8	1	—	—	—	—	255.45	1	E	Fungicide
Sec-butylamine	13952-84-6	1	—	—	—	—	12.66	1	E	Fungicide
Silicate methoxyethyl mercury		3	18.00	—	—	—	1.91	1	U	Fungicide
Sodium tetrathioperoxocarbonate (GY-81)	7345-69-9	1	—	—	—	—	137.05	1	E	Fungicide, insecticide, nematicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Tebuconazole	107534-96-3	4	1494.00	0.32	5.97	0.19	347.30	—	E	Fungicide
Terrazole	2593-15-9	2	1100.00	—	—	—	99.72	2	E	Fungicide
Thiabendazole	148-79-8	1	—	—	—	—	261.32	1	E	Fungicide
Thiophanate-methyl	23564-05-8	1	—	—	—	—	482.63	1	E	Fungicide
Thiram	137-26-8	7	500.00	0.55	3.31	0.06	36.81	—	E	Fungicide
Tolclofos-methyl	57018-04-9	3	5000.00	—	—	—	485.06	2	E	Fungicide
Tolylfluanid	731-27-1	4	—	—	—	—	482.63	1	E	Fungicide
Trans-1,2-bis(*n*-propylsulfonyl)ethene (CHE 1843)	1113-14-0	2	1560.00	—	—	—	192.68	1	U	Fungicide
Triadimefon	43121-43-3	4	—	—	—	—	385.36		E	Fungicide
Triadimenol	55219-65-3	3	2000.00	—	—	—	555.54	2	E	Fungicide
Triazoxide	72459-58-6	3	108.43	—	—	—	10.47	1	E	Fungicide
Trichogramma harzianum		2	2000.00	—	—	—	208.12	2	E	Fungicide
Tricyclazole	41814-78-2	2	100.00	—	—	—	10.41	2	E	Fungicide
Tridemorph	81412-43-3	2	1694.00	—	—	—	173.37	2	E	Fungicide
Triflumizole	68694-11-1	1	—	—	—	—	291.52	1	E	Fungicide
Triforine	26644-46-2	5	—	—	—	—	776.70	1	E	Fungicide
Triticonazole	131983-72-7	6	—	—	—	—	232.29	1	E	Fungicide
Vinclozolin	50471-44-8	1	—	—	—	—	291.52	1	E	Fungicide
Zinc borate	12447-61-9	1	—	—	—	—	261.32	1	U	Fungicide
Zineb	12122-67-7	1	—	—	—	—	212.54	1	E	Fungicide
Zirame	137-30-4	4	88.73	–0.25	5.94	0.36	29.45	—	E	Fungicide
Chemicals Primarily Active Against Plants										
2,3,6-TBA	50-31-7	2	1353.55	—	—	—	75.14	1	E	Herbicide
2,4,5-T	93-76-5	1	—	—	—	—	56.52	1	S	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
2,4-D	94-75-7	6	531.74	0.13	5.57	0.68	132.90	—	E	Herbicide
2,4-D Butotyl	1929-73-3	1	—	—	—	—	232.29	1	E	Herbicide
2,4-D Dimethylam-monium	2008-39-1	1	—	—	—	—	58.07	1	E	Herbicide
2,4-D diolamine	5742-19-8	1	—	—	—	—	69.11	1	U	Herbicide
2,4-D Isooctyl ester	1928-43-4	1	—	—	—	—	63.87	1	E	Herbicide
2,4-D sodium	2702-72-9	1	—	—	—	—	195.09	1	E	Herbicide
2,4-D Tri-isopropylamine salt	32341-80-3	1	—	—	—	—	47.04	1	U	Herbicide
2,4-DB	94-82-6	1	—	—	—	—	178.40	1	E	Herbicide
2,4-DP-p DMA salt	104786-87-0	1	—	—	—	—	32.40	1	U	Herbicide
2,4-DP Dimethylamine salt	53404-32-3	1	—	—	—	—	32.40	1	U	Herbicide
6-Benzylaminopurine (N6-Benzuladenine)	1214-39-7	1	—	—	—	—	185.71	1	E	Plant growth regulator
Acetochlor	34256-82-1	2	1133.37	—	—	—	96.27	2	E	Herbicide
Acibenzolat (CGA 245704)	135158-54-2	1	—	—	—	—	232.29	1	E	Plant activator
Acifluorfen-sodium	62476-59-9	2	1573.00	—	—	—	99.64	2	E	Herbicide
Aclonifen	74070-46-5	1	—	—	—	—	1447.88	1	E	Herbicide
Alachlor	15972-60-8	1	—	—	—	—	330.42	1	E	Herbicide
Alloxydim-sodium	55634-91-8	1	—	—	—	—	286.20	1	E	Herbicide
Ametryn	834-12-8	2	3445.00	—	—	—	336.22	2	E	Herbicide
Amidosulfuron	120923-37-7	3	2000.00	—	—	—	248.45	2	E	Herbicide
Amitrole	61-82-5	2	3575.00	—	—	—	407.29	2	E	Herbicide
Ammonium sulfamate	7773-06-0	1	—	—	—	—	289.58	1	E	Herbicide
Ancymidol	12771-68-5	1	—	—	—	—	25.32	1	E	Plant growth regulator

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Anilofos	64249-01-0	1	—	—	—	—	270.60	1	E	Herbicide
Arsenic acid	7778-39-4	1	—	—	—	—	4.23	1	U	Herbicide
Asulam	3337-71-1	4	—	—	—	—	1668.64	1	E	Herbicide
Asulam sodium	2302-17-2	4	—	—	—	—	425.80	1	E	Herbicide
Atrazine	1919-24-9	2	7118.50	—	—	—	408.98	1	E	Herbicide
Azafenidin	68049-83-2	2	2250.00	—	—	—	234.13	2	E	Herbicide
Azimsulfuron	120162-55-2	2	2250.00	—	—	—	234.13	2	E	Herbicide
Benazolin-ethyl	25059-80-7	2	4500.00	—	—	—	441.48	2	E	Herbicide
Benazolin	3813-05-6	1	—	—	—	—	984.56	1	E	Herbicide
Benfluralin	1861-40-1	2	2000.00	—	—	—	208.12	2	E	Herbicide
Benfuresate	68505-69-1	2	21136.00	—	—	—	1869.35	2	E	Herbicide
Benoxacor	98730-04-2	2	2075.00	—	—	—	215.78	2	E	Herbicide safener
Bensulfuron-methyl	83055-99-6	1	—	—	—	—	207.13	1	E	Herbicide
Bensulide	741-58-2	1	—	—	—	—	160.98	1	E	Herbicide
Bentazon	50723-80-3	4	2029.00	0.91	2.41	0.14	32.40	—	E	Herbicide
Bifenox	42576-02-3	3	5000.00	—	—	—	407.29	2	E	Herbicide
Bilanafos	35597-43-4	1	—	—	—	—	253.16	1	E	Herbicide
Bispyribac-sodium	125401-75-4	1	—	—	—	—	261.32	1	E	Herbicide
Bromacil	314-40-9	1	—	—	—	—	261.32	1	E	Herbicide
Bromoxynil	1689-84-5	2	208.50	—	—	—	21.68	2	E	Herbicide
Bromoxynil-potassium	2961-68-4	1	—	—	—	—	5.31	1	E	Herbicide
Bromoxynil (butyrate)	3861-41-4	2	825.00	—	—	—	74.79	2	U	Herbicide
Bromoxynil heptanoate	56634-95-8	1	—	—	—	—	41.70	1	U	Herbicide
Bromoxynil octanoate	1689-99-2	3	170.00	—	—	—	16.20	2	E	Herbicide
Bromoxynil Phenol	1689-84-5	3	200.00	—	—	—	21.68	2	U	Herbicide
Butachlor	23184-66-9	1	—	—	—	—	447.01	1	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Butralin	33629-47-9	2	3625.00	—	—	—	416.66	2	E	Herbicide
Butroxydim	138164-12-2	2	1610.50	—	—	—	162.61	2	E	Herbicide
Cafenstrole	125306-83-4	1	—	—	—	—	481.70	1	E	Herbicide
Capric acid/pelargonic acid	143-07-7	1	—	—	—	—	261.32	1	U	Herbicide
Carbetamide	16118-49-3	2	2000.00	—	—	—	212.54	1	E	Herbicide
Chlomethoxyfen	32861-85-1	1	—	—	—	—	—		E	Herbicide
Chloramben	133-90-4	1	—	—	—	—	159.40	1	E	Herbicide
Chloramben-ammonium	1076-46-6	1	—	—	—	—	192.68	1	U	Herbicide
Chloramben-sodium	1954-81-0	2	2000.00	—	—	—	208.12	2	U	Herbicide
Chlorflurenol	2536-31-4	1	—	—	—	—	1437.86	1	S	Growth regulator
Chloridazon	1698-60-8	2	3000.00	—	—	—	351.36	2	E	Herbicide
Chlorimuron-ethyl	90982-32-4	1	—	—	—	—	241.81	1	E	Herbicide
Chlormequat	7003-89-6	2	408.00	—	—	—	53.57	1	E	Plant growth regulator
Chlormequat chloride	999-81-5	5	555.00	–0.43	9.04	0.16	155.00	—	E	Herbicide
Chloroprop-sodium	53404-22-1	2	2334.00	—	—	—	218.55	2	U	Growth regulator
Chloroxuron	1982-47-4	2	4519.00	—	—	—	293.24	1	S	Herbicide
Chlorpropham	101-21-3	2	2000.00	—	—	—	193.05	1	E	Herbicide
Chlorsulfuron	64902-72-3	1	—	—	—	—	481.70	1	E	Herbicide
Chlorthal-dimethyl	1861-32-1	1	—	—	—	—	261.32	1	E	Herbicide
Chlorthiamid	1918-13-4	1	—	—	—	—	25.32	1	E	Herbicide
Cinmethylin	87818-31-3	1	—	—	—	—	249.71	1	E	Herbicide
Cinosulfuron	94593-91-6	2	2000.00	—	—	—	193.05	1	E	Herbicide
Clethodim	99129-21-2	1	—	—	—	—	232.29	1	E	Herbicide
Clodinafop-propargyl	105512-06-9	2	1727.50	—	—	—	177.51	2	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Clofencet	129025-54-3	2	1707.00	—	—	—	174.99	2	E	Plant growth regulator
Clomazone	81777-89-1	2	2510.00	—	—	—	261.19	2	E	Herbicide
Clopyralid	1702-17-6	2	1855.86	—	—	—	192.53	2	E	Herbicide
Cloquintocet-mexyl	99607-70-2	2	2000.00	—	—	—	208.12	2	E	Herbicide safender
Cyanazine	21725-46-2	3	445.00	—	—	—	52.41	2	E	Herbicide
Cyclanilide	113136-77-9	2	215.50	—	—	—	22.42	2	E	Plant growth regulator
Cycloate	1134-23-2	4	—	—	—	—	249.71	1	E	Herbicide
Cycloxydim	101205-02-1	2	2000.00	—	—	—	208.12	2	E	Herbicide
Cytokinin	525-79-1	1	—	—	—	—	291.52	1	U	Growth regulator
Daimuron	42609-52-9	1	—	—	—	—	232.29	1	E	Herbicide
Dalapon-sodium	127-20-8	1	—	—	—	—	286.58	1	E	Herbicide
Daminozide	1596-84-5	1	—	—	—	—	311.28	1	E	Plant growth regulator
Desmedipham	13684-56-5	1	—	—	—	—	258.67	1	E	Herbicide
Dicamba	1918-00-9	2	936.55	—	—	—	62.26	2	E	Herbicide
Dicamba-aluminum		1	—	—	—	—	241.81	1	U	Herbicide
Dicamba-diglycoamine	104040-79-1	1	—	—	—	—	44.97	1	U	Herbicide
Dicamba-dimethylammonium	2300-66-5	1	—	—	—	—	241.81	1	E	Herbicide
Dicamba-potassium	10007-85-9	1	—	—	—	—	31.94	1	E	Herbicide
Dichlobenil	1194-65-6	4	499.61	0.54	2.75	0.39	9.33	—	E	Herbicide
Dichlorprop-P	15165-67-0	1	—	—	—	—	41.06	1	E	Herbicide
Diclofop-methyl	51338-27-3	2	7971.85	—	—	—	788.26	2	E	Herbicide
Diflufenican	83164-33-4	2	3075.00	—	—	—	305.16	2	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Diflufenzopyr (BAS 654 00 H)	109293-98-3	1	—	—	—	—	541.43	1	E	Herbicide
Dikegulac-sodium	52508-35-7	1	—	—	—	—	374.86	1	E	Herbicide
Dimepiperate	61432-55-1	2	3500.00	—	—	—	193.05	1	E	Herbicide
Dimethenamid (SAN 582)	87674-68-8	1	—	—	—	—	221.60	1	E	Herbicide
Dimethipin	55290-64-7	1	—	—	—	—	84.78	1	E	Herbicide, plant growth regulator
Dinitramine	29091-05-2	2	5600.00	—	—	—	360.47	2	E	Herbicide
Dinoseb	88-85-7	5	19.90	0.42	0.31	0.01	3.18	—	S	Herbicide
Dinoseb acetate	2813-95-8	2	16.66	—	—	—	2.29	1	S	Herbicide
Dinoterb	1420-07-1	2	25.00	—	—	—	—	—	E	Herbicide
Diquat (dibromide)	85-00-7	3	184.87	—	—	—	17.81	1	E	Herbicide
Disodium methane-arsonate	144-21-8	1	—	—	—	—	72.82	1	E	Herbicide
Dithiopyr	97886-45-8	1	—	—	—	—	261.32	1	E	Herbicide
Diuron	330-54-1	3	2000.00	—	—	—	193.04	2	E	Herbicide
DMPA	299-85-4	1	—	—	—	—	25.32	1	S	Herbicide
DNOC	534-52-1	5	21.15	0.15	1.97	0.36	6.67	—	E	Herbicide
Endothall	145-73-3	2	326.72	—	—	—	29.20	2	E	Herbicide, algicide, plant growth regulator
Endothall (dimethylal-kylamine)	66330-88-9	1	—	—	—	—	37.48	1	U	Herbicide, algicide, plant growth regulator

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Endothall (dipotassium salt)	2164-07-0	1	—	—	—	—	31.60	1	U	Herbicide, algicide, plant growth regulator
EPTC	759-94-4	3	1000.00	—	—	—	25.32	1	E	Herbicide
Esprocarb	85785-20-2	1	—	—	—	—	193.05	1	E	Herbicide
Ethalfluralin	55283-68-6	1	—	—	—	—	232.29	1	E	Herbicide
Ethametsulfuron-methyl	97780-06-8	1	—	—	—	—	261.32	1	E	Herbicide
Ethephon	16672-87-0	4	1924.00	0.21	6.24	0.48	372.20	—	E	Herbicide
Ethidimuron	30043-49-3	4	513.21	0.78	2.69	0.03	59.64	—	S	Herbicide
Ethofumesate	26255-79-6	3	3464.10	—	—	—	472.79	2	E	Herbicide
Fenchlorazole	103112-36-3	2	1333.84	—	—	—	25.84	1	S	Herbicide
Fenclorim	3740-92-9	2	2750.00	—	—	—	48.26	1	E	Herbicide safener
Fenoprop	93-72-1	2	9320.00	—	—	—	1091.75	1	S	Herbicide
Fenoxaprop	95617-09-7	3	2510.00	—	—	—	440.07	2	S	Herbicide
Fenoxaprop-ethyl	66441-23-4	3	2510.00	—	—	—	440.07	2	S	Herbicide
Fenoxaprop-P	113158-40-0	3	—	—	—	—	232.29	2	E	Herbicide
Fenoxaprop-*P*-ethyl	71283-80-2	1	—	—	—	—	232.29	1	E	Herbicide
Fenridazone-sodium	83588-43-6	1	—	—	—	—	495.70	1	U	Herbicide
Fenuron	101-42-8	4	—	—	—	—	232.29	1	E	Herbicide
Ferric sulfate (see Ferrous sulfate)	10028-22-5	1	—	—	—	—	261.32	1	U	Herbicide
Ferrous sulfate heptahydrate	7782-63-0	1	—	—	—	—	261.32	1	E	Herbicide
Ferrous sulfate monohydrate	17375-41-6	1	—	—	—	—	249.71	1	U	Herbicide
Flamprop-M-methyl	63729-98-6	1	—	—	—	—	447.88	1	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Flamprop-methyl	52756-25-9	3	1000.00	—	—	—	106.27	1	S	Herbicide
Flamprop isopropyl	52756-22-6	2	1500.00	—	—	—	106.27	1	S	Herbicide
Flazasulfuron	104040-78-0	1	—	—	—	—	193.05	1	E	Herbicide
Fluazifop-butyl	69806-50-4	1	—	—	—	—	746.09	1	E	Herbicide
Fluazifop-*P*-butyl	79241-46-6	1	—	—	—	—	339.88	1	E	Herbicide
Flumetralin	62924-70-3	2	2150.00	—	—	—	223.73	2	E	Growth regulator
Flumetsulam	98967-40-9	1	—	—	—	—	261.32	1	E	Herbicide
Flumiclorac-pentyl	87546-18-7	1	—	—	—	—	261.32	1	E	Herbicide
Fluometuron	2164-17-2	1	—	—	—	—	192.68	1	E	Herbicide
Fluoroglycofen	77501-60-1	1	—	—	—	—	214.07	1	E	Herbicide
Fluoroglycofen-ethyl	77501-90-7	1	—	—	—	—	367.02	1	E	Herbicide
Fluoxypyr-meptyl	81406-37-3	2	2000.00	—	—	—	208.12	2	E	Herbicide
Flupoxam	119126-15-7	2	2250.00	—	—	—	234.13	2	E	Herbicide
Flupyrsulfuron-methyl-sodium	144740-54-5	1	—	—	—	—	216.76	1	E	Herbicide
Flurazole	72850-64-7	1	—	—	—	—	291.52	1	E	Herbicide safender
Fluridone	59756-60-4	1	—	—	—	—	232.29	1	E	Herbicide
Flurochloridone	61213-25-0	1	—	—	—	—	249.71	1	E	Herbicide
Fluroxypyr	69377-81-7	2	2000.00	—	—	—	208.12	2	E	Herbicide
Flurprimidol	56425-91-3	1	—	—	—	—	232.29	1	E	Plant growth regulator
Fluxofenim	88485-37-4	1	—	—	—	—	232.29	1	E	Herbicide safender
Fomesafen	72178-02-0	1	—	—	—	—	481.70	1	E	Herbicide
Forchlorfenuron	68157-60-8	1	—	—	—	—	261.32	1	E	Plant growth regulator

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Fosamine ammonium	25954-13-6	2	4791.29	—	—	—	498.10	2	E	Herbicide
Furilazole	121776-33-8	1	—	—	—	—	23.23	1	E	Herbicide safender
Gibberellic acid	77-06-5	1	—	—	—	—	261.32	1	E	Growth regulator
Glufosinate-ammonium	51276-47-2	4	—	—	—	—	232.29	1	E	Herbicide
Glyphosate	1071-83-6	1	—	—	—	—	232.29	1	E	Herbicide
Glyphosate-trimesium (sulfosate)	81591-81-3	2	1487.50	—	—	—	144.33	2	E	Herbicide
Halosulfuron-methyl	100784-20-1	1	—	—	—	—	261.32	1	E	Herbicide
Haloxyfop	69806-34-4	1	—	—	—	—	207.13	1	E	Herbicide
Haloxyfop-P-methyl	72619-32-0	1	—	—	—	—	134.61	1	E	Herbicide
Haloxyfop ethoxyethyl (etotyl)	87237-48-7	1	—	—	—	—	207.13	1	E	Herbicide
Hexaflurate	17029-22-0	3	193.00	—	—	—	18.59	1	S	Herbicide
Hexazinone	51235-04-2	1	—	—	—	—	261.44	1	E	Herbicide
Hydrogen cyanamide	420-04-2	1	—	—	—	—	28.74	1	E	Herbicide, plant growth regulator
ICIS-0748	81052-29-1	2	2150.00	—	—	—	223.73	2	E	Growth regulator
Imazamethabenz	100728-84-5	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazamethabenz-methyl	81405-85-8	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazamox	114311-32-9	1	—	—	—	—	214.40	1	E	Herbicide
Imazapic (AC 263,222)	104098-49-9	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazapyr	81334-34-1	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazaquine	81335-37-7	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazethapyr	81335-77-5	2	2150.00	—	—	—	223.73	2	E	Herbicide
Imazosulfuron	122548-33-8	2	2250.00	—	—	—	234.13	2	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Indole-3-butyric acid	133-32-4	1	—	—	—	—	249.71	1	E	Plant growth regulator
Ioxynil	1689-83-4	4	68.50	0.10	3.68	0.54	33.28	—	E	Herbicide
Ioxynil octanoate	3861-47-0	4	385.42	0.29	4.19	0.64	19.41	—	E	Herbicide
Isopropalin	33820-53-0	1	—	—	—	—	232.29	1	S	Herbicide
Isoproturon	34123-59-6	3	4543.04	—	—	—	313.40	2	E	Herbicide
Isouron	55861-78-4	1	—	—	—	—	232.29	1	E	Herbicide
Isoxaben	82558-50-7	1	—	—	—	—	232.29	1	E	Herbicide
Isoxaflutole	141112-29-0	1	—	—	—	—	207.13	1	E	Herbicide
Karbutilate	4849-32-5	1	—	—	—	—	579.15	1	S	Herbicide
L-Lactic acid	50-21-5	1	—	—	—	—	261.32	1	U	Growth regulator
Lactofen	77501-63-4	1	—	—	—	—	291.52	1	E	Herbicide
Lenacil	2164-08-1	1	—	—	—	—	—		E	Herbicide
Linuron	330-55-2	3	505.00	—	—	—	65.07	2	E	Herbicide
Maleic hydrazide potassium salt	51542-52-0	1	—	—	—	—	216.76	1	E	Plant growth regulator
MCPA	94-74-6	2	377.00	—	—	—	39.23	2	E	Herbicide
MCPA-thioethyl	25319-90-8	1	—	—	—	—	289.58	1	E	Herbicide
MCPA dimethylamine salt	2039-46-5	1	—	—	—	—	55.54	1	U	Herbicide
MCPB-sodium	6062-26-6	1	—	—	—	—	32.75	1	E	Herbicide
MCPP Isooctyl ester	28473-03-2	1	—	—	—	—	261.32	1	U	Herbicide
Mecoprop	7085-19-0	1	—	—	—	—	82.11	1	E	Herbicide
Mecoprop-P	16484-77-8	2	2361.00	—	—	—	151.19	2	E	Herbicide
Mecoprop dimethylamine salt	32351-70-5	1	—	—	—	—	69.92	1	U	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Mefenpyr-diethyl	135590-91-9	1	—	—	—	—	193.05	1	E	Herbicide safener
Mefluidide	53780-36-2	1	—	—	—	—	353.05	1	E	Plant growth regulator, herbicide
Mepiquat chloride	24307-26-4	1	—	—	—	—	232.29	1	E	Plant growth regulator
Metam-sodium	6734-80-1	1	—	—	—	—	58.07	1	E	Herbicide
Metamitron	41394-05-2	2	1027.72	—	—	—	176.82	1	E	Herbicide
Metazachlor	67129-08-2	2	2255.00	—	—	—	233.15	2	E	Herbicide
Methabenzthiazuron	18691-97-9	1	—	—	—	—	96.53	1	E	Herbicide
Methylarsonic acid	124-58-3	1	—	—	—	—	49.36	1	E	Herbicide
Metobromuron	3060-89-7	2	4036.00	—	—	—	137.93	1	E	Herbicide
Metolachlor	51218-45-2	1	—	—	—	—	241.81	1	E	Herbicide
Metosulam	139528-85-1	2	2125.00	—	—	—	220.74	2	E	Herbicide
Metribuzin	21087-64-9	2	459.86	—	—	—	42.01	2	E	Herbicide
Metsulfuron	79510-48-8	1	—	—	—	—	241.81	1	E	Herbicide
Metsulfuron-methyl	74223-64-6	2	2510.00	—	—	—	261.19	2	E	Herbicide
Molinate	2212-67-1	1	—	—	—	—	214.16	1	E	Herbicide
Monolinuron	1746-81-2	3	1690.00	—	—	—	181.27	2	E	Herbicide
Monosodium methyl-arsonate	2163-80-6	1	—	—	—	—	96.86	1	E	Herbicide
Napropamide	15299-99-7	1	—	—	—	—	78.03	1	E	Herbicide
Napthaleneacetic acid	2122-70-5	2	2302.92	—	—	—	238.67	2	E	Growth regulator
Nicosulfuron	111991-09-4	2	2000.00	—	—	—	208.12	2	E	Herbicide
Nonanoic acid	112-05-0	1	—	—	—	—	261.32	1	E	Herbicide, plant growth regulator
Norflurazon	27314-13-2	2	1292.15	—	—	—	130.98	2	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Orbencarb	34622-58-7	2	2000.00	—	—	—	208.12	2	E	Herbicide
Oryzalin	19044-88-3	2	503.35	—	—	—	52.38	2	E	Herbicide
Oxabentrinil	74782-23-3	3	2500.00	—	—	—	439.20	2	E	Herbicide safener
Oxadiazon	19666-30-9	2	2274.16	—	—	—	192.89	2	E	Herbicide
Oxasulfuron	144651-06-9	1	—	—	—	—	216.76	1	E	Herbicide
Oxyfluorfen	42874-03-3	1	—	—	—	—	614.58	1	E	Herbicide
Paclobutrazol	76738-62-0	2	4953.25	—	—	—	193.05	1	E	Plant growth regulator
Paraquat dichloride	1910-42-5	4	243.32	0.12	4.65	0.37	88.50	—	E	Herbicide
Pebulate	1114-71-2	1	—	—	—	—	192.68	1	E	Herbicide
Pentoxazone	110956-75-7	1	—	—	—	—	261.32	1	E	Herbicide
Phenmedipham	13684-63-4	3	3107.23	—	—	—	299.93	1	E	Herbicide
Phenyl-indole-3-thiobutyrate	85977-73-7	1	—	—	—	—	216.76	1	U	Herbicide
Phthalanilic acid	4727-29-1	2	10700.00	—	—	—	1032.82	1	E	Plant growth regulator
Picloram	1918-02-1	3	2927.91	—	—	—	528.69	1	E	Herbicide
Picloram-potassium	2545-60-0	3	2121.32	—	—	—	482.63	1	E	Herbicide
Picloram TIPA	6753-47-5	1	—	—	—	—	216.76	1	U	Herbicide
Pretilachlor	51218-49-6	1	—	—	—	—	965.25	1	E	Herbicide
Primisulfuron-methyl	86209-51-0	2	2150.00	—	—	—	223.73	2	E	Herbicide
Prodiamine	29091-21-2	1	—	—	—	—	261.32	1	E	Herbicide
Prohexadione-calcium	127277-53-6	2	2000.00	—	—	—	208.12	2	E	Plant growth regulator
Prometon	1610-18-0	1	—	—	—	—	262.95	1	E	Herbicide
Propachlor	1918-16-7	1	—	—	—	—	10.57	1	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Propanil	709-98-8	1	—	—	—	—	23.34	1	E	Herbicide
Propaquizafop	111479-05-1	2	2099.00	—	—	—	218.18	2	E	Herbicide
Propham	122-42-9	1	—	—	—	—	193.05	1	E	Herbicide
Propisochlor	86763-47-5	2	1344.00	—	—	—	66.41	1	E	Herbicide
Propyzamide	23950-58-5	2	5733.87	—	—	—	733.08	1	E	Herbicide
Prosulfocarb	52888-80-9	3	1650.00	—	—	—	232.82	1	E	Herbicide
Prosulfuron	94125-34-5	2	1622.00	—	—	—	159.59	2	E	Herbicide
Pyrazosulfuron-ethyl	93697-74-6	1	—	—	—	—	261.32	1	E	Herbicide
Pyridate	55512-33-9	1	—	—	—	—	160.51	1	E	Herbicide
Pyriminobac-methyl	136191-56-5	1	—	—	—	—	232.29	1	E	Herbicide
Pyrithiobac-sodium	123343-16-8	1	—	—	—	—	185.71	1	E	Herbicide
Quinclorac	84087-01-4	2	1974.68	—	—	—	205.46	2	E	Herbicide
Quinmerac	90717-03-6	1	—	—	—	—	232.29	1	E	Herbicide
Quizalofop	76578-12-6	2	2000.00	—	—	—	208.12	2	E	Herbicide
Quizalofop-ethyl	76578-14-8	2	2000.00	—	—	—	208.12	2	U	Herbicide
Quizalofop-*P*-ethyl	100646-51-3	2	2000.00	—	—	—	208.12	2	E	Herbicide
Quizalofop-*P*-tefuryl	119738-06-6	2	2150.00	—	—	—	223.73	2	E	Herbicide
Rimsulfuron	122931-48-0	2	1623.16	—	—	—	160.75	2	E	Herbicide
Sebuthylazine	7286-69-3	2	2732.05	—	—	—	334.37	1	S	Herbicide
Sethoxydim	74051-80-2	2	3755.00	—	—	—	482.63	1	E	Herbicide
Siduron	1982-49-6	1	—	—	—	—	2584.20	1	E	Herbicide
Simazine	122-34-9	2	7500.00	—	—	—	965.25	1	E	Herbicide
Sodium arsenite	7784-46-5	5	48.00	1.05	−1.89	0.14	0.55	—	U	Herbicide, insecticide
Sodium dimethylarsinate	124-65-2	1	—	—	—	—	261.32	1	E	Herbicide
Sulcotrione	99105-77-8	2	1800.00	—	—	—	181.36	2	E	Herbicide
Sulfentrazone	122836-35-5	1	—	—	—	—	261.32	1	E	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	$HD_5(50\%)$	#_EF	Status	Use
Sulfometuron-methyl	74222-97-2	1	—	—	—	—	481.70	1	E	Herbicide
TCA-sodium	650-51-1	1	—	—	—	—	216.71	1	E	Herbicide
Tebuthiuron	34014-18-1	2	750.00	—	—	—	73.58	2	E	Herbicide
Terbacil	5902-51-2	1	—	—	—	—	262.37	1	E	Herbicide
Terbuthylazine	5915-41-3	2	1292.15	—	—	—	130.98	2	E	Herbicide
Tetradec-11-en-1-yl acetate	20711-10-8	1	—	—	—	—	249.71	1	E	Herbicide
Thenylchlor	96491-05-3	1	—	—	—	—	232.29	1	E	Herbicide
Thiazafluron	25366-23-8	1	—	—	—	—	25.58	1	S	Herbicide
Thiazopyr	117718-60-2	1	—	—	—	—	222.18	1	E	Herbicide
Thidiazuron	51707-55-2	1	—	—	—	—	367.02	1	E	Plant growth regulator
Thifensulfuron	79277-67-1	1	—	—	—	—	241.81	1	E	Herbicide
Thifensulfuron-methyl	79277-27-3	2	2510.00	—	—	—	261.19	2	E	Herbicide
Thiobencarb	28249-77-6	1	—	—	—	—	225.09	1	E	Herbicide
Tiocarbazil	36756-79-3	2	10000.00	—	—	—	1062.70	1	E	Herbicide
Tralkoxydim	87820-88-0	2	3725.00	—	—	—	290.94	1	E	Herbicide
Tri-allate	2303-17-5	1	—	—	—	—	261.44	1	E	Herbicide
Triapenthenol	76608-88-3	1	—	—	—	—	482.63	1	S	Plant growth regulator
Triasulfuron	82097-50-5	2	2150.00	—	—	—	223.73	2	E	Herbicide
Tribenuron	106040-48-6	1	—	—	—	—	261.32	1	E	Herbicide
Tribenuron-methyl	101200-48-0	1	—	—	—	—	261.32	1	E	Herbicide
Tribufos	78-48-8	3	273.00	—	—	—	51.13	2	E	Plant growth regulator
Triclopyr BEE	64700-56-7	1	—	—	—	—	91.76	1	U	Herbicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Trifluralin	1582-09-8	4	—	—	—	—	245.55	1	E	Herbicide
Triflusulfuron	135990-29-3	2	2250.00	—	—	—	234.13	2	E	Herbicide
Triflusulfuron-methyl	126535-15-7	2	2250.00	—	—	—	234.13	2	E	Herbicide
Trinexapac-ethyl	95266-40-3	1	—	—	—	—	192.68	1	E	Plant growth regulator
Uniconazole	83657-17-4	2	1888.00	—	—	—	191.37	2	E	Plant growth regulator
Vernolate	1929-77-7	2	3445.00	—	—	—	336.22	2	E	Herbicide
Chemicals Primarily Active Against Vertebrates or Tested as Vertebrate Control Agents										
[(3-Amino-2,4,6-trichloro phenyl) methylene]hydrazide		1	—	—	—	—	34.01	1	U	Rodenticide
Benzenesulfonic acid (Bay 98663) 1,3-di-(fluorosulfonyl)cyclo-pentane (PHILLIPS 2133)	35944-73-1	7	3.16	0.28	–0.37	0.23	0.61	—	U	Rodenticide
1,3-Propanediol,2,2-bis(chloromethyl)-sulfate (PHILLIPS 2605)	12712-28-6	6	8.75	0.38	0.11	0.29	0.90	—	U	Tested as vertebrate agent
3-Chloro-*P*-toluidine		10	22.45	–0.02	2.88	0.97	0.30	—	U	Avicide
4-Aminopyridine (Avitrol)	504-24-5	33	5.34	–0.01	1.68	0.92	1.79	—	U	Avicide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
5-(*p*-Chlorophenyl)-3,7,10-trimethyl silatrane (D.M. 7537)		4	8.52	1.14	−5.20	0.05	0.04	—	U	Rodenticide
6-Aminonicotinamide		1	—	—	—	—	0.77	1	U	Rodenticide
Alpha-chloralose	15879-93-3	18	69.16	0.26	3.12	0.07	14.05	—	E	Rodenticide
Anthraquinone	84-65-1	3	2000.00	—	—	—	193.05	1	E	Bird Repellent
BAY COE 3664	39457-24-4	9	5.62	0.28	0.34	0.15	1.11	—	U	Tested as vertebrate agent
BAY COE 3675	39457-25-5	9	2.37	0.69	−2.03	0.00	0.38	—	U	Tested as vertebrate agent
Brodifacoum	56073-10-0	8	9.1	−0.12	2.49	0.77	0.81	—	E	Rodenticide
Bromadiolone	28772-56-7	2	676.58	—	—	—	53.26	2	E	Rodenticide
Bromethalin	63333-35-7	1	—	—	—	—	0.83	1	E	Rodenticide
Chlorophacinone	3691-35-8	6	25.45	−1.53	13.21	0.01	3.32	—	E	Rodenticide
Cholecalciferol (vitamin D_3)	67-97-0	1	—	—	—	—	192.68	1	E	Rodenticide
Coumatetralyl	5836-29-3	3	37.50	—	—	—	193.05	1	E	Rodenticide
Difenacoum	56073-07-5	1	—	—	—	—	9.32	1	E	Rodenticide
Difethialone	104653-34-1	3	0.87	—	—	—	0.31	2	E	Rodenticide
Flocoumafen	90035-08-8	4	51.25	−0.64	6.45	0.50	0.07	—	E	Rodenticide
Fluoroacetamide	640-19-7	2	9.46	—	—	—	1.42	1	E	Rodenticide
Methyl anthralinate	134-20-3	2	1216.17	—	—	—	82.26	2	U	Repellent
Metomidate	5377-20-8	11	74.97	0.11	3.91	0.52	24.05	—	U	Tested as vertebrate agent
Metomidate HCl	35944-74-2	8	56.20	0.15	3.24	0.03	26.85	—	U	Tested as vertebrate agent

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Status	Use
Pentobarbital-sodium	57-33-0	8	107.66	0.00	4.71	0.97	48.93	—	U	Soporific
Phencyclidine HCl	956-90-1	13	75.00	0.14	3.63	0.57	9.32	—	U	Tested as vertebrate agent
Phosacetim	4104-14-7	12	16.61	0.19	2.00	0.68	0.41	—	S	Rodenticide
Pindone	83-26-1	1	—	—	—	—	27.99	1	E	Rodenticide
Polyethoxylated aliphatic alcohols	68131-40-8	3	2006.00	—	—	—	227.85	1	U	Repellent
Scilliroside	507-60-8	1	—	—	—	—	1.35	1	S	Rodenticide
Sodium fluoroacetate (compound 1080)	62-74-8	55	5.46	0.18	0.82	0.01	0.85	—	E	Rodenticide
Sodium wafarin	129-0601	2	1310.50	—	—	—	115.97	2	U	Rodenticide
Starlicide	7745-89-3	31	5.62	–0.08	2.82	0.73	0.43	—	U	Avicide
Strychnine	57-24-9	17	6.00	0.15	1.47	0.36	1.04	—	E	Rodenticide
Terrtiary butylsulfenyl-dimethyl dithiocarbamate		1	—	—	—	—	108.01	1	U	Rodenticide
TFM (4-Nitro-3-[trifluoromethyl]phenol)	88-30-2	1	—	—	—	—	44.12	1	U	Lampricide
Thallium sulfate	7446-18-6	4	40.48	0.10	3.10	0.70	8.93	—	U	Rodenticide
Warfarin	81-81-2	3	970.57	—	—	—	120.21	2	E	Rodenticide
Zinc phosphide	1314-84-7	7	44.85	–0.34	5.40	0.15	5.45	—	E	Rodenticide

Table 3. (Continued).

Chemical	CAS_RN	N	Median	Slope	Intercept	*p*	$HD_5(50\%)$	#_EF	Status	Use
CHEMICALS WITH UNKNOWN SPECTRUM OF ACTIVITY										
Brofenprox		2	1942.00	—	—	—	201.99	2	E	Unknown
Chloretazate		2	2150.00	—	—	—	207.53	1	U	Unknown
Chloromethylmercury	115-09-3	1	—	—	—	—	1.74	1	U	Unknown
Cloxynil-sodium		1	—	—	—	—	3.72	1	U	Unknown
Dibromoitrilopropi-onamide		2	184.11	—	—	—	18.96	2	U	Unknown
Dichlorprop (racemic acid)	7547-66-2	1	—	—	—	—	48.65	1	E	Unknown
Flumequine	42835-25-6	2	2500.00	—	—	—	96.53	1	U	Unknown
Fluprimidol		1	—	—	—	—	232.29	1	U	Unknown
Hexachlorbenzol		1	—	—	—	—	482.63	1	U	Unknown
Propenamide	79-06-1	1	—	—	—	—	19.26	1	U	Unknown

Table 4. List of pesticides currently in use with $HD_5(50\%)$ below 1 mg/kg.

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	$HD_5(50\%)$	#_EF	Use Pattern
CHOLINESTERASE-INHIBITING INSECTICIDES									
Thiofanox	39196-18-4	3	1.20	na	na	na	0.12	1	
Terbufos	13071-79-9	5	9.48	1.0277	−1.5328	0.32	0.16	—	
Propaphos	7292-16-2	1	—	na	na	na	0.18	1	
Carbofuran	1563-66-2	18	1.65	0.0423	0.257	0.82	0.21	—	
Phorate	298-02-2	8	7.06	0.1817	0.4833	0.65	0.34	—	
Parathion	56-38-2	19	5.62	0.0797	1.2228	0.76	0.40	—	
Quinalphos	13593-03-8	2	20.65	na	na	na	0.42	1	
Dicrotophos	141-66-2	15	2.83	0.1787	0.3645	0.32	0.42	—	
Monocrotophos	6923-22-4	23	2.51	−0.0312	1.0218	0.79	0.42	—	
Aldicarb	116-06-3	10	2.82	0.2955	−0.6559	0.12	0.43	—	
Fenamiphos	22224-92-6	5	1.10	−0.0863	0.5444	0.66	0.43	—	
Isofenphos	25311-71-1	6	10.96	0.0994	2.7255	0.86	0.44	—	
Famphur	52-85-7	3	2.70	na	na	na	0.45	1	
Isazofos	42509-80-8	3	11.10	na	na	na	0.51	2	
EPN	2104-64-5	14	6.43	0.3624	0.604	0.33	0.53	—	
Diazinon	333-41-5	14	5.25	−0.2608	3.5883	0.29	0.59	—	

Table 4. (Continued).

Compound	CAS_RN	*n*	Median	Slope	Intercept	*p*	HD_5(50%)	#_EF	Use Pattern
Coumaphos	56-72-4	12	6.78	0.2179	0.7579	0.36	0.69	—	
Mevinphos	7786-34-7	13	3.80	0.0254	0.9409	0.88	0.70	—	
Bendiocarb	22781-23-3	4	16.24	–0.9475	8.3724	0.37	0.72	—	
Oxamyl	23135-22-0	3	4.18	na	na	na	0.78	2	
Disulfoton	298-04-4	7	11.90	0.2019	1.2104	0.60	0.81	—	
Cyanophos	2636-26-2	1	—	na	na	na	0.83	1	
Fenthion	55-38-9	23	5.62	0.2581	0.4784	0.07	0.87	—	
Triazamate	112143-82-5	1	—	—	—	—	0.93	1	
NONCHOLINESTERASE INHIBITORS									
Phenylmercuric acetate (PMA)	62-38-4	4	145.86	2.19	–9.43	0.16	0.01	—	Fungicide
Flocoumafen	90035-08-8	4	51.25	–0.64	6.45	0.50	0.07	—	Rodenticide
Chlordane	57-74-9	4	62.28	1.00	–1.63	0.44	0.09	—	Insecticide
Difethialone	104653-34-1	3	0.87	—	—	—	0.31	2	Rodenticide
Bensultap	17606-31-4	4	192.00	1.35	–2.11	0.23	0.41	—	Insecticide
Chlorfenapyr	122453-73-0	2	8.30	—	—	—	0.56	1	Insecticide, acaricide
Fenfuram	24691-80-3	1	—	—	—	—	0.69	1	Fungicide
Brodifacoum	56073-10-0	8	9.1	–0.12	2.49	0.77	0.81	—	Rodenticide
Bromethalin	63333-35-7	1	—	—	—	—	0.83	1	Rodenticide
Sodium fluoracetate	62-74-8	55	5.46	0.18	0.82	0.01	0.85	—	Rodenticide

III. Results and Discussion

Cholinesterase-inhibiting pesticides are grouped together in Table 2; all others are in Table 3. Pesticides are ordered alphabetically by their common chemical names except when a trade name only is available. A few trade names and synonyms are given to facilitate identification. All names follow the 11th Edition of the *Pesticide Manual* (Tomlin 1997) supplemented by the Nanogen Index (Packer 1975; Walker 1989). Tomlin (1997) was also used to determine whether any given product is still in commerce or is thought to no longer be marketed (superseded entries).

One advantage of this process is that it allows us to identify which pesticides currently in use are most toxic to birds and to start using some of the better known products for which field studies or incident records exist as possible "benchmarks" for equally toxic but more poorly known chemicals. From Tables 2 and 3, we arbitrarily selected those pesticides with an HD_5(50%) less than 1 mg/kg (Table 4). Of the 34 pesticides identified, 24 are cholinesterase-inhibiting insecticides. Of the remaining 10 products, 2 are insecticides including the very new pyrrole insecticide chlorfenapyr, 2 are fungicides, and the rest are rodenticides, including 3 of the second-generation coumarin anticoagulant products. Interestingly, the cholinesterase inhibitor thought to be the most toxic to birds is thiofanox (trade name Dacamox). According to the *Pesticide Manual* (Tomlin 1997), this granular and seed treatment insecticide is of only moderate toxicity to birds with LD_{50} values of 109 mg/kg and 43 mg/kg in the mallard and the bobwhite, respectively. However, this is one of those few cases where this data source is in error. The values cited by Tomlin (1997) are in fact dietary LC_{50} values; the true acute toxicity values are lower by 1.5 to 2 orders of magnitude.

In an early review of bird-kill incidents by Grue and colleagues (1983), these authors found that most incidents could be explained on the basis of pesticide toxicity and the extent to which the pesticides were used in U.S. agriculture. In a recent review of raptor incidents (Mineau et al. 1999), the higher proportion of kills resulting from labeled uses of pesticides in Canada and the U.S. relative to the U.K. was determined to be a result of the more permissive use of pesticides highly toxic to birds in North America. Certainly, those individuals familiar with pesticide bird-kill incidents throughout the world will recognize a number of compounds from Table 4 that keep coming back with depressing regularity. We believe that we have laid the groundwork for a more comprehensive review of those pesticides most hazardous to wild birds and for a fair comparison between older products and newer replacements. Recognizing that there are very few uses of pesticides that do not result in exposure to birds, we urge regulatory authorities to consider avian acute toxicity more closely before making regulatory decisions.

Acknowledgments

We thank all the individuals, companies, and institutions who volunteered data for this effort. We also thank Charles Benbrook, and the Consumers Union as well as the W. Alton Jones Foundation for the support necessary to perform the

time-consuming vetting of the database. A number of individuals demonstrated an infinite degree of patience with this task, particularly Rob Kriz and Lynn Schirml. We are grateful to Tom Aldenberg and Rick Bennett for comments on an earlier draft of this paper. Over the years, we benefitted from many a discussion with colleagues from around the world on this subject and, without being able to thank them all, would like to acknowledge at least the OECD, SETAC, and the USEPA for holding many of the forums where these discussions took place.

Appendix 1. Comparison of the equations for the expected value and variance from a sample with and without a covariate for bird weight. (A Fortran program to compute an HD_5 with body weight as a covariate is available by writing to the authors.)

	Without covariate	With covariate
Estimated expected value	$\bar{y} = \sum yi/n$	$\hat{y}_o = \bar{y} + b(x_o - \bar{x})$
Variance of estimated expected value	$\sigma^2 \left[\frac{1}{n} \right]$	$\sigma^2 \left[\frac{1}{n} + \frac{(x_o - \bar{x})^2}{\sum (xi - \bar{x})^2} \right]$
Variance estimate (s^2)	$\sum (yi - \bar{y})^2/(n-1)$	$\sum (yi - \hat{y}_i)^2/(n-2)$
Degrees of freedom	$n - 1$	$n - 2$

$$b = \frac{\sum y_i(x_i - \bar{x})}{\sum (x_i - \bar{x})^2}$$

$$\hat{y}_i = \bar{y} + b(x_i - \bar{x})$$

x_0 is the logarithm of the weight of the bird which you want to protect
$\hat{y}_0$ is the expected value of the logarithm of the LD_{50} for the species of weight x_0
σ is the standard deviation of the original $\log(LD_{50})$ data set
σ^2 is the unknown true population variance of the original $\log(LD_{50})$ data set
s^2 is the estimator of the variance

References

Aldenberg T, Slob W (1993) Confidence limits for hazardous concentrations based on logistically distributed NOEC toxicity data. Ecotoxicol Environ Saf 25:48–63.

Baril A, Mineau P (1996) A distribution-based approach to improving avian risk assessment (abstract). 17th Annual SETAC, Washington, DC.

Baril A, Jobin B, Mineau P, Collins BT. (1994) A consideration of inter-species variability in the use of the median lethal dose (LD_{50}) in avian risk assessment. Tech Rep Series 216 Canadian Wildlife Service Headquarters, Hull, Québec.

Benbrook CM, Groth E, Halloran JM, Hansen MK, Marquardt S (1996) Pest Management at the Crossroads. Consumers Union, Yonkers, NY.

Dunning JB (1993) CRC Handbook of Avian Body Masses. CRC Press, Boca Raton.

Fischer DL, Hancock GA (1997) Interspecies extrapolation of acute toxicity in birds: body size scaling vs. phylogeny (abstract) 18th Annual SETAC. San Francisco, CA.

Grolleau G, Caritez JL (1986). Toxicité par ingestion forcée, de différents pesticides

pour la perdrix grise, *Perdix perdix* L. et la perdrix rouge, *Alectoris rufa* L. Gibier Faune Sauvage 3:185–196.

Grue CE, Fleming WJ, Busby DG, Hill EF (1983) Assessing hazards of organophosphate pesticides to wildlife. Trans N Am Wildl Nat Res Conf (Washington, DC) 48:200–220.

Hart ADM, Thompson HM (1995) Significance of regurgitation in avian toxicity tests. Bull Environ Contam Toxicol 54:789–796.

Hudson RH, Tucker RK, Haegele MA (1984) Handbook of Toxicity of Pesticides to Wildlife. No. 153. U.S. Dept. of the Interior, Fish and Wildlife Service, Washington, DC.

Joermann G (1991) Comparative toxicity of pesticides to birds. Nachrbl Dtsch, Pflanzenschutzd (Stuttg) 43:275–279.

Kooijman SALM (1987) A safety factor for LC_{50} values allowing for differences in sensitivity among species. Water Res 21:269–276.

Luttik R, Aldenberg T (1995) Extrapolation factors to be used in case of small samples of toxicity data (with special focus on LD_{50} values for birds and mammals). RIVM Report. National Institute of Public Health and Environment. Bilthoven, The Netherlands.

Luttik R, Aldenberg T (1997) Extrapolation factors for small samples of pesticide toxicity data: special focus on LD_{50} values for birds and mammals. Environ Toxicol Chem 16:1785–1788.

Mineau P (1991) Difficulties in the regulatory assessment of cholinesterase-inhibiting insecticides. In: Mineau P (ed) Cholinesterase Inhibiting Insecticides. Elsevier, Amsterdam, pp 277–299.

Mineau P, Jobin B, Baril A (1994) A critique of the avian 5-day dietary test (LC_{50}) as the basis of avian risk assessment. Tech Rep No. 215. Canadian Wildlife Service Headquarters, Hull, Québec.

Mineau P, Collins BT, Baril A (1996) On the use of scaling factors to improve interspecies extrapolation of acute toxicity in birds. Regul Toxicol Pharmacol 24:24–29.

Mineau P, Fletcher MR, Glaser LC, Thomas NJ, Brassard C, Wilson LK, Elliott JE, Lyon L, Henny CJ, Bollinger T, Porter SL (1999) Poisoning of raptors with organophosphorus and carbamate pesticides with emphasis on Canada, U.S., and U.K. J Raptor Res 33:1–37.

Newman MC, Ownby DR, Mezin LCA, Powell DC, Christensen TRL, Lerberg SB, Anderson BA (2000) Applying species-sensitivity distributions in ecological risk assessment: assumptions of distribution type and sufficient number of species. Environ Toxicol Chem 19:508–515.

Packer K (1975) Nanogen Index: A Dictionary of Pesticides and Chemical Pollutants. Nanogens International, Freedom, CA.

Sample BE, Arenal CA (1999) Allometric models for interspecies extrapolation of wildlife toxicity data. Bull Environ Contam Toxicol 62:653–663.

Schafer EW, Brunton RB (1979) Indicator bird species for toxicity determinations: is the technique usable in test method development? In: Beck JR (ed) Vertebrate Pest Control and Management Materials. American Society for Testing and Materials, Philadelphia, pp 157–168.

Schafer EW Jr, Bowles WA Jr, Hurlbut J (1983) The acute oral toxicity, repellancy and hazard potential of 998 chemicals to one or more species of wild and domestic birds. Arch Environ Contam Toxicol 12:355–382.

SETAC (1996) Report of the SETAC/OECD Workshop on Avian Toxicity Testing. OECD, Paris.

Smith GJ (1987) Pesticide Use and Toxicology in Relation to Wildlife: Organophosphorus and Carbamate Compounds. U.S. Fish and Wildlife Service, Washington, DC.

Stephan CE, Rogers JW (1985) Advantages of using regression analysis to calculate results of chronic toxicity tests. In: Bahner RC, Hansen DJ (eds) Aquatic Toxicology and Hazard Assessment: 8th Symposium. STP 891. American Society for Testing and Materials, Philadelphia, pp 328–338.

Tomlin CDS (1997) The Pesticide Manual, 11th Ed. British Crop Protection Council, Binfield, Berkshire, UK.

Tucker RK, Haegele MA (1971) Comparative acute oral toxicity of pesticides to six species of birds. Toxicol Appl Pharmacol 20:57–65.

Van Straalen NM, Denneman CAJ (1989) Ecotoxicological evaluation of soil quality criteria. Ecotoxicol Environ Saf 18:241–251.

Wagner C, Lokke H (1991) Estimation of ecotoxicological protection levels from NOEC toxicity data. Water Res 25:1237–1242.

Walker SB (1989) Consolidated Index for the Updated Nanogen Index. Nanogens International, Freedom, CA.

Manuscript received March 17, 2000; accepted July 10, 2000.