Environment Canada Environnement Canada

National Agri-Environmental Standards Initiative (NAESI)

Report No. 2-42

Developing Risk-Based Rankings for Pesticides in Support of Standard Development at Environment Canada: Setting Pesticide Priorities for Aquatic Ideal Performance Standards and Ranking the Aquatic Hazard of In-Use Pesticides in Canada.

Technical Series 2006

Photos:
Bottom Left- clockwise

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Elk Creek, BC: Joseph Culp, National Water Research Institute, Environment Canada
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Prepared and published by
Environment Canada
Gatineau, QC

December 2006

**NATIONAL AGRI-ENVIRONMENTAL STANDARDS INITIATIVE
TECHNICAL SERIES**

DEVELOPING RISK-BASED RANKINGS FOR PESTICIDES IN SUPPORT OF STANDARD DEVELOPMENT AT ENVIRONMENT CANADA: SETTING PESTICIDE PRIORITIES FOR AQUATIC IDEAL PERFORMANCE STANDARDS AND RANKING THE AQUATIC HAZARD OF IN-USE PESTICIDES IN CANADA.

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NOTE TO READERS

The National Agri-Environmental Standards Initiative (NAESI) is a four-year (2004-2008) project between Environment Canada (EC) and Agriculture and Agri-Food Canada (AAFC) and is one of many initiatives under AAFC's Agriculture Policy Framework (APF). The goals of the National Agri-Environmental Standards Initiative include:

- Establishing non-regulatory national environmental performance standards (with regional application) that support common EC and AAFC goals for the environment
- Evaluating standards attainable by environmentally-beneficial agricultural production and management practices; and
- Increasing understanding of relationships between agriculture and the environment.

Under NAESI, agri-environmental performance standards (i.e., outcome-based standards) will be established that identify both desired levels of environmental condition and levels considered achievable based on available technology and practice. These standards will be integrated by AAFC into beneficial agricultural management systems and practices to help reduce environmental risks. Additionally, these will provide benefits to the health and supply of water, health of soils, health of air and the atmosphere; and ensure compatibility between biodiversity and agriculture. Standards are being developed in four thematic areas: Air, Biodiversity, Pesticides, and Water. Outcomes from NAESI will contribute to the APF goals of improved stewardship by agricultural producers of land, water, air and biodiversity and increased Canadian and international confidence that food from the Canadian agriculture and food sector is being produced in a safe and environmentally sound manner.

The development of agri-environmental performance standards involves science-based assessments of relative risk and the determination of desired environmental quality. As such, the National Agri-Environmental Standards Initiative (NAESI) Technical Series is dedicated to the consolidation and dissemination of the scientific knowledge, information, and tools produced through this program that will be used by Environment Canada as the scientific basis for the development and delivery of environmental performance standards. Reports in the Technical Series are available in the language (English or French) in which they were originally prepared and represent theme-specific deliverables. As the intention of this series is to provide an easily navigable and consolidated means of reporting on NAESI's yearly activities and progress, the detailed findings summarized in this series may, in fact, be published elsewhere, for example, as scientific papers in peer-reviewed journals.

This report provides scientific information to partially fulfill deliverables under the Pesticide Theme of NAESI. This report was written by M. Whiteside, P. Mineau, C. Morrison, and K. Harding of Environment Canada. The report was edited and formatted by Denise Davy to meet the criteria of the NAESI Technical Series. The information in this document is current as of when the document was originally prepared. For additional information regarding this publication, please contact:

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NOTE À L'INTENTION DES LECTEURS

L'Initiative nationale d'élaboration de normes agroenvironnementales (INENA) est un projet de quatre ans (2004-2008) mené conjointement par Environnement Canada (EC) et Agriculture et Agroalimentaire Canada (AAC) et l'une des nombreuses initiatives qui s'inscrit dans le Cadre stratégique pour l'agriculture (CSA) d'AAC. Elle a notamment comme objectifs :

- d'établir des normes nationales de rendement environnemental non réglementaires (applicables dans les régions) qui soutiennent les objectifs communs d'EC et d'AAC en ce qui concerne l'environnement;
- d'évaluer des normes qui sont réalisables par des pratiques de production et de gestion agricoles avantageuses pour l'environnement;
- de faire mieux comprendre les liens entre l'agriculture et l'environnement.

Dans le cadre de l'INENA, des normes de rendement agroenvironnementales (c.-à-d. des normes axées sur les résultats) seront établies pour déterminer les niveaux de qualité environnementale souhaités et les niveaux considérés comme réalisables au moyen des meilleures technologies et pratiques disponibles. AAC intégrera ces normes dans des systèmes et pratiques de gestion bénéfiques en agriculture afin d'aider à réduire les risques pour l'environnement. De plus, elles amélioreront l'approvisionnement en eau et la qualité de celle-ci, la qualité des sols et celle de l'air et de l'atmosphère, et assureront la compatibilité entre la biodiversité et l'agriculture. Des normes sont en voie d'être élaborées dans quatre domaines thématiques : l'air, la biodiversité, les pesticides et l'eau. Les résultats de l'INENA contribueront aux objectifs du CSA, soit d'améliorer la gérance des terres, de l'eau, de l'air et de la biodiversité par les producteurs agricoles et d'accroître la confiance du Canada et d'autres pays dans le fait que les aliments produits par les agriculteurs et le secteur de l'alimentation du Canada le sont d'une manière sécuritaire et soucieuse de l'environnement.

L'élaboration de normes de rendement agroenvironnementales comporte des évaluations scientifiques des risques relatifs et la détermination de la qualité environnementale souhaitée. Comme telle, la Série technique de l'INENA vise à regrouper et diffuser les connaissances, les informations et les outils scientifiques qui sont produits grâce à ce programme et dont Environnement Canada se servira comme fondement scientifique afin d'élaborer et de transmettre des normes de rendement environnemental. Les rapports compris dans la Série technique sont disponibles dans la langue (français ou anglais) dans laquelle ils ont été rédigés au départ et constituent des réalisations attendues propres à un thème en particulier. Comme cette série a pour objectif de fournir un moyen intégré et facile à consulter de faire rapport sur les activités et les progrès réalisés durant l'année dans le cadre de l'INENA, les conclusions détaillées qui sont résumées dans la série peuvent, en fait, être publiées ailleurs comme sous forme d'articles scientifiques de journaux soumis à l'évaluation par les pairs.

Le présent rapport fournit des données scientifiques afin de produire en partie les réalisations attendues pour le thème des pesticides dans le cadre de l'INENA. Ce rapport a été rédigé par M. Whiteside, P. Mineau, C. Morrison et K. Harding d'Environnement Canada. De plus, il a été révisé et formaté par Denise Davy selon les critères établis pour la Série technique de l'INENA. L'information contenue dans ce document était à jour au moment de sa rédaction. Pour plus de renseignements sur cette publication, veuillez communiquer avec l'organisme suivant :

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1 INTRODUCTION

Environment Canada has been tasked with developing environmental standards for implementation in Agriculture and Agri-Food Canada's Agricultural Policy Framework (AAFC; APF). The Wildlife Toxicology Division of the Wildlife and Landscape Science Directorate of EC's Science and Technology Branch was tasked specifically with developing comparative environmental risk-based ranking tools for pesticides in support of standard development. The development of standardised risk-based ranking methods will enable Environment Canada to prioritise in-use pesticides for the development of Water Quality Guidelines. It will also provide environmentally-oriented advice to AAFC under the APF, allowing for the promotion of reduced risk pest management strategies. Furthermore, standardised pesticide ranking tools will enable EC to objectively assess the potential environmental impact of alternative pesticide products and prioritize them for research and monitoring. This paper outlines the steps taken to reach a risk-based ranking of active ingredients according to their potential impact on aquatic life and environment. The ranking system does not consider the effects of chemical mixtures, but rather focuses on the potential harm posed on a chemical by chemical basis.

As a first output of our assessment tool, our intent was to compare our rankings with those obtained with a scoring system (a modified APPLES performed by the PMRA– see below) hitherto used to identify priority chemicals for the development of Water Quality Guidelines or Ideal Protection Standards developed under NAESI.

2 BACKGROUND ON EXISTING RISK ASSESSMENT SCHEMES AND SOME OF OUR INITIAL CHOICES

There are general principles and structures of pesticide measurement systems which apply to how risk ranking schemes are generally constructed. Primarily this has to do with the choice of data

(input), data manipulation, and the risk measure (output).

As far as input data are concerned, it is possible to have metrics based on toxicity alone, or use toxicity/exposure combinations. This decision is influenced by the complexity of the risk ranking system. For instance, at the simplest level, the index for effect is based on a measure of toxicity alone i.e. hazard identification. Often this is the case with point based systems, where many very simple endpoints are scored and the scores aggregated. The score given to toxicity will be incorporated in a final algorithm with scores of other variables. Other more complex systems, such as APPLES (see below) or the risk ranking system developed for Prince Edward Island by Environment Canada (Dunn, 2003), may combine toxicity and exposure in a single metric to generate the risk measure. In this present system a final metric is obtained through the combination of toxicity and exposure in a ratio, and not by a combination of scores. A somewhat related issue is whether the cumulated quantity of each active ingredient is the starting point for the development of a risk index i.e. by using sales statistics as the basis for estimating pesticide use, or whether risk is assessed on the basis of actual (from surveys) or label application rates and later aggregated by the extent and frequency of treatment. The decision taken in the present system was to use the single application rate rather than a measure that is already aggregated. Risk is therefore assessed on the basis of a single application. Following this is a choice to use exact values or toxicity classes for the toxicity variable. Information may be lost by using a scoring system early on in the calculations, and also the use of a toxicity class does not allow for consideration that the application rate does modify the toxic potential of a compound. It was decided therefore, to use actual toxicity endpoint values in the system presented here, and not a score. Finally, there is the choice of suitable toxicity endpoints to derive a comparative risk assessment system. This choice is a function of data availability, validity and representativeness.

We chose to use the LC50 and EC50 (e.g. immobilisation) toxicity endpoints.

How data are manipulated is an important factor. Four main approaches have evolved to deal with cases where many data points are available: restricting data input to a single species or to a few defined species, taking the lowest value from all available data for a given taxon, using a distribution approach to derive a defined toxicity data point, and weighting of toxicity values (see Mineau and Whiteside, 2005 for a more detailed explanation of each approach). We decided to use a species sensitivity distribution (SSD) from which any value – usually a defined tail of the distribution at the sensitive end – can be derived.

Many pesticide ranking tools have been developed throughout the world over the past decade (see Davis et al 1994 for a comparative evaluation of methodologies). One of these, APPLES (A Pesticide Priority List: Evaluation Scheme) (Teed, 2004) was initially developed with the same goal as ours – that of establishing a priority list of active ingredients – and it has been used to prioritise compounds for the development of Canadian Water Quality Guidelines, as well as for the initial development of Ideal Protection Standards under NAESI. A modified ranking of APPLES was recently performed by the PMRA (Pest Management Regulatory Agency) (Delorme et al, 2005). A ranking of risk posed by a pesticide is developed based on a scoring system that includes toxicity and the environmental fate. The system uses standard acute toxicity tests for single species to obtain a toxicity measure. The species and test time frame used are: rainbow trout (Oncorhynchus mykiss) 96-hour LC50 (mg/L), water flea (Daphnia magna) 48-hour EC50 (mg/L), and a green alga (Selenastrum capricornutum) 48-hour EC50 (mg/L) bioassay. The most sensitive acute effect per species is used as the toxicity value and a score is attributed based on that number. The PMRA's ranking also uses a categorized scoring system for

the physical/chemical properties, whereas we use a simple fate and runoff model (GENEEC – see below) to derive and estimated exposure concentration in the environment. Finally, the PMRA's system does not factor application rate into its score. Other aspects included in the PMRA's ranking such as the quantity of pesticides used, detections in water surveillance exercises or political imperatives were ignored here.

Our aim here is to rank the 286 active ingredients identified as the current in-use agricultural subset of pesticides in Canada and compare our risk-quotient based index (which, arguably, is a more accurate approach to chemical risk assessment in the aquatic environment) to the results obtained earlier this year by the PMRA (Pest Management Regulatory Agency) using a slightly modified APPLES (Delorme et al, 2005). It should be noted that we compared only those compounds that are used on crops in Canada. The PMRA on the other hand included more compounds than we did in their analysis. Therefore in order to compare their results with ours, we used the score they attributed each compound, but took out a number of chemicals not used on crops in Canada. We then re-ranked the final list of active ingredients, so that the final rankings for the PMRA's exercise appear different than those cited by Delorme at al (2005).

3 PREDICTING EXPOSURE TO AQUATIC BIOTA

3.1 Candidate active ingredients

Our starting point was the list of 286 candidate active ingredients proposed for the modified APPLES ranking performed by the PMRA. These candidate active ingredients are currently registered in Canada for commercial, agricultural or restricted use in agriculture, but not applied directly to bodies of water.

We relied on pesticide labels for information on application methods. In line with the above

definition of candidate active ingredients, we considered only labels recommended for commercial, agricultural or restricted use. Also, we retrieved only information regarding applications on crops grown out-of-doors, thus excluding applications in greenhouses, on ornamentals, in or around buildings, on machinery, on harvested produce, livestock, etc. Following these criteria, 52 of the candidate active ingredients were excluded. Although these active ingredients are used in agriculture, they are not applied to crops. Another 13 active ingredients were excluded because the label was not available electronically (i.e. no longer in current use), 3 were fumigants for which label data was simply not extracted and 6 active ingredients had incomplete data (4/6 had no toxicity data, and 3/6 had no physical/chemical data). Active ingredients that were excluded from the analysis are identified in Appendix A along with the justification.

3.2 The GENEEC model

The GENEEC model (GENeric Estimated Exposure Concentration) is a simple model developed by the USEPA that is used for estimating predicted concentrations of pesticide in water at the field-edge. It is based on other well known models i.e. PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System) which are commonly used in Canada and the US for regulatory risk assessments, and also AGDRIFT (Agricultural Drift), but is generic as it does not consider site-specific attributes such as climate, soils, topography or crop. As a result, GENEEC requires few input variables and is easy to use. It is analogous to the EU's Level 1 Focus models. Input variables are related to the application method (e.g. the rate of application and application directions) as well as pesticide properties (physical and chemical properties and fate variables). (They are not listed here because some were obtained from the PMRA and are considered by the latter to be proprietary information.) Pesticide transport to, and persistence in,

surface water are well reflected in the GENEEC model because of the inclusion of specific pesticide parameters as input variables.

The model estimates the expected pesticide concentration in a one hectare by two meter deep pond following a single large rainfall/runoff event, from a treated ten hectare agricultural field, that will have removed a large quantity of pesticide from the field to the water all at one time. An important assumption of GENEEC is that the pond is directly adjacent to the field and that there is no intervening vegetation. The model outcome is a series of estimated environmental concentrations (EECs): peak concentration, concentration at 96 hours, 21 days, 60 days, and 90 days. Appendix B gives the results of the GENEEC model runs for each of the chemicals. A risk quotient can then be calculated by dividing the EEC (we used the 96 hour) by the toxicity value (we used the HC5 – hazardous concentration). Since GENEEC is a single event model, longer-term and multiple-day average concentrations can be calculated based on these outcomes.

Details regarding the GENEEC model are available on the web at http://www.epa.gov/oppefed1/models/water/geneec2_description.htm and http://www.epa.gov/oppefed1/models/water/geneec2_users_manual.htm.

3.3 Application rate

Label application rates are usually relevant to the quantity of product, rather than the active ingredient. All label rates for crop applications were therefore converted to kg of active ingredient per hectare. In most cases, the conversion from the product rate was straightforward and relied on the product guarantee, product density and/or specific gravity (based on proprietary information obtained from the PMRA), as well as simple unit conversions. The application volume per hectare was also required for application rates which were reported as a quantity of

product per volume. When available, we used the application volume suggested on the label. If it was not reported however, we estimated the application volume to be 1000 L/ha for orchard crops and other fruit crops such as grapes and berries. For vegetable and other field crops, we used an estimated application volume of 300 L/ha. These estimated volumes were found on many labels and are therefore believed to be realistic. For seed treatments, rates are typically reported as an amount of product per weight of seeds and thus a seeding rate (weight of seeds per hectare) was required for the conversion. We estimated the seeding rate to be 10 kg of seed per hectare for corn, 120 kg of seed per hectare for wheat, 80 kg of seed per hectare for cereals other than wheat as well as for soybean and other beans and peas, 5 kg of seed per hectare for canola and vegetable crops other than beans and peas, and 35 kg of seed per hectare for flax. These fall within the wide range of seeding rates found in various crop production guides.

Following the standardization of application rates, the maximum allowed label application rate for each active ingredient was selected. When actual pesticide use data become available in the future, we suggest that these be used instead of label rates for a more accurate representation of risk.

3.4 Application directions

The GENEEC model also requires information on the type of application (granular, aerial spray, ground spray, airblast spray), the droplet size (very fine to fine, fine to medium, medium to coarse, coarse to very coarse), sprayer configuration (low boom or high boom ground sprayer), depth of incorporation, etc. which all have an impact on drift and on runoff .

Any given active ingredient may potentially have many different types of application e.g. be applied both as a spray and as a granular. We therefore needed a scenario that could

accommodate as many types of applications as possible – i.e. a fair compromise. For that reason, the chosen scenario is that of a pesticide applied with a low boom sprayer and medium to coarse droplets. This scenario minimizes the impact of drift and maximizes runoff, and although this is a scenario fit for liquid applications, it was found to be relatively comparable to granular applications where drift is negligible. On the other hand, we recognize that drift is a major factor in orchard applications (as airblast sprayers are associated with a high drift potential) and this is not captured by the chosen scenario. We thus need to assume that all orchard applications were made in low wind conditions and that drift is minimal. Though to our defence, because trees in orchards are often sprayed to drip, a considerable amount of active ingredient does in fact reach the ground and may be transported in runoff.

We considered that none of the applications involved incorporation of the pesticide into the soil. This would have reduced runoff in the model. We also assumed that pesticides were not wetted in, as this is not common practice. Finally, we assumed that there were no buffer zones applied to any of the products. Although spray buffer zones are mandated on some pesticide labels, there is no to minimal enforcement of this requirement and common wisdom has it that abeyance is very uneven.

3.5 Pesticide properties

There are many available sources for pesticide property data and, as is often the case when comparing values from different sources, we generally found considerable variation. Typically, older products will have been tested more often, thereby generating a wider range of values. Because of this, we did not exclusively select the value that fit a worst-case scenario as this potentially could have created a bias toward overestimating the risk of older products. Instead,

when more than one value was available, we calculated a median. Such a measure is not sensitive to wide variations. We made sure that duplicated values (i.e. same value but reported in more than one source) were eliminated before medians were calculated.

As far as we know, Koc values we obtained were generated for technical or 'pure' active ingredients. For soil half-life, we used preferentially Canadian field data (proprietary information obtained from the PMRA) over other field data (i.e. OSU, USDA, GLEAMS). If there were no field data then lab data was selected in order to minimize the data gaps. No differentiation was made between values reported as DT50 and T1/2 values, as they are often used interchangeably. Data however, were selected for single applications only (i.e. not multiple applications). Aerobic water DT50 values also are lab generated and for technical or 'pure' active ingredients. The same situation applied to water photolysis rates. As mentioned earlier, where there was more than one value per active ingredient for the above variables we chose to calculate a median, thereby generating one value per active ingredient per endpoint. For some compounds certain physical/chemical values were missing, and attempts were made to fill in the data gaps. Where an aerobic water value was missing the EFED (Environmental Fate and Effects Division of the USEPA Office of Pesticide Programs) recommended default to use is twice the aerobic soil value (as outlined in the users manual for GENEEC and this is the approach we followed (see http://www.epa/gov/oppefed1/models/water/geneec2_users_manual.htm). Some missing water photolysis values were filled in with information from the European Commission pesticide review reports (http://europa.eu.int).

Once the list of input variables was as complete as possible, the values were combined with the label data and then run through the GENEEC model.

3.6 Model outputs

Examination of model outputs indicated that GENEEC was particularly sensitive to Koc values -- as well as to application rates of course. For short term outputs (either peak or 96 hour integration) the aquatic DT50 and photolysis rates have limited influence on the results. Because of the scenario we adopted across the board, drift was minimal so any orchard-field crop differences were minimized. GENEEC was designed to provide U.S. regulators with a conservative screening tool (similar to a FOCUS level 1 assessment in Europe) but it was most appropriate here because of its generic treatment of site-specific attributes. Urban and colleagues (1998) used GENEEC for a ranking assessment of pesticides. They also compared the GENEEC output to more rigorous PRIZM/EXAMS modeling for 10 unnamed pesticides. For 7 pesticides, the GENEEC predictions for peak residue levels were slightly higher to approximately 3X higher than the predicted concentrations in areas of use by PRIZM/EXAMS modeling (with a mode of 2X). The other three products had predictions that were 6X, 7X and 11X levels predicted by PRIZM/EXAMS for relevant use areas. With the information provided, it is impossible to assess whether the poor fit in the case of these three products is a result of model failure or because of the peculiarities of the regionally-specific PRIZM/EXAMS scenarios; e.g. use of the pesticides in low rainfall areas. At this stage, it will only be appropriate to use GENEEC output as a relative ranking of likely pesticide residues rather than as absolute values. In Appendix F, we conducted a brief ‘validation’ exercise by comparing GENEEC ‘end of field’ residue values to those obtained downstream of an intensive agricultural area in California. Although absolute values differed greatly as would be expected, the relative values obtained in the California surveillance exercise provided a reasonable fit ($R2 = 0.52$) with values predicted by GENEEC.

4 DERIVING AN ACUTE TOXICITY MEASURE FOR AQUATIC BIOTA

4.1 Sources of toxicity data

Core toxicity data are available from the regulatory review process in the US and in Europe. Canadian toxicity data were also provided, in confidence, by the PMRA, although it was not used. Toxicity data are generated following recognised guidelines and are generally of good quality. However, an important drawback is that such data typically are restricted to a small number of species. For example, submitted crustacean data may only be for *Daphnia* species**.** The situation is similar with aquatic vertebrates, where submitted data are often only for a few fish species such as the rainbow trout and the bluegill sunfish. We have previously argued against restricting data to one or only a few species (Mineau and Whiteside 2005): by relying on a single indicator species, interspecies differences in susceptibility are not addressed. This is especially true in the case of pesticides with targeted modes of action. Fortunately, other publicly available data compendia exist for aquatic biota, thereby increasing the number of species for which toxicity data is available. The disadvantage of using these data is that they may be of varying quality and protocols may not be as standardised. Nevertheless, we opted to consider all available data in order to derive a distributional toxicity measure that will account for differences in inter-species sensitivity differences or species sensitivity distributions (SSDs).

Available toxicity data for any species of fish, crustaceans, aquatic insects, algae, and macrophytes were therefore drawn from sources such as the USEPA pesticide registration data (from the 'One liner' database), Agritox (http://www.inra.fr/agritox/), European Commission pesticide review reports (http://europa.eu.int/comm/food/plant/protection/evaluation /exist_subs_rep_en.htm), the Pesticide Manual, as well as the USEPA ECOTOX database

(formerly ACQUIRE), a compendium of literature data (http://www.epa.gov/ecotox/ ecotox_home.htm).

4.2 Selection of toxicity endpoints

Data were selected according to the criteria in Table 1. For all animal species, we selected LC50 and EC50 (immobilization) values. LC50 is the lethal concentration for 50% of the population, while EC50 is the concentration where 50% of the population is affected. To derive water quality criteria in the US, Stephan et al. (1985) recommend the use of EC50 measures based on death plus immobilization to better reflect the total severe acute adverse impact of the test material on the test species. If both LC50 and EC50 (immobilization) values were available for any pesticide, they were both considered. No preference was given to one endpoint over the other. We selected values associated with exposure periods ranging from 24 to 96 hours for fish, crustaceans and insects. Data from tests with an exposure period of 48 hours for aquatic invertebrates and 96 hours for fish are commonly accepted for risk assessments and are consistent with current OECD, USEPA, and Environment Canada test guidelines. By expanding the exposure period, we increased the number of test species for which we had data, in turn increasing the number of chemicals for which we could potentially generate species sensitivity distributions (Table 2). For Crustacea, especially, restricting data to the typical 48-hour test period would have left data for *Daphnia* species only.

Using a similar rationale for aquatic plants, we selected EC50 values (growth or population effects) from tests with an exposure period of 24 hours up to 120 hours (1-5 days) for algae and 24 hours up to 336 hours (1-14 days) for macrophytes. These maximum exposure periods are in line with EPA test guidelines for tier one testing. They also encompass exposure periods from

other guidelines: the OECD recommends an exposure period of 3 days for tests on algae and Environment Canada recommends an exposure period of 5 days for tests on the macrophyte *Lemna*.

When the test duration was not reported, we accepted only data from chemical companies i.e. submitted for registration in the US or in Europe (80% of the data in Agritox was submitted for registration in Europe) or from the Pesticide Manual. By doing so, we assumed that companies followed standard test guidelines and therefore, that the data fit our criteria for the exposure time. Similarly, we accepted all EC50 values from these sources even though the effect was not reported, assuming that the measured effect was also in line with guidelines.

Table 1: Summary of the criteria used for the selection of acute toxicity data for aquatic organisms.

Taxa	Accepted endpoints	Accepted exposure periods
Fish	LC_{50} and/or EC50 (immobilization)	24 - 96 hours
Crustaceans	LC_{50} and/or EC50 (immobilization)	24 - 96 hours
Insects	LC_{50} and/or EC50 (immobilization)	24 - 96 hours
Algae	EC_{50} (growth or population effects)	24 - 120 hours
Macrophytes	EC_{50} (growth or population effects)	24 - 336 hours

Table 2: Description of the data in relation to the accepted exposure period. Expanding the accepted exposure periods beyond those recommended by guidelines has increased the number of chemicals for which species sensitivity distributions become possible.

Taxon	Exposure periods [1]	Number of active ingredients for which data are available	Number of active ingredients with data for at least 5 species	Number of active ingredient – species combinations
Fish	96 h (G)	257	103	1638
	24 to 96 h (A)	258	124	2060
Crustaceans	48 h (G)	250	33	654
	24 to 96 h (A)	257	60	1170

Table 2: Description of the data in relation to the accepted exposure period. Expanding the accepted exposure periods beyond those recommended by guidelines has increased the number of chemicals for which species sensitivity distributions become possible.

Taxon	Exposure periods [1]	Number of active ingredients for which data are available	Number of active ingredients with data for at least 5 species	Number of active ingredient – species combinations
Insects	48 h (G)	59	14	188
	24 to 96 h (A)	74	24	584
Algae	120 h (G)	117	14	353
	24 to 120 h (A)	189	65	770
Macrophytes	336 h (G)	103	3	119
	24 to 336 h (A)	119	3	155

[1] *G: Guideline recommended exposure period.*

A: Accepted exposure period for data selection.

Others have also adopted a similar strategy of accepting a range of exposure periods to maximize the number of tested species to include in a distribution, although the accepted exposure periods varied markedly between authors. For instance, ECETOC (1993) has suggested exposure periods ranging from 96 to 168 hours for fish, 24 to 48 hours for crustaceans, and 12 hours for algae (as used also by DeZwart 2002). More recently, Maltby et al. (2005) selected data with exposure periods ranging from 48 to 504 hours for fish, 24 to 168 hours for invertebrates, 24 to 168 hours for algae, and 48 to 672 hours for macrophytes. Our choice of exposure periods was aimed at maximizing the number of species, but without significantly deviating from guideline recommendations.

Following our criteria for data selection, toxicity data were collated for a total of 682 species (238 fish, 183 crustacean, 175 insect, 74 algae and 12 macrophyte species) spanning across 260 active ingredients.

4.3 Standardization of data

Species names were standardized i.e. spelling was unified and synonym species names were changed where applicable. When a test organism was named at the genus level only, it was considered as a separate species.

We also classified all records as either 'technical' or 'formulation'. The classification was based on the purity of the test material. Test materials with a proportion of active ingredient of at least 90% were classified as technical grade. Those with a proportion of active ingredient between 80% and 90% were generally classified as such as well, unless it was clearly stated that these were formulated products (for instance when the type of formulation was reported e.g. wettable powder, emulsifiable concentrate, etc.). Test materials with less than 80% of active ingredient were classified as formulations, unless it was clearly stated that these were technical grade products. No corrections were made to the toxicity value to adjust for the proportion of active ingredient.

Where there was no information regarding the purity of the test material, company data were assumed to be for the technical product. This is because companies typically have been submitting data only for the technical product for pesticide registration. Only very recently have some jurisdictions (e.g. in Europe) proposed to move towards data requirements which would also include tests with formulations.

We found that records from the ECOTOX database were already classified as 'pesticide active ingredient' or 'pesticide formulation'. However, upon close examination of ECOTOX field descriptions (http://www.epa.gov/ecotox/datafields.pdf) and coding guidelines (http://www.epa.gov/ecotox/aquiresop.pdf), our understanding was that this classification was not

necessarily a reflection of the purity of the test chemical. This was supported by examples where 'pure' test materials were classified as a 'pesticide formulation' in ECOTOX. Consequently we preferred to follow the above methodology to separate technical products from formulations.

4.4 Multiple toxicity values

A geometric mean was calculated when more than one value was available for a given species – active ingredient combination. This would have occurred when we selected data for more than one of the accepted endpoints, for more than one exposure period, or simply when many tests were performed on the same species – active ingredient combination, subsequently giving rise to multiple values that fit our criteria. Technical products and formulations were dealt with separately.

Values with a 'greater than' or 'lower than' qualifier were included in calculations and the qualifier was disregarded. We found that these values generally had a good spread and therefore we assumed that including these values in the calculation would not significantly skew the resulting geometric mean. A value was occasionally rejected if it was considered too low to be associated with a 'greater than' qualifier or too high to be associated to a 'lower than' qualifier. Such decisions to exclude a value were made on a case-by-case basis by comparing the value in question with other values for that same combination. Also, values were carefully examined prior to calculations to eliminate duplicate values, i.e. the same value generated from the same test, but reported in more than one source. Equal weight was given to all unique values.

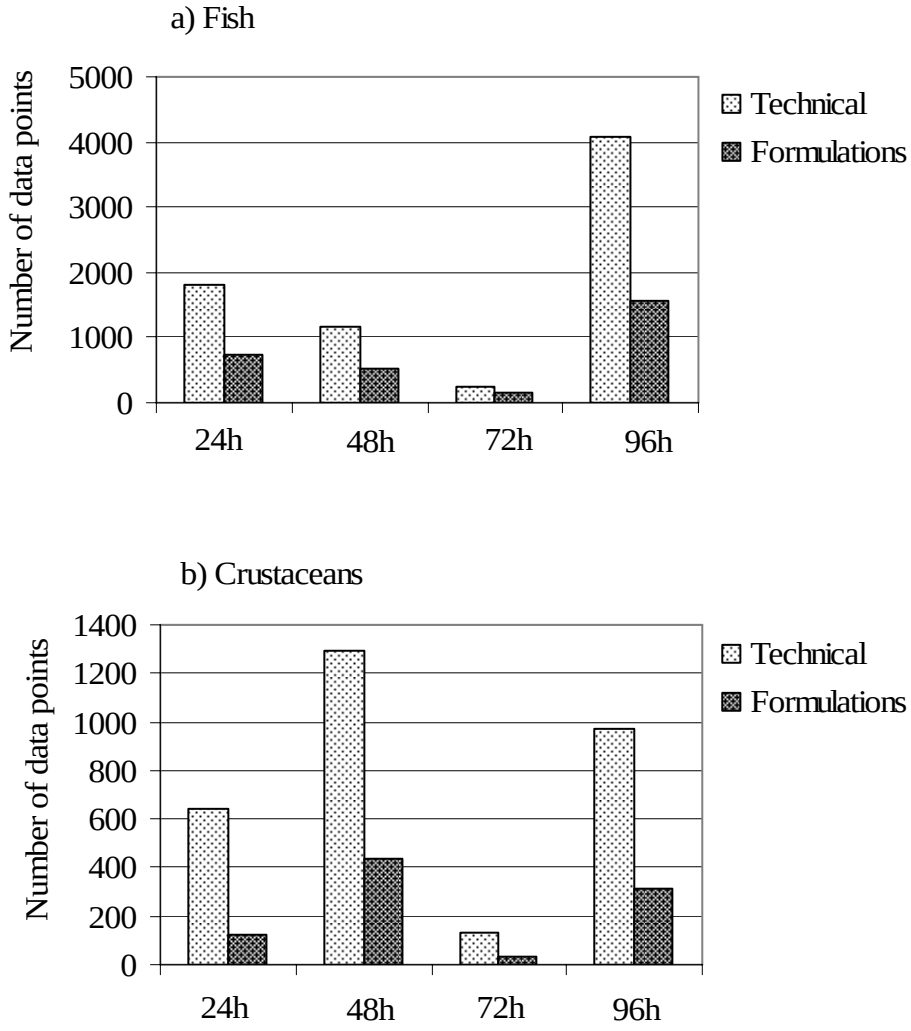
Because some jurisdictions (e.g. USEPA) routinely recalculate LC50s based on the raw data and their preferred probit model, it is possible that different LC50 values generated from the same test were included in the ultimate computation of geometric means. Also, while most sources

reported only one value per species – active ingredient combination, ECOTOX often reported many values per combination, all of which were selected if they fit our criteria. Therefore, we may have selected several ECOTOX values that were drawn from only one study e.g. when a study generated many results at different exposure periods. We did not group these values in order to have a single data point per study when calculating the geometric mean. Instead we treated all values as if they were independent i.e. as if they were generated from different tests. We recognize that by combining many values from one study with values from other sources, more weight will have been given to the study with multiple data points. The use of geometric means prevented any serious biasing of the data, since it determines the average factor.

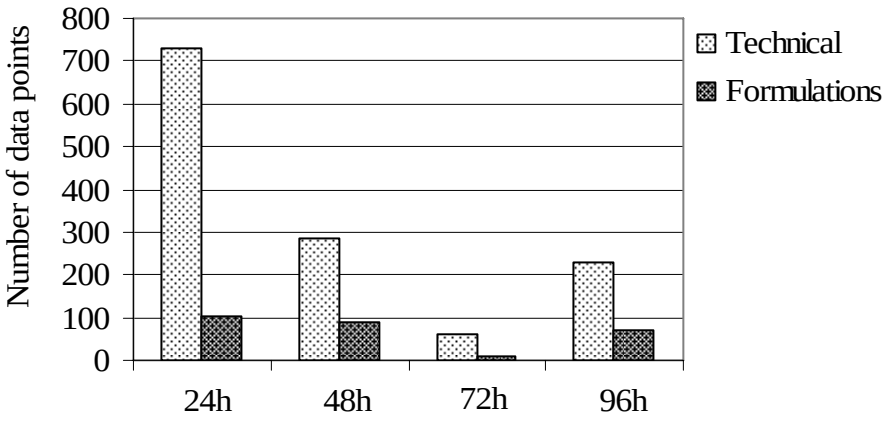
Additionally, because the toxicity will typically increase with a longer exposure period, our decision to select all values within a range of accepted exposure periods may have introduced a bias to the resulting toxicity estimate. Examining the frequency of data points across exposure periods (Figure 1) can give us some insight into how our decisions will have affected the geometric mean. In the case of fish (Fig. 1a), most data points are associated with a 96-hour exposure period which suggests that the overall effect from having selected values from an expanded exposure period will likely not be significant i.e. that the geometric mean calculated with all the data would not be significantly different than a geometric mean calculated with only data from guideline recommended 96-hour tests. Similarly, for crustaceans (Fig. 1b) we expect that a measure of central tendency such as a geometric mean will yield results similar to what would have been obtained from considering only 48-hour test results. On the other hand, insect toxicity may have been underestimated, in particular for the technical products, as most of the data is from 24-hour tests rather than the guideline recommended 48-hour tests (Fig. 1c). Finally, for algae and macrophytes, we do not expect to have significantly underestimated the toxicity, as

the majority of the data is from tests with an exposure period of at least 96-hours (Fig, 1d and 1e). In addition, vascular plants may take longer to respond to toxicity testing and therefore the use of longer study times is favoured in test design.

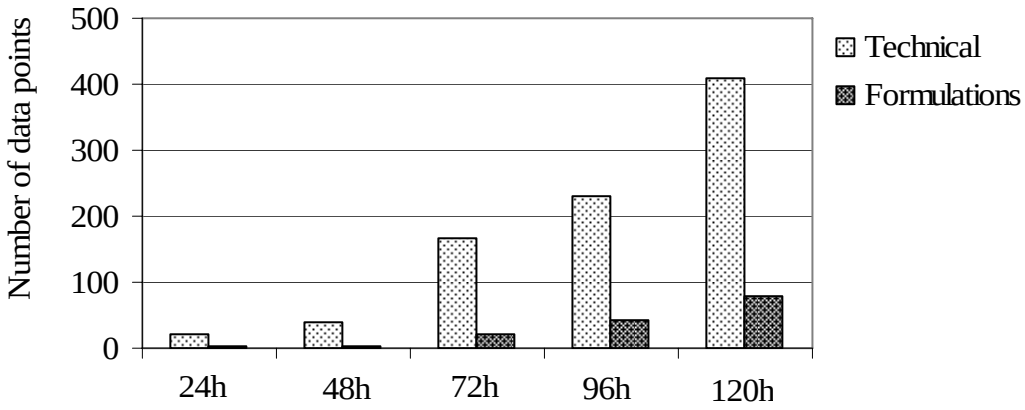
Figure 1: Distribution of data points according to the exposure period for major aquatic taxa.



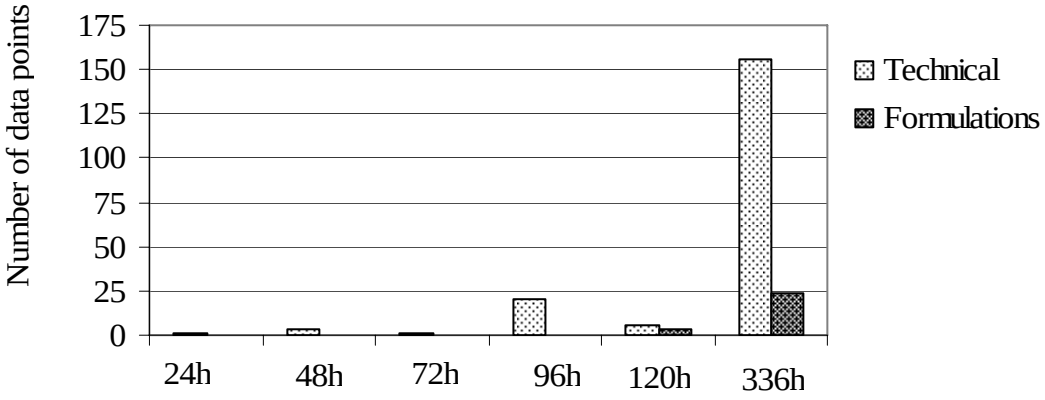
c) Insects



d) Algae



e) Macrophytes



4.5 Possible sources of variation

Data were pooled across habitats i.e. we did not separate the data in distinct groups of freshwater and saltwater species. To do so would have further restricted the range of species included in a distribution. In addition, some have argued that to group data for both habitats would not significantly affect the outcome. DeZwart (2002) found no significant difference between the sensitivities to chemicals of freshwater and saltwater species and consequently combined the data from both habitats to generate distributions. For his analysis, he considered 160 chemicals (92 pesticides) with data mostly from ECOTOX. More recently, Maltby et al. (2005) also explored the differences between HC5 estimates from distributions generated with data for freshwater and saltwater crustaceans across 10 insecticides. No significant differences between estimates from both habitats were found, even though saltwater species tended to be more sensitive. They concluded that the taxonomic composition (e.g. the choice to combine major taxa such as arthropods and fish) had a greater impact on the hazard estimate than to combine freshwater and saltwater data within one taxon. Because we kept data for major taxa in separate groups, we believe that combining freshwater and saltwater data will ultimately not significantly affect our hazard estimate.

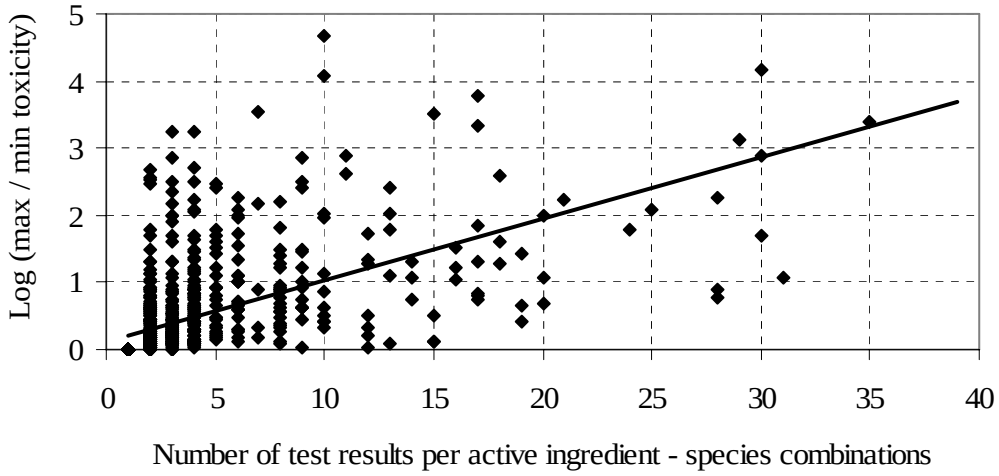
Moreover, we did not group the data according to life stages. The concern of an added source of variation due to differences in the life stage would not have been raised if we had considered only data generated for the pesticide review process, since guidelines recommend that tests be performed on certain specific life stages only. For example, guidelines for crustacean testing recommend the use of *Daphnia* species at the juvenile life stage only. But because we also chose to accept data from other sources to expand the range of species for species sensitivity distributions, selected data spans across many life stages. For instance, our crustacean data

includes many species other than *Daphnia* e.g. shrimp, crabs and lobsters, which were tested at different life stages. Although this situation will likely have increased the variation, we did not attempt to group the data according to life stages. Selecting only certain life stages would have limited the range of species for our analysis e.g. if we had only considered juvenile crustacean species, we would have excluded many species other than *Daphnia* which is not consistent with our objective to maximise the number of species for distributions. In addition, exposure to chemicals takes place across different life stages and therefore may be more reflective of 'reality'.

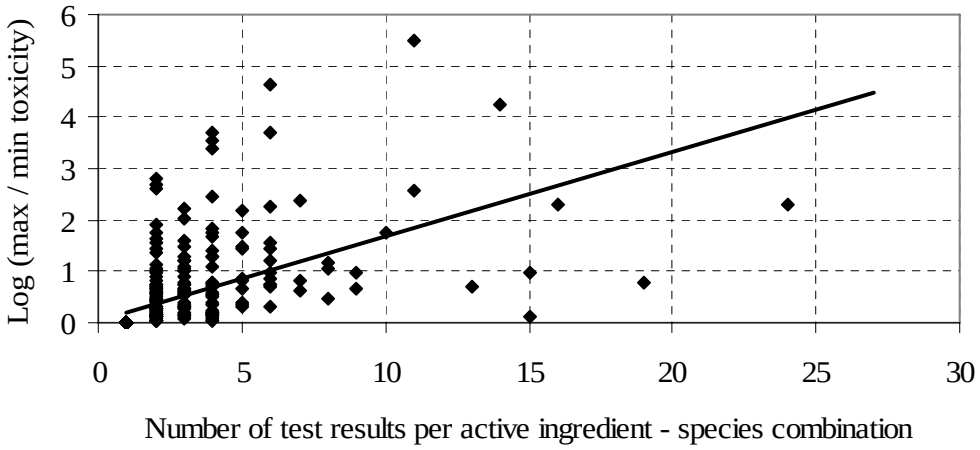
Overall, variance is substantial (Figure 2). Whether this variance is due to factors such as the life stage is unclear. In previous analyses with avian and mammal data, we found significant differences in toxicity even when we took great care in comparing the same species, sex, and life stage. It is therefore possible that differences in sensitivity due to interlab and intertest variance are intrinsic to the data and we would not have benefited from additional groupings.

Figure 2: Variation of the toxicity data for fish and *crustaceans.*

a) Fish, technical



b) Crustaceans, technical



4.6 Methodology for species sensitivity distributions (SSDs)

4.6.1 ETX 2.0

Species sensitivity distributions were generated for each of the major aquatic taxa i.e. fish, crustaceans, insects, algae and macrophytes. We derived HC5 (hazardous concentration) values, using the ETX 2.0 software (van Vlaargingen et al. 2004), for all active ingredients where data was available for at least 5 or more species. ETX 2.0 is a program used to calculate the

hazardous concentrations and fraction affected, based on normally distributed toxicity data, to derive environmental risk limits for chemical substances. Separate distributions were generated for the technical active ingredients and the formulations. Data for technical active ingredients are used in this ranking exercise.

With a low number of species (5 to 10), visual inspection of the data was critical. If the sample was considered normal based on a cumulative probability plot and the Anderson – Darling test, we generated the SSD, even with such a low sample size. If on the other hand normality was not met, we used the small sample method as detailed below. With a sample of more than 10 species, a small number of clear outliers may have been removed to attain normality, but with at least 10 species left to generate the distribution (only 3/267 compounds - glyphosate for fish, diquat for algae and metribuzin for macrophytes - had one or 2 outliers removed resulting in fewer than 10 species available to generate the distribution). Outliers were removed based on judgment and efforts were made to resolve cases of possible bi-modality. Overall there were not many cases where outliers were removed (13/267 records for all taxa with over 10 species per compound). Outliers were generally toxicity points that were very different (either higher or lower) than all other values for different species for a compound, that once removed made the data normal. If on the other hand, normality was not achieved after removing one or more outlying values, the BurrliOZ model (see section 4.6.3) was used to estimate the hazardous concentrations. Similarly, if there were no apparent outliers and the data were not normally distributed, but had a sample of more than 10 species, the BurrliOZ model again was used.

4.6.2 Small sample analyses (ETX 2.0)

The small sample method was applied when, for a given active ingredient, we had toxicity values

for fewer than 5 species. This method consists of deriving a mean from the sample but applying an externally-derived standard deviation (SD). We derived representative standard deviations (SDs) from those species' sensitivity distributions that were based on normally distributed toxicity data (see Appendix C).

4.6.2.1 Technical products

Standard deviations were determined for fish, crustacean, insect or algal data sets that contained 5 or more species, and were normal, in most cases with minimal or no exclusion of outliers. Pesticides were classed as insecticides, herbicides, fungicides or other (primarily microbicides). The resulting data were analysed by factorial ANOVA with taxonomic group and pesticide type as variables.

The array was unbalanced, with missing cells for insecta (Table 3). This is also plotted for easier visual inspection in Figure 3.

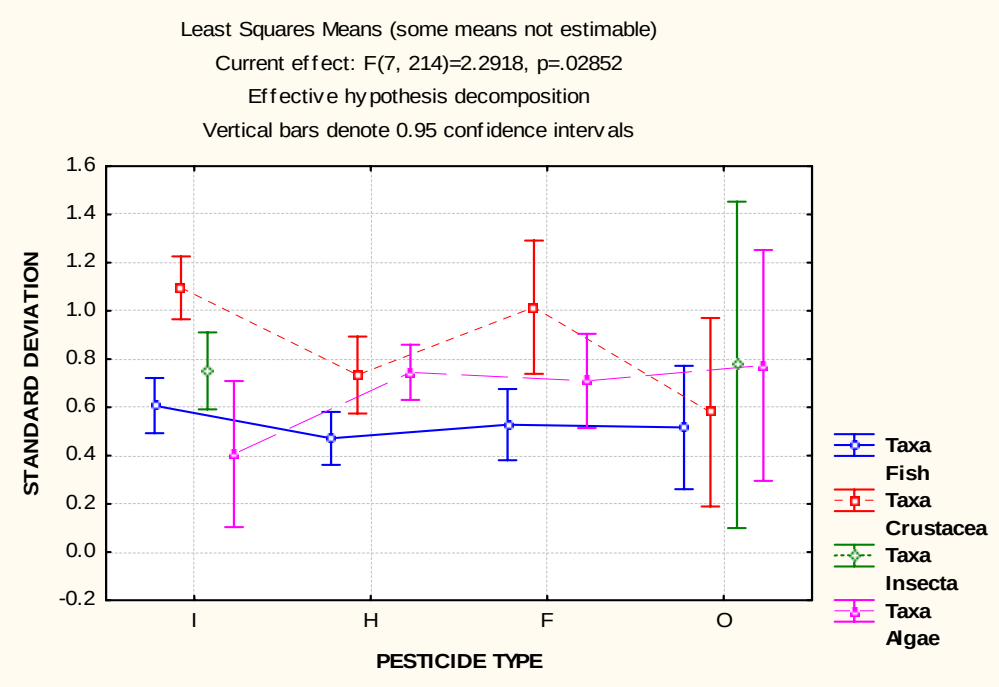
Table 3: Mean standard deviation for each pesticide type*taxon combination for technical products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
Insecticide	Fish	0.607034	0.058038	0.492634	0.721435	35
	Crustacea	1.095556	0.066080	0.965306	1.225806	27
	Insecta	0.751314	0.080931	0.591791	0.910838	18
	Algae	0.406249	0.153555	0.103574	0.708923	5
Herbicide	Fish	0.471391	0.055700	0.361599	0.581182	38
	Crustacea	0.734318	0.080931	0.574795	0.893842	18
	Insecta					
	Algae	0.745134	0.058038	0.630734	0.859534	35
Fungicide	Fish	0.528341	0.074927	0.380651	0.676031	21
	Crustacea	1.015058	0.140176	0.738755	1.291361	6
	Insecta					
	Algae	0.709593	0.099120	0.514218	0.904969	12

Table 3: Mean standard deviation for each pesticide type*taxon combination for technical products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
Other	Fish	0.516557	0.129778	0.260750	0.772363	7
	Crustacea	0.579564	0.198239	0.188813	0.970315	3
	Insecta	0.775934	0.343360	0.099133	1.452735	1
	Algae	0.773867	0.242792	0.295296	1.252438	2

Figure 3: Least mean square estimates of standard deviations for technical products separated by pesticide type and taxon.



Therefore, the ANOVA was run excluding insecta. Results are shown in Table 4. Pesticide type was not significant by itself because of the very high variance exhibited but there was a significant pesticide type*taxon interaction as well as a highly significant effect of taxon.

Table 4. Analysis of variance model for the analysis of standard deviations for pesticides in the form of tec

	SS	d.f
Intercept	40.58279	1
TYPE SD	0.27185	3
Taxa	2.03774	2
TYPE SD*Taxa	1.85734	6
Error	23.78619	197

The clear difference among taxa was with the crustacea, these showing a higher standard deviation than the other two taxonomic groups, especially with regard to insecticide and, to a lesser extent, fungicide toxicity. Fish tended to have lower standard deviations, especially with respect to herbicides and fungicides. The information available on algae was quite spotty as were data on 'other' miscellaneous pesticides. The latter, not surprisingly tended to introduce a lot of variance. Therefore, the analysis was repeated (Table 5) with datasets for fish and crustacea and the three main pesticide types only (i.e. the best datasets). Now, a clear effect of pesticide type appeared – at the expense of the interaction term which was no longer significant. A Tukey HSD post hoc test confirmed that crustacea datasets did indeed have higher standard deviations (Table 6) and that insecticide datasets tended to have higher standard deviations than herbicide or fungicide datasets (Table 7).

Table 5: Analysis of variance model for the analysis of standard deviations for pesticides in the form of tec

	SS	Degrees of f
Intercept	54.78029	1
Pesticide type	1.68933	2
Taxon	4.23771	1
Type*Taxon	0.38382	2
Error	14.29740	139

Table 6. Tukey HSD for ANOVA results of table 5. Homogeneous groups with alpha = 0.05.

Pesticide type	Taxon	Mean Standard Deviation	1	2	3	4
Herbicides	Fish	0.471391	****			
Fungicides	Fish	0.528341	****	****		
Insecticides	Fish	0.607034	****	****		
Herbicides	Crustacea	0.734318		****	****	
Fungicides	Crustacea	1.015058			****	****
Insecticides	Crustacea	1.095556				****

Table 7: Tukey HSD for ANOVA results of table 5. Homogeneous groups with alpha = 0.05.

Pesticide type	Mean Standard Deviation	1	2
Herbicides	0.555903	****	
Fungicides	0.636500	****	
Insecticides	0.819778		****

On the basis of these results, and keeping in mind the sample size limitations of the data available to us and the greater taxonomic distance between fish and the two groups of invertebrates, we proposed the following standard deviation values to be used in the small sample procedure for technical pesticide active ingredients (Table 8).

Table 8: Proposed average Standard Deviation values derived from technical products only. These values were used in the small sample procedure of ETX 2.0 for technical active ingredients.

Pesticide type	Taxon	Mean Standard Deviation	N
Insecticides	Fish	0.607034	35
Insecticides	Crustacea	1.095556	27
Insecticides	Insecta	0.751314	18

Herbicides	Fish	0.471391	38
Herbicides	Crustacea and Insecta	0.734318	18
Fungicides & Other	Fish	0.525395	28
Fungicides & Other	Crustacea and Insecta	0.860497	10
All	Algae	0.706922	54

4.6.2.2 Formulated products

HC5 values for formulated products were not derived for this report. However, for the sake of completeness, we anticipated the need to derive a set of mean standard deviations for formulated products also. Here, the sample of available species sensitivity distributions and derived standard deviations were smaller with missing cells for both insecta and algae (Table 9, Figure 4) and very low sample sizes for fungicides. We therefore decided to test whether SDs generated for technical a.i.'s could serve as a proxy for formulated products. In order to test for a technical vs. formulated effect, we analysed fish and crustacean with only the insecticide and herbicide data sets, this time including pesticide 'form' (technical or formulated) in the analysis (Table 10).

Table 9: Mean standard deviations for each pesticide type*taxon combination for formulated products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
Insecticides	Fish	0.599714	0.063593	0.473431	0.725997	27
	Crustacea	1.244812	0.099631	1.046965	1.442660	11
	Insecta	0.811738	0.124894	0.563723	1.059753	7
	Algae					
Herbicides	Fish	0.489999	0.064804	0.361310	0.618687	26
	Crustacea	0.733198	0.080143	0.574049	0.892346	17
	Insecta	0.149725	0.233656	-0.314269	0.613719	2
	Algae	0.865944	0.190779	0.487094	1.244793	3

Table 9: Mean standard deviations for each pesticide type*taxon combination for formulated products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
Fungicides	Fish	0.699725	0.165219	0.371632	1.027818	4
	Crustacea	1.509012	0.330439	0.852826	2.165199	1
	Insecta					
	Algae	0.809173	0.330439	0.152987	1.465359	1
Other	Fish	0.389150	0.165219	0.061057	0.717244	4
	Crustacea	0.774392	0.233656	0.310399	1.238386	2
	Insecta					
	Algae					

Table 10. Analysis of variance model for the analysis of standard deviations for pesticides in the form of e

	SS
Intercept	95.81912
Form of a.i.	0.06819
Type	3.35487
Taxon	7.21409
Form of a.i.*Type	0.04155
Form of a.i.*Taxon	0.05025
Type*Taxon	1.05644
Form of a.i.*Type*Taxon	0.08340
Error	18.72256

Because the form of the a.i. did not appear to be important, we combined the data for technical and formulated products (Table 11) and used the combined means as a basis for choosing appropriate SDs to be used for formulated products (Table 12). Indeed, these values could have been used to generate small sample SSDs for technical products also even though we opted to use the values in Table 8 for the latter.

Figure 4: Least mean square estimates of standard deviations for formulated products separated by pesticide type and taxon.

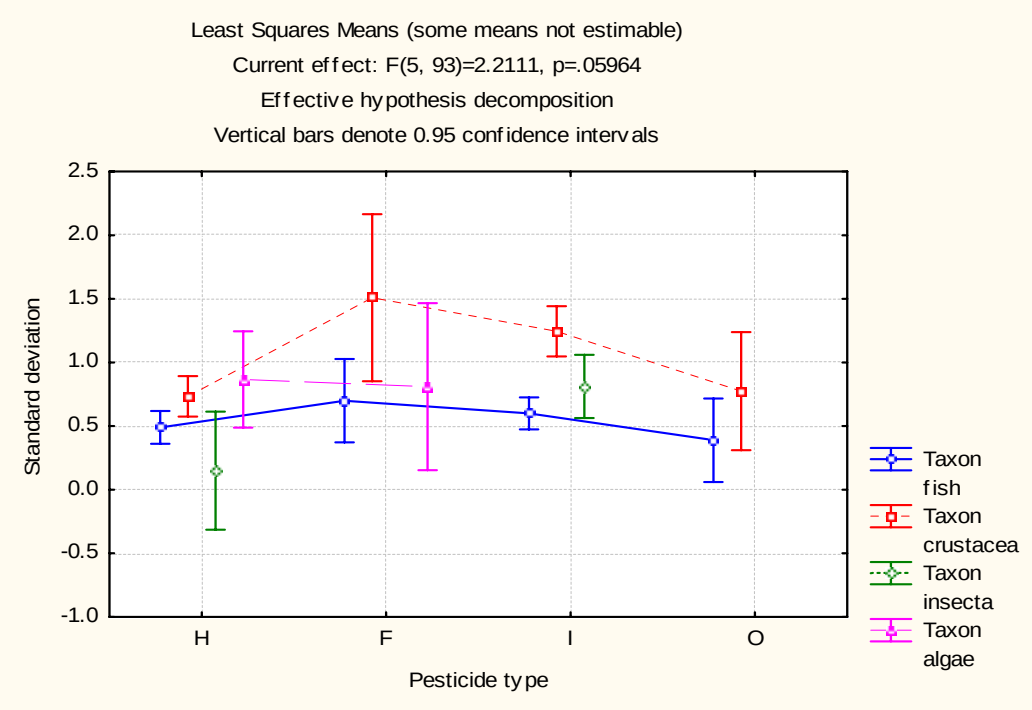


Table 11: Mean standard deviations for each pesticide type*taxon combination for combined technical and formulated products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
Insecticides	Fish	0.603846	0.042747	0.519744	0.687949	62
	Crustacea	1.138762	0.054602	1.031334	1.246189	38
	Algae	0.406249	0.150528	0.110092	0.702405	5
	Insecta	0.768233	0.067318	0.635788	0.900678	25
Herbicides	Fish	0.478950	0.042074	0.396172	0.561728	64
	Crustacea	0.733774	0.056894	0.621837	0.845711	35
	Algae	0.754672	0.054602	0.647244	0.862099	38
	Insecta	0.149725	0.238006	-0.318540	0.617990	2
Fungicides	Fish	0.555762	0.067318	0.423317	0.688208	25

Table 11: Mean standard deviations for each pesticide type*taxon combination for combined technical and formulated products.

Pesticide type	Taxon	Mean Standard Deviation	Standard error of the mean	- 95% confidence	+ 95% confidence	N
	Crustacea	1.085623	0.127219	0.835325	1.335921	7
	Algae	0.717253	0.093354	0.533585	0.900922	13
	Insecta					
Other	Fish	0.470227	0.101486	0.270558	0.669896	11
	Crustacea	0.657495	0.150528	0.361339	0.953652	5
	Algae	0.773867	0.238006	0.305602	1.242132	2
	Insecta	0.775934	0.336591	0.113707	1.438160	1

Table 12: Proposed standard deviations for the combined technical and formulated datasets.

Pesticide type	Taxon	Mean standard deviation	N
Insecticides	Fish	0.603846	62
Insecticides	Crustacea	1.138762	38
Insecticides	Insecta	0.768233	25
Herbicides	Fish	0.478950	64
Herbicides	Crustacea and insecta	0.702204	37
Fungicides & Other	Fish	0.529626	36
Fungicides & Other	Crustacea and insecta	0.897136	13
All	Algae	0.71691	58

A final analysis was to see whether the SD for formulated products could be derived from the SD derived from the technical equivalent. This proved disappointing. Within a taxon, there was not a good relationship between the two. In other words, it was not possible to predict the standard deviation of species sensitivity distributions for miscellaneous formulations on the basis of

technical ingredient result. This is shown for the two largest datasets, fish and crustacea below (Figures 5 and 6, respectively).

Figure 5: A comparison of the standard deviations for technical and formulation datasets for a range of pesticides tested in crustacea.

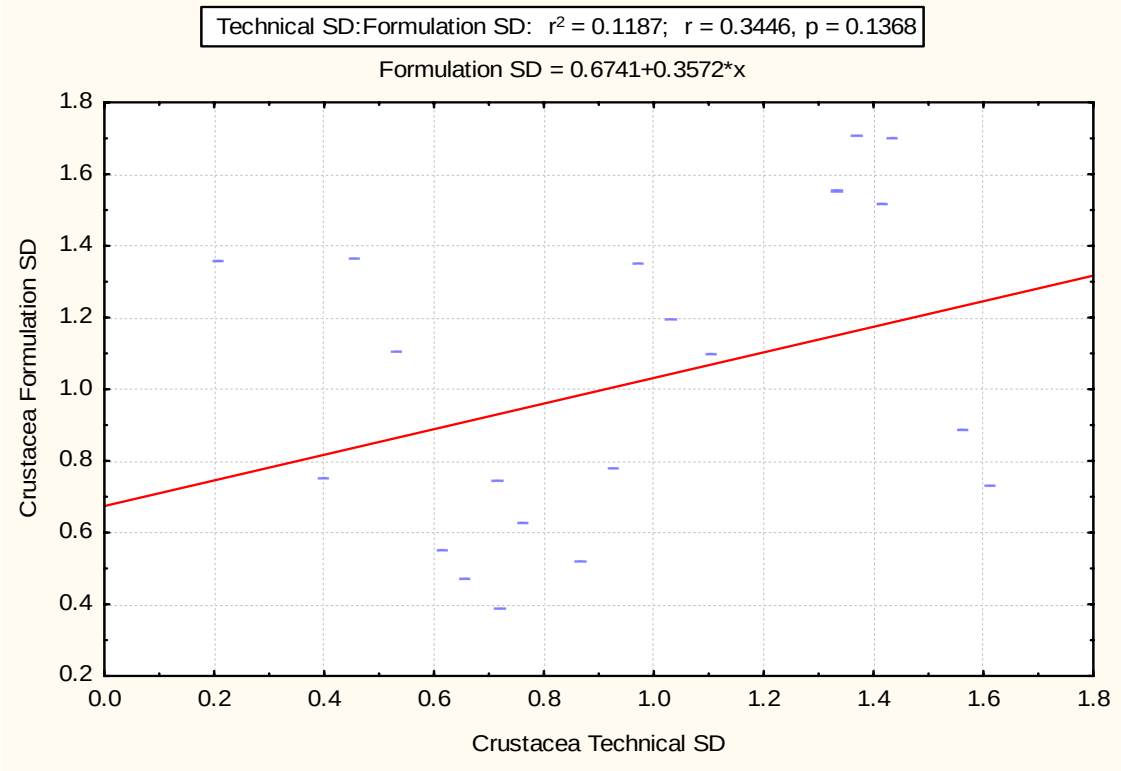
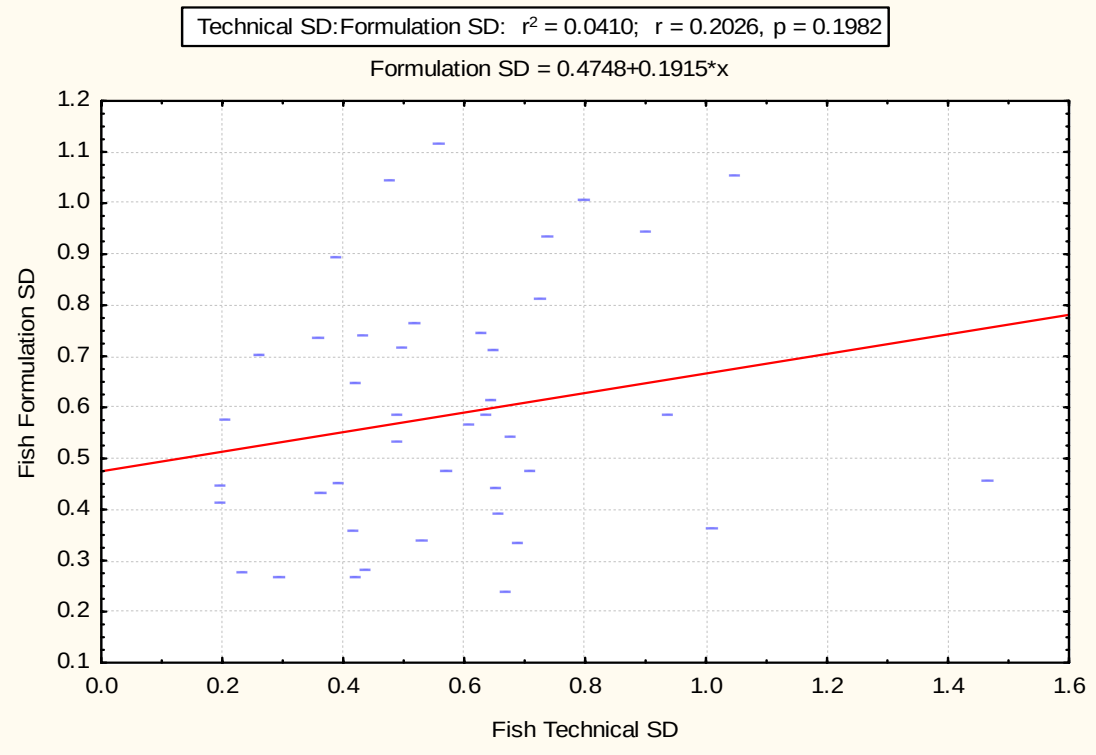


Figure 6: A comparison of the standard deviations for technical and formulation datasets for a range of pesticides tested in fish.



4.6.3 The BurrliOZ model

For some of the data sets that were clearly not normal even after elimination of a few outlying values, the Australian statistical software package BurrliOZ was used. BurrliOZ uses the Burr Type III distributions, a flexible family of distributions, to estimate the concentrations of chemicals whereby a certain percentage of species will survive. Our assessment of this method is that it is quite insensitive to departures from normality, but does provide data very comparable to ETX when the data are normally distributed. This model is used by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand to generate Water Quality Guidelines.

Details regarding the BurrliOZ model are available on the web at http://www.cmis.csiro.au/Envir/burrlioz/.

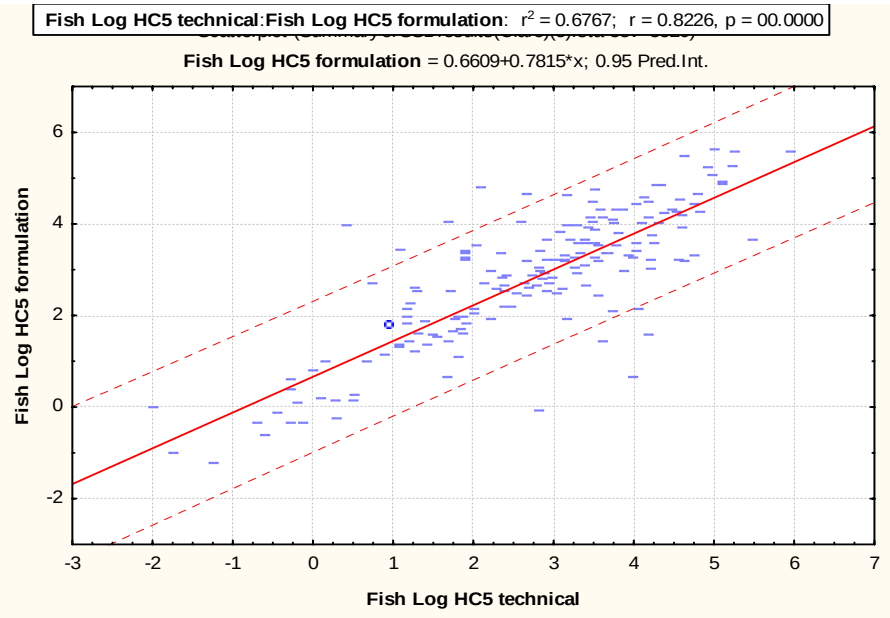
4.6.4 Comparing technical and formulated toxicity values

If runoff (as opposed to drift) is the principal mode of entry of a pesticide to aquatic systems, it is not clear whether exposure is to the formulation, the technical ingredient stripped of other formulation constituents or to something in between. Undoubtedly, this is formulation specific and the likelihood of formulants accompanying the active ingredient as the pesticide is being washed off from an agricultural field depends on their specific physicochemical characteristics, solubility, Koc, volatility etc…. Because our rankings are based on technical toxicity endpoints (as are all early tier assessments of pesticides) it is relevant to ask whether our rankings would have been very different if we had used formulated toxicity data instead.

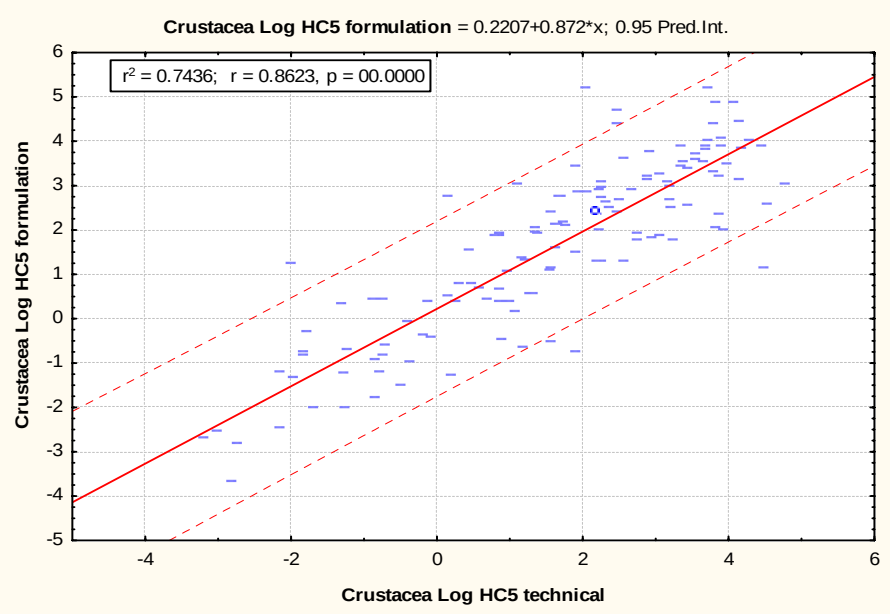
The following graphs show the relationship between the technical and formulated toxicity HC5 values for fish, crustaceans, aquatic insects, algae, and macrophytes (data are given in Appendix G). While the formulated toxicities were not discussed in detail in this report, HC5 values for formulations were calculated per active ingredient, thereby enabling this comparison. In all cases, HC5 (technical) and HC5 (formulation) were positively correlated and the regression was significant. The 95% prediction bands are shown. The strongest correlation between technical and formulated products was for aquatic insects with 76% of the variation in formulation toxicity explained by the technical HC5. Similarly, the proportion of explained variance for crustacea and fish was 75% and 69% respectively. The models for macrophytes and algae have somewhat lower predictive powers, with the proportion of explained variance being 48% and 31% respectively but sample size is more of an issue here.

Figure 7: A comparison of the toxicity values between technical and formulation datasets for fish, crustaceans, aquatic insects, algae and macrophytes.

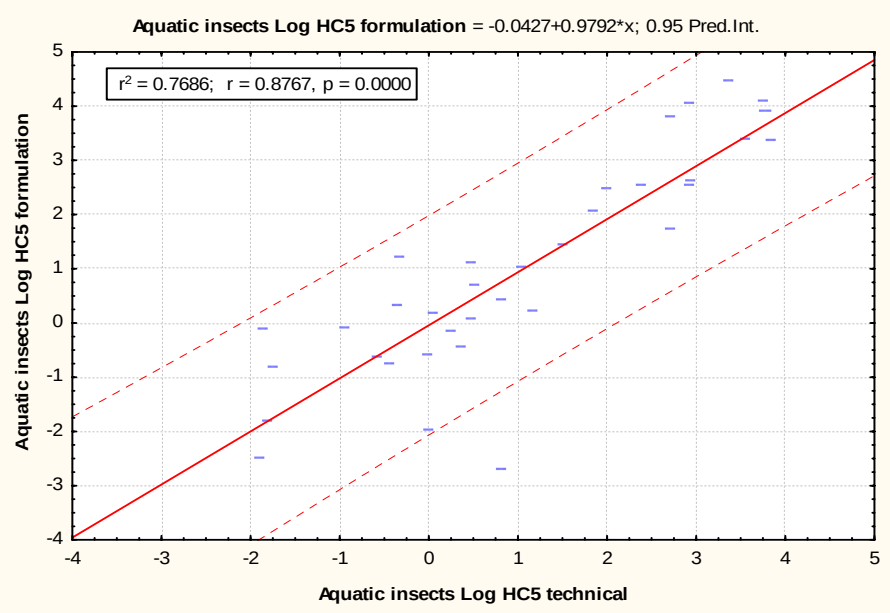
a) Fish Technical vs. Formulation



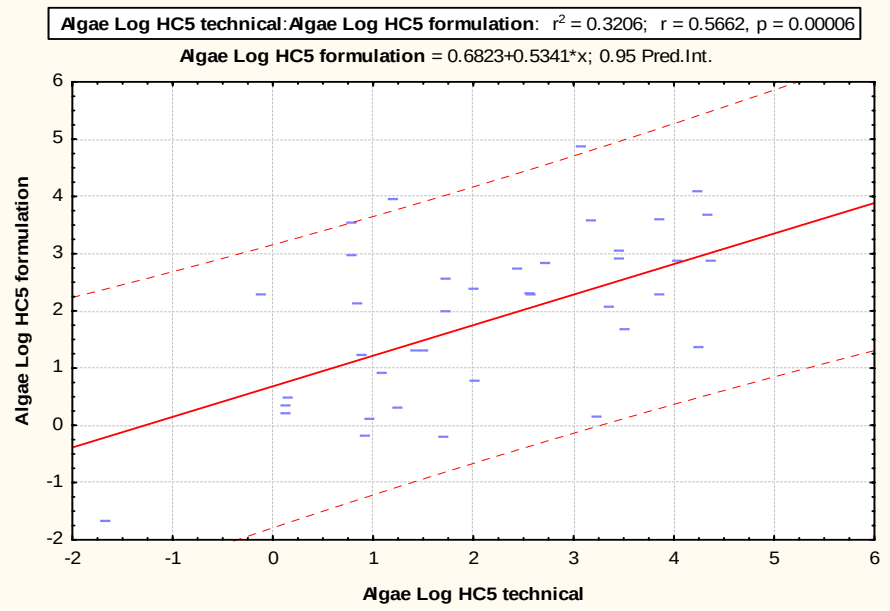
b) Crustacean Technical vs. Formulation



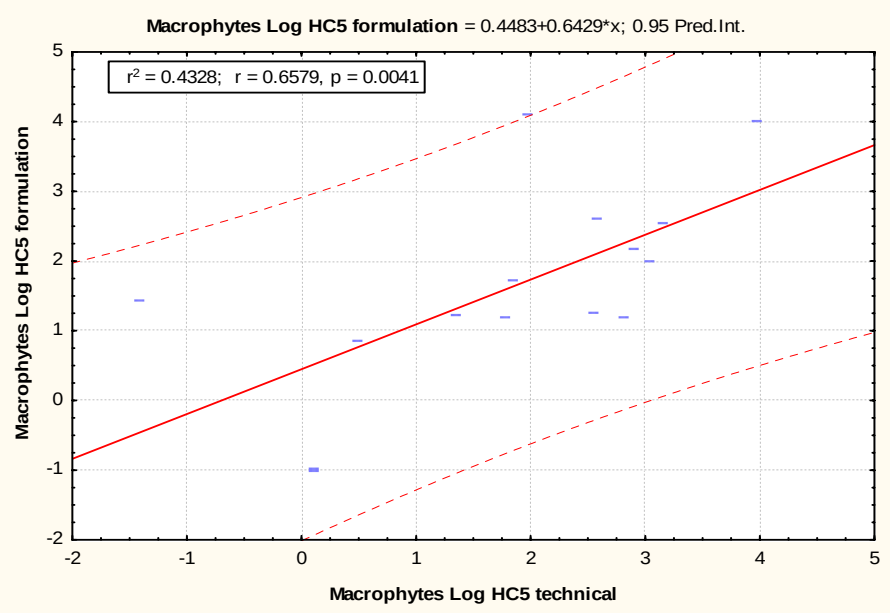
c) Aquatic insects Technical vs. Formulation



d) Algae Technical vs. Formulation



e) Macrophytes Technical vs. Formulation



The 95% prediction bounds show that, for most taxa, predicted HC5 values for formulated material could easily range by two orders of magnitude above or below the estimate for the technical material. The data for aquatic insects followed an almost perfect 1:1 relationship whereas all the other groups showed the same tendency: formulation HC5 values were higher (lower toxicity) than technical HC5s for compounds of very high toxicity. For technical compounds of very low toxicity, the opposite was true with formulated HC5 values being lower (more toxic) than expected from a 1:1 ratio. The fitted difference between technical and formulated HC5 values at either end of the toxicity range was approximately one order of magnitude, somewhat higher for algae.

5 GENERATING A COMPARATIVE RISK RANKING

For each major taxon, risk was derived by dividing the 96-hour estimated environmental

concentration generated by GENEEC by HC5 values from the ETX 2.0 and/or BurrliOZ models. Risk values were generated separately for fish, insecta, crustacea, algae and macrophytes. The highest risk derived for either crustacea or insecta was retained as the invertebrate risk value; similarly the highest risk demonstrated by either algae or macrophytes was retained as the plant risk.

In order to compare our results with the recent ranking exercise done by the PMRA, we derived a similarly weighted overall risk index. Weighing factors were chosen to represent ecological importance and recovery potential (Delorme et al, 2005). The fish risk value was given a relative weight of 8, the invertebrate risk value 5, and the plant value 3. Again, based on decisions taken for the PMRA's exercise, we compensated for any missing data by adjusting the denominator according to available data. For example, we divided the overall risk by 16 when there were no data gaps for a given active ingredient (8+5+3), by 13 if plant or algae data were missing (8+5), or by 8 if invertebrate and plant or algae data were missing. This approach does have some serious drawbacks. Essentially, it amounts to giving the missing taxon a risk index approximately equal to the average of the risk computed for the taxa for which data are available. If, for example, plant data were not available for a given insecticide because it was not thought necessary to test plants given a probable low toxicity to that group, removing plants from the index and adjusting the denominator accordingly (rather than giving them an arbitrary low risk score) results in an average score as high as if plants had been as sensitive as fish and crustacean to the insecticide in question. Clearly, this decision needs to be revisited although it does interject an element of natural 'fairness' by penalising compounds for which there are data gaps. In spite of the drawback, we used this method here in order to make our results most comparable with the PMRA's modified APPLES rankings. The resulting risk values were ranked to generate a

compound specific ranking which is presented in Appendix D.

The top-10 pesticides identified with this risk-based ranking system are: tefluthrin, phorate, dimethoate, methamidophos, diazinon, trichlorfon, chlorypyrifos, permethrin, thriam and thifensulfuron-methyl. The pesticide showing the most concern is tefluthrin. It has a very low solubility and is adsorbed well by soil particles, although it has a fairly slow degradation time. Overall, tefluthrin has a low run-off potential. However, it is highly toxic to fish and even more so to invertebrates so that even with a low exposure, the toxicity is enough to put aquatic biota at risk.

In comparison to the PMRA's scheme, there were a number of similarities between the rankings, however notable differences occurred as well. Please note again that the following comparison is based on our ranking against the PMRA's ranking that we modified after removing the compounds not used on crops in Canada. 22 of the same compounds occurred within the top 50 ranked active ingredients for both schemes. Tefluthrin, which was first in our ranking, came third in the PMRA's ranking. Other closely ranked compounds, with positions in our list and in the PMRA's list in brackets, included: Diazinon (5:15), Trichlorfon (6:7), Chlorpyrifos (7:1), Azinphos-methyl (12:8) and Pyridaben (21:2). The closely ranked compounds all have similar toxicities and exposures in both schemes. Diazinon for example, is fairly toxic to fish, moderately toxic to algae, but is highly toxic to invertebrates, with a moderate environmental fate presence. The high sensitivity of most taxa is reflected in both the current ranking and the PMRA's ranking. Likewise chlorpyrifos, which is the highest ranked compound in the PMRA's system, is very toxic to both fish and invertebrates, both taxa receiving the highest possible score for toxicity (8/8 for fish and 5/5 for invertebrates). The same is reflected in our system as fish are

sensitive to chlorpyrifos, and invertebrates even more so. The exposure is moderate in both cases as well. The result therefore is similar rankings in both schemes for these compounds.

Six compounds analyzed in our system are fumigants. They include: metam, potassium n-methyldithiocarbamate, methyl isothiocyanate, cloropicrin, 1, 3-Dichloropropene, and methyl bromide. Since we are unsure whether the GENEEC model applies to fumigants we did not include them in the main ranking. However, if the model does apply, the results are worrisome. Because of very high application rates and high toxicity, all six fumigants occur in the top 15 ranked compounds (Appendix E). If indeed these compounds make it to the aquatic environment, the results could have significant implications in terms of their risk to aquatic life. At least one of the fumigants (1, 3-Dichloropropene) has been detected as a surface water contaminant in areas of use (Merriman et al, 1991). Detectable levels were found in surface waters for short periods both during and after soil fumigant application. In comparison, in the PMRA's scheme, 3 out of 6 fumigants (metam, methyl isothiocyanate, and methyl bromide) are ranked in the top 40 compounds. One fumigant is not ranked (potassium n-methyldithiocarbamate) and the other two occur 88th (1, 3-dichloropropene) and 186th (chloropicrin).

As expected, there were some important variations to the rank of some of the active ingredients between the present scheme and the PMRA's. The 15 compounds which showed the largest discrepancies between the ranking results included (our ranking: PMRA's ranking): Picloram (193:27), 2,4-D (30:194), Thifensulfuron-methyl (10:172), Difenoconazole (180:31), Mancozeb (35:184), Dodine (32:171), Fludioxonil (200:63), Triticonazole (191:54), Tribenuron methyl (49:183), Tebuconazole (129:6), Thiram (9:131), Fenamidone (136:20), Flusilazole (179:64), and Amitrole (50:161). It appears there are three main reasons for the discrepancies: toxicity based

on a single species vs. multiple species, the data used and the scoring system, and variance in the sources of exposure values.

To derive the toxicity of a compound, we used all species of fish, crustacea, insects, algae and macrophytes for which there was information on acute toxicity testing, for the time frames outlined in Table 1 (refer to section 4.2). A single toxicity value was then generated for each species by taking the geometric mean of the toxicity values, and these mean values were run through the ETX 2.0 and/or BurrliOZ programs to generate the HC5 (hazardous concentration). By considering all available data for all species, a distributional toxicity measure that accounts for differences in species sensitivities can be derived for major aquatic biota based on exact values. The PMRA's system, on the other hand, used standard acute toxicity tests for single species to obtain a toxicity measure. The species and test timeframe used were: rainbow trout (*Oncorhynchus mykiss*) 96-hour LC50 (mg/L), water flea (*Daphnia magna*) 48-hour EC50 (mg/L), and a green algae (*Selenastrum capricornutum*) 48-hour EC50 (mg/L) bioassay. The most sensitive acute effect per species is used as the toxicity value and a score is attributed based on that number. By relying on a single indicator species, interspecies differences in susceptibility are not addressed, and the result may not be an accurate representation of the impact of the compound across a range of taxa. Over-reliance on a single indicator species may not be the most appropriate method of assessment, since many new pesticides have been developed with highly targeted modes of action. In many cases, it may not be known to what degree the test species is representative of other fish, invertebrate and algae species. Where data were not available for the test timeframe criteria the PMRA was using, results were accepted from a test performed with the same exposure period but for another similar species. This may not be ideal, since inter-species differences can be significant, even between related species. We believe that generating a

toxicity value based on a distributional analysis of available toxicity data produces a more accurate measure of pesticide risk than a single-species method. The difference in methodology does contribute to the variation in active ingredient rankings.

Some of the differences in rankings may be related to our inclusion of macrophyte data, which were not used in the PMRA's rank score. This is especially true with results derived for herbicides. For instance, thifensulfuron-methyl is ranked 10th in our ranking and 172nd in the PMRA's ranking. Thifensulfuron-methyl is not especially toxic to fish or invertebrates, as was reflected in both models. It is, however, fairly toxic to algae, which is also reflected in both models; and even more toxic to macrophytes. Since the PMRA ranking does not include a test species for macrophytes, the inherent toxicity to macrophytes is neither addressed nor reflected in the compound's ranking. The result is similar for 2,4-D, a compound that ranked 30th in our method and 194th in the PMRA's scheme and tribenuron methyl which was ranked 49th in this ranking and 183rd in the PMRA's ranking. All three examples are amongst the fifteen compounds with the largest discrepancies between the ranking results.

Other compounds with large discrepancies are picloram which placed 193rd in our method and 27th by the PMRA, and mancozeb which placed 35th in our method and 184th by the PMRA. For picloram, the difference appears to be related to exposure. Picloram is very soluble and is not adsorbed well by soil particles. It therefore has a high run-off potential and a fairly slow degradation time. These are the elements that contribute to a high score in PMRA's ranking. Our integrated ranking does not rank picloram as highly because of the compound's relatively low toxicity. For mancozeb the discrepancy comes down to a matter of missing data. Both an invertebrate and algae toxicity score is missing from the PMRA's score; our data indicate that

both invertebrates and algae are fairly sensitive to mancozeb.

Some of the differences in the variables may be attributed to our integrated risk ratio vs. the PMRA's scoring strategy. Use of a scoring strategy can result in a loss of information and a small variation in a single test result can alter rankings dramatically. Another limitation is that the use of toxicity classes prevents the consideration of the application rate as an important modifier of real toxic potential. We therefore believe our approach is a more realistic representation of potential effects.

In the present ranking system, the fate parameters measured included: soil half-life, water solubility, organic carbon soil sorption (Koc), and water photolysis. In the PMRA's prioritization exercise, the fate parameters measured included: soil half-life, organic carbon soil sorption (Koc), water solubility and the log octanol water partition coefficient. To obtain physical and chemical information about the compounds, data were selected from the PMRA, GLEAMS (Groundwater Loading Effects of Agricultural Management Systems), OSU (Oregon State University) Extension Pesticide Properties Database, and USDA NRCS 2005 (National Resources Conservation Service). For the PMRA's ranking, the following sources were used to gather fate information: Pesticide Manual, OSU (Oregon State University) Extension Pesticide Properties Database, HSDB (Hazardous Substances Data Bank), and the Pesticide Action Network Database. Given that the above list covers a variety of sources and jurisdictions, differences in the results for the same parameter are likely to occur between sources. These factors also contribute to differences between the present rankings and those derived by the PMRA.

Of course, the comparison we have made here excludes any consideration of sales data and positive detections by water quality surveillance exercises – both of which also get incorporated

into final PMRA's ranking based on a modified APPLES. These considerations can still be overlain on our integrated risk-based rankings. The latter reflect the inherent risk (at the field edge) of using a particular product. Given our incomplete coverage of products in water surveillance exercises, given also the uncertainty in our estimates of pesticide sale or use in Canada and given also that pesticide use can shift dramatically in response to market forces, it could be argued that a ranking based on fate and toxicity characteristics alone is preferable anyway.

6 PRIORITIES FOR STANDARD DEVELOPMENT

Based on the results of this ranking exercise, the following active ingredients should be considered as priorities for the development of standards within the context of NAESI (our ranking: PMRA's tox/fate ranking): tefluthrin (1:3), phorate (2:37), dimethoate (3:87), methamidophos (4:76), diazinon (5:15), trichlorfon (6:7), chlorypyrifos (7:1), permethrin (8:28), thriam (9:131), thifensulfuron-methyl (10:172), flufenacet (11:80), azinphos-methyl (12:8), cypermethrin (13:49), carbofuran (14:29), and endosulfan (15:50). Of these, only chlorpyrifos, tefluthrin and trichlofon were chosen for IPS development in 2005/6. Standards were also developed for the following pesticides (our ranking: PMRA's tox/fate ranking): diquat (108:56), atrazine (58:18), quintozene (79:78), methomyl (52:26), fluroxypyr (93:24), pendimethalin (71:10), and malathion (53:4). Some of our top candidates may be on the verge of being phased out. Therefore, before recommending the top candidates for IPS development, the PMRA should be consulted to see which active ingredients are slated to be phased out. Nevertheless, we believe that we have identified additional high priority pesticides for our current IPS development strategy.

7 MODEL VALIDATION BASED ON ECOLOGICAL INCIDENT DATA - SPECIFICALLY FOR FISH

There is limited historical information of incidents of mortality and other adverse effects in fish, wildlife, and plants caused by pesticides. The vast majority of ecological incidents are not observed or reported. Fish kills are a type of ecological incident that may be more visible than others and therefore may stand a better chance of being reported. The information of ecological incidents for a pesticide is important as it can be used to confirm a risk predicted by a risk assessment model, or show that the risk is perhaps greater than or less than that predicted by the model. In order to attempt an initial validation of the aquatic risk-based ranking developed above, the US EPA's EIIS (Ecological Incident Information System) database was used along with information from California and PEI pesticide incident records.

The US EPA's EIIS database (Nick Mastrota, pers. comm.) is a compilation of incident reports from pesticide registrants, government agencies and other voluntary submissions from state and federal agencies. The State of California incident data was obtained from California Fish and Game (Bob Hosea, pers. comm.) and the list of PEI incidents from Environment Canada Atlantic Region (Bill Ernst, pers. comm.). The objective was to see where pesticides with recorded incidents fit in to the current ranking scheme.

For the analysis, certain criteria were required. The US EPA's EIIS database classifies incidents as 'highly probable', 'probable', 'possible', 'unlikely' or 'unrelated' in terms of being caused by the pesticide. Only records with a certainty of highly probable, probable, or possible were retained. Likewise, only records where pesticides had a 'registered use' or where the use was 'undetermined' were kept for analysis (as opposed to pesticides that were misused or spilled). Furthermore, incidents where pesticides were applied to crops or turf were used, as well as

records when the use type was not reported. The result was a collection of 397 fish kills related to the list of pesticides covered by this ranking exercise. Application rates associated with incidents are rarely if ever given and it is therefore impossible to see how closely they correspond to maximum label rates used in our compilation. The California and PEI databases did not contain as detailed information as the US EPA's EIIS database, but did require selection of incidents that were reported as 'highly probable', 'probable', and 'possible' as opposed to 'unlikely' or 'unrelated'. The result was 26 incidents in the PEI database, and 19 in the California database that were related to the pesticides used on crops in Canada. The latter may represent duplication if the records were communicated to the EIIS database.

The 206 active ingredients used on crops in Canada, and for which we have information, were ranked according to their fish hazard. This was accomplished by dividing the GENEEC 96-hour predicted exposure concentration by the HC5 fish toxicity (see sections above for more details on methodology). The 15 top ranked active ingredients in order of decreasing hazard were tefluthrin, phorate, thiram, endosulfan, azinphos-methyl, chlorpyrifos, ziram, terbufos, captan, chlorothalonil, ferbam, dimethoate, folpet, diazinon, and dinocap. (See Appendix H for the ranking of all 206 compounds for fish with the associated number of ecological incidents.)

An examination of the incident data reveals good correspondence between the hazard-based rankings and the reported ecological incidents. Azinphos-methyl had 98 reported occurrences which was the highest number of incidents for a given pesticide in the US EPA EIIS database (for the criteria we were looking at), and it occurs 5th in our ranking. There are also 11 recorded incidents from PEI for azinphos-methyl, which again was the largest number of incidents for a given pesticide that was recorded in the PEI database. The high number of occurrences suggests

that this is a toxic chemical to fish, which is reflected in our ranking as well. Endosulfan (4th in our rankings) also had a high number of fish incidents with 58 reported cases. In addition to this are 9 recorded incidents from the PEI database; 13 were recorded in California from 1984-2003. Terbufos, which came 8th in our ranking, had 67 incidents reported in the US EPA EIIS database, while chlorpyrifos which had 26 incidents, and 2 in the California dataset from 1996-2001, came 6th. The top two ranked pesticides for their toxicity to fish – tefluthrin and phorate – had 7 and 10 associated incidents respectively in the EIIS database. Therefore, it appears that our rankings are quite predictive of fish kills. Not all top rated pesticides have been found to give rise to fish kills however. As outlined in our analysis of UK bee kills (Harding et al. 2006), it is likely that an important predictor is the extent of use of the different pesticides, which is not available here. Also, it may be easier to diagnose kills from some classes of pesticides (e.g. cholinesterase inhibitors through a cholinesterase assay) than others. An absence of recorded kills is not very meaningful in itself.

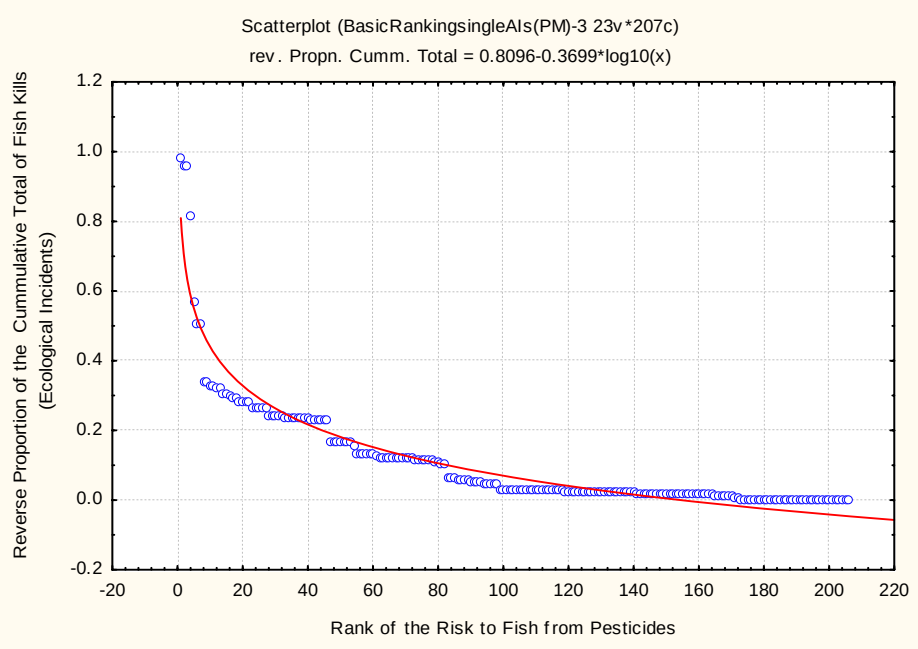
7.1 Defining 'benchmark' pesticides

The concept of using benchmark pesticides to define ideal performance standards under the NAESI program was suggested by Mineau and Whiteside (2005). This is the obvious approach where we are lacking full and comprehensive field data to build a predictive model. A benchmark approach was adopted by Mineau and Duffe (2001) for birds before the models described in Mineau (2002) were developed. In this approach, risk indices associated with specific mortality incidents were used to infer lethal risk with other untested pesticide uses. Similarly, Sheehan et al (1995) developed benchmarks of acceptability for pesticide impacts on prairie slough based on selected studies that investigated the loss of invertebrate biomass that would be sufficient to affect consumers. This approach may not provide for a nice linear scale of

pesticide risk but it does allow picking an empirically determined level of acceptability rather than an arbitrarily-chosen value of 10 or 100 as is often the case.

41/206 pesticides have an associated incident or incidents and, despite their heavy concentration in the top ranks of our fish hazard compilation, they are distributed throughout our rankings. The pesticide furthest down the ranked list that had a recorded incident was Fosetyl-al. It was ranked 205/206 and the incident was from an application to turf/golf course. However, 80% of recorded fish kills are found in the first 47 ranked compounds; 20 out of those 47 pesticides are associated with incidents. Figure 8 shows a plot of the cumulative proportion of incidents against rank. The overall fit of the graph shows that the risk increases logarithmically with an approximate inflection point corresponding to rank 45-50. Atrazine (with an ETR of 0.14) is in 47th position and ideally suited as a benchmark. There were 26 kills associated with this pesticide. It could be said therefore that any pesticide application equivalent to or with a higher ETR than 0.14 carries a very high (beyond the standard?) risk of giving rise to fish kills. A more protective cut off point might be metolachlor which is ranked 83rd, and is the next natural breaking point on the graph. There were 18 kills associated with metolachlor. About 90% of the pesticides above this mark are responsible for recorded fish kills. Both atrazine and metolachlor are major use compounds and it is therefore not surprising that a higher number of incidents would be recorded with them compared to other active ingredients with a similar ranking.

Figure 8: Inverse cumulative proportion of EIIS fish kills plotted against the ranked fish hazard index.



We recognize that this is a preliminary step at validating our risk-based ranking with actual recorded ecological incidents, given that the incident data is only a partial representation of what is happening in the field (because many incidents are not reported or observed); nevertheless, we believe that the risk indices as defined here could form the basis of workable protection standards, whether ideal or currently achievable.

8 ACKNOWLEDGEMENTS

We are grateful for the support of the NAESI initiative that allowed us to perform this work. Peter Delorme and Nick Mastrota offered constructive comments on earlier drafts. We are also very grateful to Ian Kennedy who rewrote GENEEC to allow batch entries. Any errors of omission or commission as well as the opinions expressed herein are the sole responsibility of the authors.

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10 APPENDICES

APPENDIX A: Active ingredients that were excluded from the analysis with justification. Those compounds in red are in-use products that should be incorporated into our ranking scheme.

AI Code	AI Accepted Name (PMRA)	Why were these AI rejected?
ALP	Aluminum phosphide	Post harvest application or use as rodenticide
MGP	Magnesium phosphide	Post harvest application
PHI	Phosphine	Post harvest application
BDX	Cyanazine	Historical EP only; label in hard copy
DIE	Dieldrin	Historical EP only; label in hard copy
DIG	Dichlorprop present as dimethylamine salt	Historical EP only; label in hard copy
DIS	Disulfoton	Historical EP only; label in hard copy
DNB	Dinoseb in free form	Historical EP only; label in hard copy
DXS	2,4-D present as sodium salt	Historical EP only; label in hard copy
END	Endrin	Historical EP only; label in hard copy
ETY	Ethoxyquin	Historical EP only; label in hard copy
FEM	Fenitrothion	Historical EP only; label in hard copy
MTB	Metobromuron	Historical EP only; label in hard copy
PRL	Propanil	Historical EP only; label in hard copy
PTH	Parathion	Historical EP only; label in hard copy
CUB	Copper (tribasic copper sulphate)	Incomplete data (no toxicity data)
FLB	Flamprop-m (form not specified)	Incomplete data (no toxicity data)
GIA	Gibberellic acid A3	Incomplete data (no phys/chem data)
GIB	Gibberellins	Incomplete data (no toxicity or phys/chem data)
NAD	Naphthaleneacetamide	Incomplete data (no toxicity data)
SUS	Lime sulphur or calcium polysulphide	Incomplete data (no phys/chem data)

AI Code	AI Accepted Name (PMRA)	Why were these AI rejected?
FDR	Pyridate	Not in the database - Historical EPs only
ABM	Abamectin	Not used on crops
ALM	d-trans Allethrin	Not used on crops
ARP	Arsenic pentoxide	Not used on crops
ARS	Imazapyr	Not used on crops
AZN	Azaconazole	Not used on crops
BBU	Bromacil present in free form, as dimethylamine salt, or as lithium salt	Not used on crops
BDC	Bendiocarb	Not used on crops
BNS	Borax	Not used on crops
BOA	Boracic acid (Boric acid)	Not used on crops
BOC	Disodium octaborate tetrahydrate	Not used on crops
BTS	Bis(trichloromethyl)sulfone	Not used on crops
CAZ	Carbendazim	Not used on crops
CNB	Chloroneb	Not used on crops
CRO	Chromic acid	Not used on crops
CUO	Cupric oxide	Not used on crops
CUP	Cuprous oxide (also expressed in terms of copper as elemental)	Not used on crops
CUQ	Copper 8-quinolinolate	Not used on crops
CUR	Copper as elemental, present as mixed copper ethanolamine complexes	Not used on crops
CXF	Cyfluthrin	Not used on crops
DAM	Daminozide	Not used on crops
DEB	Denatonium benzoate	Not used on crops
DFB	Diflubenzuron	Not used on crops
DIR	Dithiopyr	Not used on crops
DOM	Dodemorph-acetate	Not used on crops

AI Code	AI Accepted Name (PMRA)	Why were these AI rejected?
DVP	Dichlorvos plus related active compounds	Not used on crops
ETO	Ethylene oxide	Not used on crops
FBT	Fenbutatin oxide	Not used on crops
GAR	Tetrachlorvinphos	Not used on crops
HQB	Oxine benzoate	Not used on crops
IPB	Iodocarb (proposed common name)	Not used on crops
ISX	Isoxaben	Not used on crops
KRE	Fosamine ammonium	Not used on crops
MEE	Mecoprop present as acid	Not used on crops
MGK	N-Octyl bicycloheptene dicarboximide	Not used on crops
MSM	Arsenic as elemental, present as monosodium methane arsonate (MSMA)	Not used on crops
OXA	Oxadiazon	Not used on crops
PAZ	Paclobutrazol	Not used on crops
PBU	Piperonyl butoxide	Not used on crops
PCP	Pentachlorophenol plus related active chlorophenols	Not used on crops
PTX	Oxycarboxin	Not used on crops
QAC	N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride	Not used on crops
QAK	Didecyl dimethyl ammonium chloride	Not used on crops
QAO	N-alkyl (67% C12, 25% C14, 7% C16, 1% C18) dimethyl benzyl ammonium chloride	Not used on crops
REZ	Resmethrin	Not used on crops
SDD	Sodium dimethyldithiocarbamate	Not used on crops
TCS	TCA present as sodium salt	Not used on crops
TRB	Etridiazole	Not used on crops
TXP	4-(Cyclopropyl-alpha-hydroxy-methylene)-3,5-dioxo-cyclohexane	Not used on crops

AI Code	AI Accepted Name (PMRA)	Why were these AI rejected?
ZNO	Zinc oxide	Not used on crops
BAY	Propoxur	Not used on crops
MEU	1-Methylcyclopropene	Post harvest application
CIP	Chlorpropham	Post-harvest application

APPENDIX B: GENEEC output: estimated environmental concentrations (ug/L).

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
ACA	Acifluorfen (form not specified)	24.65661	24.2838	22.30084	18.51945	16.19813
ACP	Acephate	73.02192	65.40425	37.83635	16.41534	11.04586
AME	S-Metolachlor	68.53762	68.05737	65.41082	59.85161	56.01359
AMI	Amitrole	446.9866	439.4355	399.585	325.1489	280.5801
AMN	Aminoethoxyvinylglyc	1.079245	1.040648	0.851903	0.569122	0.438124
AMZ	Amitraz	10.59105	9.422062	5.269503	2.228729	1.495842
ASS	Imazamethabenz (form not specified)	21.83232	21.70954	21.02889	19.5751	18.55075
ATR	Atrazine	172.3908	172.1085	170.5206	166.9853	164.3637
AVG	Difenzoquat (methyl sulphate salt)	2.854755	2.515711	1.357598	0.56908	0.387006
AZY	Azoxystrobin	6.412664	6.360895	6.076753	5.490912	5.095402
BAD	6-Benzyladenine	2.029889	2.014456	1.929619	1.753484	1.633566
BAX	Metribuzin	107.6506	104.9343	91.12168	67.69501	55.18916
BET	Bensulide	113.5549	112.7493	108.3104	99.09046	92.81109
BMS	Flusilazole	0.464793	0.460999	0.440176	0.39764	0.369262
BRY	Bromoxynil (octanoate)	5.125416	4.911382	3.894228	2.463322	1.845899
BTL	Desmedipham	24.88633	24.61952	23.1726	20.26922	18.37309
BZN	Bentazon (form not specified)	47.97061	47.36456	44.10575	37.70231	33.62682
CAB	Carbaryl	318.0191	309.0957	264.2302	190.6199	152.8096
CAF	Carbofuran	56.34917	56.09415	54.67304	51.59326	49.38453
CAP	Captan	294.359	268.1272	166.7917	77.11225	52.35411

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
CCC	Chlormequat (form not specified)	50.75435	49.69432	44.19612	34.39936	28.85422
CFP	Clodinafop-propargyl	0.240845	0.184044	0.062661	0.022261	0.014841
CFZ	Clofentezine	0.980448	0.856365	0.446115	0.182913	0.12403
CHE	Chlorimuron-ethyl	0.364088	0.363382	0.359413	0.350611	0.344117
CHH	Boscalid	12.04745	11.98759	11.6553	10.94788	10.45137
CHL	Chlorthal (form not specified)	81.49044	79.63758	70.05494	53.57255	44.62073
CLE	Clethodim	3.171484	3.042569	2.429352	1.553848	1.170024
CLM	Cloransulam (form not specified)	1.437149	1.392593	1.171595	0.820561	0.646944
CNQ	Clomazone	39.58371	39.21085	37.1775	33.03405	30.27689
COD	Clothianidin	3.445509	3.441148	3.416645	3.362204	3.321937
COY	Terbufos	21.91017	15.50218	4.551771	1.599972	1.066648
CSL	Chlorsulfuron	0.513677	0.510072	0.490199	0.448422	0.419554
CUS	Copper (copper sulphate)	0.03518	0.033336	0.024963	0.014588	0.010685
CUY	Copper (copper oxychloride)	0.01	0.01	0.01	0.01	0.01
CUZ	Copper (copper hydroxide)	9.594969	9.092192	6.808949	3.979412	2.914716
CYH	Cyhalothrin-lambda	0.05633	0.041805	0.013477	0.00483	0.00325
CYM	Cypermethrin	3.036672	2.646077	1.365094	0.55489	0.374406
CYO	Cymoxanil	7.164084	6.838171	5.320281	3.262865	2.410854
CYP	Cyprodinil	8.364325	8.263888	7.720922	6.653568	5.973432
CYZ	Cyromazine	10.17658	10.14346	9.958362	9.554184	9.261508
DAZ	Dazomet	1.973369	1.853675	1.332054	0.727041	0.514046

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
DBR	Deltamethrin	0.051131	0.038682	0.013016	0.004693	0.003167
DCB	Dichlobenil	370.8412	369.2348	360.2843	340.9043	327.0165
DCF	Dicofol	13.70265	13.29903	11.27067	8.038168	6.431187
DFF	Diflufenzopyr (form not specified)	2.099068	2.002268	1.55276	0.947355	0.698396
DFZ	Difenoconazole	0.194172	0.19079	0.172892	0.140078	0.120852
DIA	Diazinon	238.213	231.6608	198.5646	144.008	115.8224
DIC	Dicamba (form not specified)	153.4816	150.3835	134.2701	105.3003	88.73159
DIH	Dichlorprop (form not specified)	8.652167	8.376834	7.010749	4.867072	3.82085
DIK	Dichloran	599.7612	592.0411	550.4749	469.4616	418.3719
DIM	Dimethoate	95.05328	91.29401	73.33243	47.37157	35.83542
DIN	Dinocap	7.228334	7.046912	6.121346	4.552667	3.71552
DIQ	Diquat(form not specified)	1.991824	1.071313	0.233184	0.082344	0.055266
DME	Dimethomorph	6.258122	6.174213	5.724142	4.850129	4.301479
DOD	Dodine (dodecylguanidine monoacetate)	5.258247	4.053587	1.425149	0.514823	0.345827
DPA	Diphenylamine	3.766883	2.835195	0.926821	0.32796	0.21864
DPB	2,4-DB (form not specified)	60.05382	56.75092	41.99284	23.87414	17.11735
DPI	Clopyralid	9.296091	9.170978	8.500665	7.195941	6.375089
DPP	Diclofop-methyl	4.148876	3.915227	2.870824	1.623956	1.170811
DPY	Rimsulfuron	0.584167	0.447567	0.155457	0.055359	0.036906
DUB	Chlorpyrifos	30.94995	30.17641	26.21223	19.55164	16.02976
DUR	Diuron	148.0792	147.233	142.547	132.6109	125.6701

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
DXA	2,4-D (acid)	105.601	102.5772	87.42044	62.7003	50.09249
DXB	2,4-D (unspecified amine salt)	111.624	108.119	90.76439	63.32171	49.81856
DXF	2,4-D (unspecified ester)	118.4026	114.6852	96.27526	67.1692	52.84927
DYR	Anilazine	31.58035	30.54819	25.43442	17.50448	13.68452
EFR	Ethalfluralin	9.704358	9.391463	7.837826	5.423758	4.257215
ENT	Endothall (form not specified)	49.65464	47.67574	38.23113	24.62856	18.60722
EPT	EPTC	242.0119	236.3729	207.431	157.2844	129.8256
ESF	Endosulfan	20.17259	19.28725	15.11054	9.439126	7.08286
ETF	Ethephon	23.93271	23.0691	18.84853	12.55611	9.656052
ETM	Ethametsulfuron (form not specified)	0.982855	0.979392	0.96002	0.917621	0.886839
ETS	Ethofumesate	155.9437	154.8837	149.0389	136.7473	128.2482
FAA	N-Decanol	434.7254	405.2008	280.3946	145.7417	101.5504
FAB	N-Octanol	140.9411	108.6013	38.02426	13.55298	9.035416
FAD	Famoxadone	1.352064	1.301259	1.054521	0.692946	0.529449
FAL	Fosetyl-al	0.005715	0.003061	0.000584	0.000204	0.000136
FBZ	Indar	0.892496	0.88241	0.827724	0.720325	0.652036
FED	Fenamidone	2.784723	2.731828	2.454926	1.951111	1.658677
FER	Ferbam	190.3994	186.9308	168.7174	135.2667	115.633
FEX	Fenhexamid	16.84082	16.58639	15.2297	12.6518	11.07518
FLD	Fludioxonil	0.005905	0.005025	0.002376	0.00093	0.00063
FLM	Flumetsulam	3.298378	3.277356	3.161154	2.914867	2.742992

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
FLR	Fluroxypyr 1-methylheptyl ester	5.976555	5.88963	5.426114	4.536103	3.985191
FLS	Flucarbazone-sodium	1.272266	1.270158	1.258262	1.231572	1.211596
FLT	Flufenacet	25.78113	25.70458	25.27665	24.34208	23.66526
FLZ	Fluazinam	1.727639	1.697381	1.537428	1.242862	1.069298
FMS	Foramsulfuron	1.221491	1.196536	1.066862	0.834487	0.70208
FOF	Fomesafen	10.70416	10.11245	7.473904	4.242087	3.039699
FOL	Folpet	183.6746	173.6565	128.811	73.48752	52.75475
FOM	Formetanate (form not specified)	135.0452	131.2067	111.9407	80.46542	64.37614
FOR	Formaldehyde	45.71217	43.9007	35.24798	22.75335	17.20673
FPF	Fenoxaprop-p-ethyl	0.43113	0.407935	0.302981	0.174142	0.125923
FRA	Florasulam	0.175577	0.163743	0.11363	0.059267	0.041335
FZA	Fluazifop-p-butyl	1.331105	1.278435	1.024839	0.662091	0.502327
GLG	Glufosinate ammonium	32.99759	30.97651	22.1859	12.05562	8.51188
GOO	Azinphos-methyl	42.57621	41.06483	33.69039	22.57539	17.39512
GPI	Glyphosate (isopropylamine salt)	16.46072	15.18558	9.989113	4.948113	3.442715
GPM	Glyphosate (mono-ammonium salt)	20.278474	19.51695	15.824748	10.461711	8.064474
GPP	Glyphosate (potassium salt)	20.138623	19.382348	15.715612	10.389561	8.008857
GPS	Glyphosate (acid)	23.07551	22.20894	18.00747	11.90471	9.176816
GPT	Glyphosate (trimethylsulfonium salt)	12.32822	10.92446	6.013729	2.527995	1.699368
HEC	Hexaconazole	0.047762	0.047567	0.046479	0.04414	0.042477
IDO	Iodosulfuron-methyl-sodium	0.068444	0.063799	0.04417	0.022971	0.016008

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
IMI	Imidacloprid	11.25091	9.862475	5.228069	2.133754	1.42798
IMP	Imazethapyr	45.72167	45.60128	44.92476	43.42407	42.3166
IMZ	Imazamox	1.071736	1.033593	0.848207	0.568374	0.437801
IPD	Iprodione	35.64043	34.16066	27.13729	17.21524	12.91502
IXF	Isoxaflutole	2.649855	2.408082	1.482758	0.678903	0.460198
KRB	Propyzamide	59.94127	59.49896	57.06528	51.99987	48.54057
KRS	Kresoxim-methyl	3.649032	3.179254	1.641586	0.65963	0.441025
LUN	Linuron	153.8752	152.9033	147.5337	136.195	128.3142
MAA	MCPA (acid)	72.95962	72.08622	67.37605	58.05179	52.06304
MAB	MCPA (dimethylammine salt)	104.6118	102.584	91.99949	72.79288	61.68561
MAE	MCPA (unspecified ester)	42.59517	41.93771	38.44013	31.8113	27.77025
MAH	Maleic hydrazide (form not specified)	103.5732	97.70402	71.65727	40.23099	28.71757
MAL	Malathion	7.480307	4.674647	1.136779	0.397999	0.265332
MAN	Maneb	47.52658	46.99665	44.12285	38.4101	34.72042
MAS	MCPA (potassium salt)	115.5051	112.6221	97.93828	72.95925	59.57786
MCZ	Mancozeb	76.78194	72.56585	53.63645	30.46839	21.84809
MEA	Mecoprop (potassium salt)	51.959384	51.246792	47.433194	40.034175	35.397097
MEC	Mecoprop (form not specified)	38.238507	37.71409	34.907542	29.46238	26.049811
MEI	Dimethenamid	61.85637	61.01748	56.52429	47.80257	42.3316
MEM	Metsulfuron-methyl	4.362646	4.346125	4.253743	4.051583	3.904874
MER	Mesotrione	6.335142	6.234687	5.702132	4.694901	4.082759

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
MET	Methoxychlor	7.431363	5.982829	2.364772	0.875288	0.591669
MEW	Mecoprop d-isomer (potassium salt)	47.235798	46.587989	43.121081	36.3947	32.179177
MEX	Tribenuron methyl	7.408744	7.148648	5.881497	3.958768	3.056292
MEZ	Mecoprop d-isomer (amine salt)	27.838305	25.704958	17.021451	8.398115	5.775273
MFN	Metalaxyl-m (mefenoxam)	29.18559	27.98613	22.28552	14.19272	10.66646
MML	Methomyl	87.04703	85.81558	79.23821	66.54409	58.63866
MMM	Thifensulfuron-methyl	52.58115	51.29607	44.73593	33.50985	27.45374
MOM	Methamidophos	43.56565	41.56955	32.29002	19.75035	14.5754
MOR	Chinomethionat	4.720393	4.636399	4.192727	3.379331	2.902598
MPR	(S)-Methoprene	0.943568	0.880791	0.611879	0.321225	0.225257
MTA	Metalaxyl	2.040209	2.025365	1.943654	1.772576	1.654935
MTL	Metolachlor	92.20771	91.61638	88.34931	81.43794	76.62495
MTR	Metiram	9.493365	5.774212	1.385155	0.489011	0.327516
MXF	Methoxyfenozide	7.719836	7.698519	7.579333	7.31881	7.129941
MYC	Myclobutanil	3.551662	3.53383	3.434842	3.223593	3.074866
NAA	1-Naphthalene actetic acid (form not specified)	0.000035	0.000034	0.000029	0.00002	0.000016
NAL	Naled	31.1743	26.02145	11.51766	4.321668	2.882395
NAP	Naptalam (form not specified)	84.05	81.86907	70.75276	52.14166	42.34643
NBP	Napropamide	172.9788	171.6394	164.2799	149.0292	138.6698
NIO	Nicosulfuron	1.107147	1.052816	0.803901	0.478812	0.349467
NXI	Acetamiprid	5.889427	5.745769	5.011939	3.756358	3.078964

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
OXB	Oxamyl	98.37637	96.03931	84.07375	63.43371	52.19444
OXR	Oxyfluorfen	2.434625	2.344668	1.906831	1.264367	0.973349
PAQ	Paraquat (form not specified)	2.765176	1.511576	0.332474	0.117449	0.078849
PEN	Pendimethalin	4.783949	4.190412	2.204251	0.896648	0.600102
PFL	Permethrin	8.183468	6.900567	3.155357	1.203917	0.804479
PFN	Picolinafen	0.214277	0.203042	0.15199	0.088635	0.064709
PHR	Phorate	119.2002	118.3542	113.6941	103.9603	97.28402
PHS	Phosalone	7.334597	7.213335	6.569718	5.370209	4.653299
PHY	Propamocarb hydrochloride	36.52511	35.70612	31.48654	24.1009	20.00796
PIC	Picloram (form not specified)	103.3054	102.8915	100.5795	95.53557	91.88861
PID	Picloram (triisopropanolamine salt)	1.147838	1.143239	1.11755	1.061506	1.020985
PIR	Pirimicarb	32.62095	31.55394	26.30042	18.11533	14.15546
PMP	Phenmedipham	3.297509	3.164162	2.525193	1.623811	1.23312
PON	Propiconazole	4.515539	4.477413	4.268477	3.839271	3.550797
PRI	Primisulfuron-methyl	1.315989	1.292645	1.169909	0.942864	0.808503
PRO	Prometryne	116.2519	115.5284	111.5295	103.0764	97.1937
PRT	Phosmet	38.31368	37.53916	33.50007	26.26424	22.14044
PSF	Prosulfuron	0.442471	0.434644	0.393485	0.317296	0.272176
PYA	Pyraclostrobin	1.105291	1.01968	0.67012	0.328588	0.225887
PYD	Pyridaben	1.418703	1.150924	0.464631	0.171658	0.115089
PYR	Pyrethrins	0.028637	0.024152	0.01105	0.00424	0.002845

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
PYZ	Pyrazon (chloridazon)	151.9419	150.7354	144.1149	130.3917	121.0677
PZN	Pymetrozine	0.924058	0.909098	0.829545	0.681028	0.592077
QPE	Quizalofop p-ethyl	1.793862	0.52637	0.10031	0.035108	0.023406
QTZ	Quintozene	7.610213	7.287667	5.756696	3.646519	2.756418
QUC	Quinclorac	5.720594	5.70074	5.589617	5.34586	5.168414
SLF	Sulfosulfuron	0.931105	0.923015	0.87875	0.787547	0.726057
SMZ	Simazine	223.5794	222.5019	216.5096	203.6041	194.4169
SOD	Sethoxydim	15.96495	15.0858	11.15775	6.339726	4.544608
SPI	Spinosad	0.344921	0.309393	0.179109	0.078003	0.052576
SUL	Sulphur	20	20	20	20	20
TCM	2-(Thiocyanomethylthio)benzothiazole	0.584251	0.504497	0.250893	0.09881	0.065998
TEL	Tefluthrin	20	18.89116	8.706863	3.370331	2.280186
TER	Terbacil	162.0535	161.7546	160.0724	156.3225	153.5376
TET	Chlorothalonil	187.3816	184.2426	167.6575	136.6649	118.0926
TEU	Tebuconazole	2.869874	2.853438	2.762427	2.570021	2.436114
TFS	Triflusulfuron methyl	1.187889	1.115982	0.802281	0.438144	0.309848
TFY	Trifloxystrobin	1.017165	0.968457	0.742469	0.445371	0.326207
TFZ	Tebufenozide	7.802673	7.745287	7.429515	6.771979	6.322685
THE	Thiamethoxam	1.280032	1.245149	1.069317	0.777947	0.626568
THI	Thiram	164.398	156.9127	121.8149	74.68193	55.30511
TLL	Triadimenol	0.840963	0.834569	0.799412	0.726592	0.677155

AI Code	AI Accepted Name	Peak concentration	96-hour	21-day	60-day	90-day
TPA	Tepraloxydim	2.046513	1.965071	1.576403	1.0161	0.767846
TPM	Thiophanate-methyl	37.72087	35.05739	23.91835	12.21941	8.475202
TPR	Triclopyr	173.5336	171.2288	158.8712	134.7726	119.5757
TRA	Tralkoxydim	6.348987	5.91471	4.083102	2.115936	1.47312
TRF	Trifluralin	10.23597	9.921399	8.349562	5.884164	4.68133
TRI	Trichlorfon	132.6281	128.9068	110.2092	79.50761	63.72719
TRL	Triallate	22.41162	22.04317	20.0865	16.44186	14.26486
TRR	Triforine	21.4564	21.14689	19.49535	16.32198	14.3557
TRS	Triasulfuron	1.126009	1.068429	0.807011	0.472847	0.342877
TRT	Triticonazole	0.201075	0.200296	0.195953	0.186541	0.17979
TZL	Thiabendazole	9.325561	9.202327	8.539112	7.260357	6.464458
VIL	Vinclozolin	21.47383	21.33045	20.53918	18.8843	17.74757
VIT	Carbathiin	2.2947	2.093105	1.31087	0.610052	0.414651
VPR	Hexazinone	95.11291	94.79675	93.02577	89.13218	86.29005
ZIN	Zineb	61.34005	60.57487	56.45126	48.36452	43.22708
ZIR	Ziram	193.338	191.1047	179.0304	155.0655	139.6192
ZOX	Zoxamide	3.594216	3.467702	2.849129	1.914227	1.477101

Please note that physical/chemical properties used in GENEEC may be considered proprietary if obtained from the PMRA. Those obtained from other sources are available from the authors.

APPENDIX C: Standard deviation data extracted from the aquatic toxicity dataset.

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
ABM	Abamectin		I	0.4043	Fish
ACP	Acephate		I	0.7878	Crustaceans
ACP	Acephate		I	0.6367	Fish
ALM	d-trans Allethrin		I	0.2031	Crustaceans
ALM	d-trans Allethrin		I	0.5818	Fish
ALM	d-trans Allethrin		I	0.5103	Insects
AMI	Amitrole		H	1.0664	Crustaceans
AMI	Amitrole		H	0.5807	Fish
ATR	Atrazine (plus related active triazines)		H	0.5566	Algae
ATR	Atrazine (plus related active triazines)		H	0.4550	Crustaceans
ATR	Atrazine (plus related active triazines)		H	0.5700	Fish
AZY	Azoxystrobin		F	1.6634	Algae

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
AZY	Azoxystrobin		F	0.7445	Crustaceans
BAX	Metribuzin		H	0.5148	Algae
BAY	Propoxur		I	0.4906	Fish
BAY	Propoxur		I	0.5510	Insects
BBU	Bromacil present in free form, as dimethylamine salt, or as lithium salt		H	0.4822	Algae
BDC	Bendiocarb		I	1.1648	Crustaceans
BDX	Cyanazine		H	0.4780	Algae
BET	Bensulide		H	0.2484	Fish
BOA	Boracic acid (Boric acid)		I	0.5921	Fish
BRY	Bromoxynil present as the ester of n-octanoic acid or n-pentanoic acid		H	0.5291	Algae
CAB	Carbaryl		I	0.1825	Algae
CAB	Carbaryl		I	0.9260	Crustaceans
CAB	Carbaryl		I	0.3921	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
CAF	Carbofuran		I	1.3736	Crustaceans
CAF	Carbofuran		I	0.7086	Fish
CAF	Carbofuran		I	1.1783	Insects
CAP	Captan		F	0.7268	Algae
CAP	Captan		F	0.4692	Fish
CAZ	Carbendazim		F	0.8941	Fish
CCC	Chlormequat		O	0.4730	Fish
CFP	Clodinafop-propargyl		H	0.5563	Algae
CHL	Chlorthal present as acid or as dimethyl ester		H	0.7953	Fish
CNQ	Clomazone		H	0.6859	Algae
COY	Terbufos		I	0.4790	Fish
CSL	2-Chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2 yl)aminocarbonyl]benzene sulfonamide		H	1.2301	Algae
CSL	2-Chloro-N-[(4-methoxy-6-methyl-1,3,5-triazin-2 yl)aminocarbonyl]benzene sulfonamide		H	0.4908	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
CUQ	Copper 8-quinolinolate		F	0.5965	Algae
CUY	Copper as elemental, present as copper oxychloride		F	0.6201	Fish
CXF	Cyfluthrin		I	0.7891	Fish
CYM	Cypermethrin		I	0.6782	Crustaceans
CYM	Cypermethrin		I	0.3580	Fish
CYM	Cypermethrin		I	0.7962	Insects
CYO	Cymoxanil		F	0.7263	Algae
CYO	Cymoxanil		F	0.2854	Fish
CYP	Cyprodinil		F	0.4856	Algae
CYP	Cyprodinil		F	0.6640	Crustaceans
CYP	Cyprodinil		F	0.3785	Fish
DAZ	Dazomet		O	0.7333	Fish
DBR	Deltamethrin		I	0.4609	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DBR	Deltamethrin		I	0.6616	Insects
DCB	Dichlobenil		H	0.1918	Algae
DCB	Dichlobenil		H	0.4005	Crustaceans
DCB	Dichlobenil		H	0.1900	Fish
DCF	Dicofol		I	0.5181	Fish
DFF	Diflufenzopyr		H	0.0731	Algae
DIA	Diazinon		I	1.1016	Crustaceans
DIA	Diazinon		I	0.7255	Fish
DIA	Diazinon		I	0.5495	Insects
DIC(d)	Dicamba present as acid, as diethanolamine salt, as dimethylamine salt, or as butoxyethyl ester, or as sodium salt	Dicamba, acid	H	1.3016	Algae
DIC(d)	Dicamba present as acid, as diethanolamine salt, as dimethylamine salt, or as butoxyethyl ester, or as sodium salt	Dicamba, acid	H	0.7593	Fish
DIE	Dieldrin		I	0.8458	Crustaceans

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DIE	Dieldrin		I	0.3860	Fish
DIE	Dieldrin		I	0.8650	Insects
DIH(b)	Dichlorprop (present as butoxyethyl ester, as isooctyl ester, or as ethylhexyl ester)	Dichlorprop (2,4-DP), butoxyethyl ester	H	0.1840	Fish
DIM	Dimethoate		I	1.8207	Crustaceans
DIM	Dimethoate		I	1.4641	Fish
DIQ	Diquat		H	0.3544	Algae
DIQ(a)	Diquat	Diquat dibromide	H	0.7135	Crustaceans
DIQ(a)	Diquat	Diquat dibromide	H	0.6059	Fish
DIQ(b)	Diquat	Diquat	H	0.4896	Fish
DIS	Disulfoton		I	0.2660	Crustaceans
DIS	Disulfoton		I	0.9448	Fish
DNB	Dinoseb in free form		H	0.6340	Crustaceans
DNB	Dinoseb in free form		H	0.3150	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DPY	Rimsulfuron		H	0.7537	Algae
DSG	1,3-Dichloropropene		O	0.6898	Algae
DSG	1,3-Dichloropropene		O	0.4376	Fish
DUB	Chlorpyrifos		I	0.2410	Algae
DUB	Chlorpyrifos		I	0.9330	Crustaceans
DUB	Chlorpyrifos		I	0.9367	Fish
DUB	Chlorpyrifos		I	0.7250	Insects
DUR	Diuron		H	0.3848	Algae
DUR	Diuron		H	0.6453	Crustaceans
DUR	Diuron		H	0.5001	Fish
DVP	Dichlorvos plus related active compounds		I	0.3535	Algae
DVP	Dichlorvos plus related active 72		I	1.5620	Crustaceans
DVP	Dichlorvos plus related active compounds		I	0.6481	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DVP	Dichlorvos plus related active compounds		I	0.5402	Insects
DXA	2,4-D present as acid		H	1.0624	Algae
DXA	2,4-D present as acid		H	1.3330	Crustaceans
DXA	2,4-D present as acid		H	0.7382	Fish
DXB(d)	2,4-D present as amine salts (dimethylamine salt, diethanolamine salt, or other amine salts)	2,4-D dimethylamine salt	H	0.1937	Fish
DXF(d)	2,4-D present as low volatile esters	2,4-D ethylhexyl ester	H	1.0255	Algae
DXF(a)	2,4-D present as low volatile esters	2,4-D butoxyethyl ester	H	0.7183	Crustaceans
DXF(a)	2,4-D present as low volatile esters	2,4-D butoxyethyl ester	H	0.2849	Fish
DXF(d)	2,4-D present as low volatile esters	2,4-D ethylhexyl ester	H	0.9492	Fish
END	Endrin		I	1.3184	Crustaceans
END	Endrin		I	1.5547	Insects
ENT(a)	Endothall	Endothall, unstated stereochemistry	H	0.2075	Crustaceans

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
ENT(a)	Endothall	Endothall, unstated stereochemistry	H	0.5571	Fish
ESF	Endosulfan		I	1.3696	Crustaceans
ESF	Endosulfan		I	0.9107	Insects
FAB	N-Octanol		H	0.0602	Fish
FAD	Famoxadone		F	0.3463	Algae
FBT	Fenbutatin oxide		I	0.8392	Fish
FED	Fenamidone (RPA 407213)		F	0.8074	Algae
FEM	Fenitrothion		I	0.4351	Algae
FEM	Fenitrothion		I	0.9730	Crustaceans
FEM	Fenitrothion		I	0.3606	Fish
FEM	Fenitrothion		I	0.3870	Insects
FER	Ferbam		F	0.7926	Fish
FLD	Fludioxonil		F	0.2357	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
FLT	Flufenacet		H	1.9280	Algae
FMS	Foramsulfuron		H	0.6176	Algae
FOL	Folpet		F	0.5966	Fish
FOR	Formaldehyde		O	0.5311	Crustaceans
FOR	Formaldehyde		O	0.5281	Fish
FPF	Fenoxaprop-p-ethyl (isomer)		H	0.1886	Fish
FRA	Florasulam		H	1.4809	Algae
GLG	Glufosinate ammonium		H	0.2075	Fish
GOO	Azinphos-methyl		I	1.0300	Crustaceans
GOO	Azinphos-methyl		I	0.7990	Fish
GPI	Glyphosate (present as isopropylamine salt)		H	0.8637	Crustaceans
GPI	Glyphosate (present as isopropylamine salt)		H	0.6774	Fish
GPS	Glyphosate acid		H	0.2050	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
IDO	Iodosulfuron-methyl-sodium		H	1.5579	Algae
IMI	Imidacloprid		I	1.8240	Crustaceans
IPB	Iodocarb (proposed common name)		F	0.2111	Fish
IPD	Iprodione		F	0.7606	Algae
IPD	Iprodione		F	0.1507	Fish
IXF	Isoxaflutole		H	0.6638	Algae
KRB	Propyzamide		H	1.0103	Fish
KRS	Kresoxim-methyl		F	0.3987	Algae
LUN	Linuron		H	0.6716	Algae
LUN	Linuron		H	0.3628	Fish
MAA	MCPA present as acid		H	0.7677	Fish
MAL	Malathion		I	1.4351	Crustaceans
MAL	Malathion		I	0.7097	Insects

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
MAN	Maneb		F	0.7179	Crustaceans
MAN	Maneb		F	0.4764	Fish
MBR	Methyl bromide		O	0.7384	Fish
MCZ	Mancozeb		F	0.3117	Fish
MEE	Mecoprop present as acid		H	0.2721	Fish
MER	Mesotrione		H	0.5410	Algae
MET	Methoxychlor		I	0.5868	Crustaceans
MET	Methoxychlor		I	0.4329	Fish
MET	Methoxychlor		I	0.5820	Insects
MML	Methomyl		I	0.2940	Fish
MML	Methomyl		I	0.7618	Crustaceans
MMM	Thifensulfuron methyl		H	0.2866	Algae
MOM	Methamidophos		I	0.3058	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
MPR	(S)-Methoprene		I	0.7163	Crustaceans
MPR	(S)-Methoprene		I	0.6430	Fish
MSM	Arsenic as elemental, present as monosodium methane arsonate		H	0.5847	Crustaceans
MSM	Arsenic as elemental, present as monosodium methane arsonate		H	0.6504	Fish
MTL	Metolachlor		H	0.7323	Algae
MTR	Metiram		F	1.0814	Fish
NAL	Naled		I	1.3277	Crustaceans
NAL	Naled		I	1.0242	Fish
NAL	Naled		I	1.0739	Insects
OXA	Oxadiazon		H	1.1629	Algae
OXA	Oxadiazon		H	0.7558	Crustaceans
OXA	Oxadiazon		H	0.4090	Fish
OXB	Oxamyl		I	0.3802	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
OXR	Oxyfluorfen		H	2.0636	Algae
PAQ(a)	Paraquat	Paraquat	H	0.2651	Crustaceans
PAQ(a)	Paraquat	Paraquat	H	0.6676	Fish
PAQ(b)	Paraquat	paraquat dichloride	H	0.4212	Fish
PBU	Piperonyl butoxide		O	0.5510	Crustaceans
PCP	Pentachlorophenol plus related active chlorophenols		O	0.6566	Crustaceans
PCP	Pentachlorophenol plus related active chlorophenols		O	0.4204	Fish
PCP	Pentachlorophenol plus related active chlorophenols		O	0.7759	Insects
PEN	Pendimethalin		H	0.6849	Algae
PFL	Permethrin		I	1.0986	Crustaceans
PFL	Permethrin		I	0.6275	Fish
PFL	Permethrin		I	0.8747	Insects
PHR	Phorate		I	1.7323	Crustaceans

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
PHR	Phorate		I	0.9281	Fish
PHS	Phosalone		I	0.6563	Fish
PHY	Propamocarb hydrochloride		F	0.2498	Fish
PIC(a)	Picloram present as acid or as isooctyl esters or as potassium salt	Picloram, potassium salt	H	0.2596	Fish
PIC(b)	Picloram present as acid or as isooctyl esters or as potassium salt	Picloram, acid	H	0.8036	Crustaceans
PIC(b)	Picloram present as acid or as isooctyl esters or as potassium salt	Picloram, acid	H	0.4645	Fish
PON	Propiconazole		F	0.1950	Fish
PRL	Propanil		H	0.3133	Algae
PRL	Propanil		H	0.2338	Fish
PRL	Propanil		H	0.6162	Crustaceans
PRO	Prometryne plus related active triazines		H	0.6497	Algae
PRT	Phosmet		I	0.8004	Crustaceans
PRT	Phosmet		I	0.8984	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
PSF	Prosulfuron		H	0.3932	Algae
PTH	Parathion		I	1.3325	Crustaceans
PTH	Parathion		I	0.5354	Insects
PYA	Pyraclostrobin		F	1.2027	Algae
PYD	Pyridaben		I	0.8192	Algae
PYR	Pyrethrins		I	0.4163	Fish
PZN	Pymetrozine		I	0.0342	Fish
QUC	Quinclorac		H	0.1729	Fish
REZ	Resmethrin		I	0.4125	Fish
SDD	Sodium dimethyldithiocarbamate		F	1.4150	Crustaceans
SMZ	Simazine plus related active triazines		H	0.4293	Algae
SMZ	Simazine plus related active triazines		H	0.7255	Crustaceans
SMZ	Simazine plus related active triazines		H	0.6878	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
SOD	Sethoxydim		H	0.8665	Fish
TCS	TCA present as sodium salt		H	1.6268	Crustaceans
TCS(b)	TCA present as sodium salt	TCA (trichloroacetic acid)	H	0.3781	Fish
TER	Terbacil		H	0.4886	Algae
TET	Chlorothalonil		F	0.7787	Crustaceans
TET	Chlorothalonil		F	0.4338	Fish
THI	Thiram		F	1.0482	Fish
THI	Thiram		F	1.7702	Crustaceans
TPM	Thiophanate-methyl		F	0.4226	Algae
TPM	Thiophanate-methyl		F	0.4693	Fish
TRA	Tralkoxydim		H	0.6499	Algae
TRF	Trifluralin		H	0.8030	Crustaceans
TRF	Trifluralin		H	0.4977	Fish

Table C1: Technical product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
TRI	Trichlorfon		I	1.6111	Crustaceans
TRI	Trichlorfon		I	0.6773	Fish
TRI	Trichlorfon		I	0.5184	Insects
TRL	Triallate		H	0.5844	Algae
TRT	Triticonazole		F	0.3781	Algae
TXP	4-(Cyclopropyl-alpha-hydroxy-methylene)-3,5-dioxo-cyclohexane		O	0.8580	Algae
TXP	4-(Cyclopropyl-alpha-hydroxy-methylene)-3,5-dioxo-cyclohexane		O	0.2851	Fish
VIL	Vinclozolin		F	0.5962	Fish
ZIN	Zineb		F	0.7062	Fish
ZIR	Ziram		F	0.8934	Fish

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
ACP	Acephate		I	0.5780	Fish
AMZ	Amitraz		I	0.4853	Fish
ATR	Atrazine (plus related active triazines)		H	0.4650	Fish
ATR	Atrazine (plus related active triazines)		H	1.3533	Crustaceans
ATR	Atrazine (plus related active triazines)		H	0.7735	Algae
BAY	Propoxur		I	0.5773	Fish
BDX	Cyanazine		H	0.1354	Fish
CAB	Carbaryl		I	0.4417	Fish
CAB	Carbaryl		I	0.7716	Crustaceans
CAB	Carbaryl		I	2.0350	Insects
CAF	Carbofuran		I	0.4690	Fish
CYM	Cypermethrin		I	0.7275	Fish
DCB	Dichlobenil		H	0.7429	Crustaceans
DCB	Dichlobenil		H	0.1156	Insects
DCF	Dicofol		I	0.7562	Fish
DFB	Diflubenzuron		I	0.2949	Fish
DFB	Diflubenzuron		I	2.1959	Crustaceans

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DIA	Diazinon		I	0.8054	Fish
DIA	Diazinon		I	1.0829	Crustaceans
DIA	Diazinon		I	0.2872	Insects
DIE	Dieldrin		I	0.8884	Fish
DIM	Dimethoate		I	0.4451	Fish
DIQ	Diquat		H	0.6093	Fish
DIQ	Diquat		H	0.9311	Crustaceans
DIQ	Diquat		H	0.1839	Insects
DIQ(a)	Diquat	Diquat dibromide	H	0.5576	Fish
DIQ(a)	Diquat	Diquat dibromide	H	0.7358	Crustaceans
DIQ(b)	Diquat	Diquat	H	0.5231	Fish
DUB	Chlorpyrifos		I	0.5792	Fish
DUB	Chlorpyrifos		I	0.5729	Insects
DVP	Dichlorvos plus related active compounds		I	0.7039	Fish
DVP	Dichlorvos plus related active compounds		I	0.8745	Crustaceans
DXA	2,4-D present as acid		H	0.9230	Fish

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
DXB	2,4-D present as amine salts (dimethylamine salt, diethanolamine salt, or other amine salts)		H	0.4063	Fish
DXB	2,4-D present as amine salts (dimethylamine salt, diethanolamine salt, or other amine salts)		H	0.7045	Crustaceans
DXB(d)	2,4-D present as amine salts (dimethylamine salt, diethanolamine salt, or other amine salts)	2,4-D dimethylamine salt	H	0.4045	Fish
DXB(d)	2,4-D present as amine salts (dimethylamine salt, diethanolamine salt, or other amine salts)	2,4-D dimethylamine salt	H	0.6315	Crustaceans
DXF	2,4-D present as low volatile esters		H	0.2452	Fish
DXF	2,4-D present as low volatile esters		H	0.1481	Crustaceans
DXF(a)	2,4-D present as low volatile esters	2,4-D butoxyethyl ester	H	0.3771	Crustaceans
DXF(c)	2,4-D present as low volatile esters	2,4-D isooctyl ester	H	1.2751	Crustaceans
END	Endrin		I	0.6298	Fish
ENT	Endothall		H	1.0331	Fish
ENT	Endothall		H	0.8900	Crustaceans
ENT(a)	Endothall	Endothall, unstated stereochemistry	H	1.1072	Fish
ENT(a)	Endothall	Endothall, unstated stereochemistry	H	1.3443	Crustaceans
ENT(b)	Endothall	Endothall, mono(N,N-dimethylalkylamine)	H	0.4330	Fish
ENT(b)	Endothall	Endothall, mono(N,N-	H	0.8217	Crustaceans

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
		dimethylalkylamine)			
ESF	Endosulfan		I	0.4171	Fish
ESF	Endosulfan		I	1.6949	Crustaceans
FAA	N-Decanol		H	0.4638	Fish
FEM	Fenitrothion		I	0.4217	Fish
FEM	Fenitrothion		I	1.3340	Crustaceans
FEM	Fenitrothion		I	1.0156	Insects
FLR	Fluroxypyr 1-methylheptyl ester		H	0.0528	Fish
FOR	Formaldehyde		O	0.3318	Fish
FOR	Formaldehyde		O	1.0908	Crustaceans
GOO	Azinphos-methyl		I	0.9975	Fish
GOO	Azinphos-methyl		I	1.1803	Crustaceans
GPI	Glyphosate (present as isopropylamine salt)		H	0.5088	Crustaceans
GPS	Glyphosate acid		H	0.5686	Fish
GPS	Glyphosate acid		H	0.5376	Crustaceans
KRB	Propyzamide		H	0.3571	Fish

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
MAL	Malathion		I	1.0094	Fish
MAL	Malathion		I	1.6894	Crustaceans
MAL	Malathion		I	0.3873	Insects
MAN	Maneb		F	1.0381	Fish
MCZ	Mancozeb		F	0.8092	Algae
MET	Methoxychlor		I	0.7334	Fish
MML	Methomyl		I	0.2594	Fish
MML	Methomyl		I	0.6143	Crustaceans
MPR	(S)-Methoprene		I	0.6078	Fish
MSM	Arsenic as elemental, present as monosodium methane arsonate		H	0.4319	Fish
PAQ	Paraquat		H	0.5136	Fish
PAQ	Paraquat		H	0.4262	Crustaceans
PAQ(a)	Paraquat	Paraquat	H	0.2305	Fish
PAQ(b)	Paraquat	paraquat dichloride	H	0.6408	Fish
PAQ(b)	Paraquat	paraquat dichloride	H	0.4988	Crustaceans
PAQ(b)	Paraquat	paraquat dichloride	H	1.0411	Algae

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
PCP	Pentachlorophenol plus related active chlorophenols		O	0.2614	Fish
PCP	Pentachlorophenol plus related active chlorophenols		O	0.4580	Crustaceans
PEN	Pendimethalin		H	0.7832	Algae
PFL	Permethrin		I	0.7381	Fish
PFL	Permethrin		I	0.4143	Insects
PHS	Phosalone		I	0.3828	Fish
PIC	Picloram present as acid or as isooctyl esters or as potassium salt		H	0.2607	Fish
PIC(a)	Picloram present as acid or as isooctyl esters or as potassium salt	Picloram, potassium salt	H	0.6943	Fish
PID	Picloram present as amine salts (alkanolamine salt, diethanolamine salt, or triisopropanolamine salt)		H	0.3787	Fish
PON	Propiconazole		F	0.4384	Fish
PRL	Propanil		H	0.2667	Fish
PRL	Propanil		H	0.5376	Crustaceans
PRT	Phosmet		I	0.9330	Fish
PTH	Parathion		I	0.4244	Fish
PTH	Parathion		I	1.5374	Crustaceans
PTH	Parathion		I	0.9698	Insects

Table C2: Formulated product data

Modified AI code	AI Accepted name (PMRA)	AI (Detail)	Pesticide Type	Mean standard deviation	Taxon
PYR	Pyrethrins		I	0.3525	Fish
QAK	Didecyl dimethyl ammonium chloride		O	0.3589	Fish
SDD	Sodium dimethyldithiocarbamate		F	1.5090	Crustaceans
SMZ	Simazine plus related active triazines		H	0.3279	Fish
TCM	2-(Thiocyanomethylthio)benzothiazole		O	0.6045	Fish
TET	Chlorothalonil		F	0.2757	Fish
THI	Thiram		F	1.0467	Fish
TRF	Trifluralin		H	0.7098	Fish
TRI	Trichlorfon		I	0.5331	Fish
TRI	Trichlorfon		I	0.7178	Crustaceans

APPENDIX D: Our final rankings for weighted community risk compared to those obtained with the PMRA's modified APPLES ranking.

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
TEL	Tefluthrin	8714.8876	1	71.84	3	2
PHR	Phorate	5738.0249	2	61.43	39	37
DIM	Dimethoate	2856.5690	3	55.71	87	84
MOM	Methamidophos	662.9658	4	57.14	76	72
DIA	Diazinon	380.4886	5	66.58	15	10
TRI	Trichlorfon	312.8779	6	68.57	7	1
DUB	Chlorpyrifos	204.2788	7	75.79	1	6
PFL	Permethrin	154.8136	8	62.86	28	20
THI	Thiram	153.6834	9	49.47	131	122
MMM	Thifensulfuron-methyl	137.4786	10	42.89	172	162
FLT	Flufenacet	137.3050	11	56.58	80	69
GOO	Azinphos-methyl	133.1950	12	68.57	8	4
CYM	Cypermethrin	125.9593	13	60.00	49	36
CAF	Carbofuran	98.0017	14	62.86	29	15
ESF	Endosulfan	71.0358	15	60.00	50	35

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
TET	Chlorothalonil	55.7806	16	63.95	23	7
NAL	Naled	55.3237	17	59.21	57	40
CAB	Carbaryl	50.3782	18	57.37	70	52
FER	Ferbam	47.6270	19	55.70	91	72
COY	Terbufos	39.8696	20	68.57	9	11
PYD	Pyridaben	36.5142	21	75.00	2	19
DCB	Dichlobenil	33.7417	22	54.74	95	73
MEM	Metsulfuron-methyl	31.0474	23	54.21	98	75
TRS	Triasulfuron	30.1353	24	53.42	102	78
CYH	Cyhalothrin-lambda	23.1917	25	67.89	12	13
ZIR	Ziram	22.5436	26	56.58	81	55
VPR	Hexazinone	22.1746	27	52.89	108	81
PRO	Prometryne	21.1049	28	65.79	17	11
OXR	Oxyfluorfen	20.6871	29	60.53	46	17
DXF	2,4-D (unspecified ester)	18.9021	30	36.18	194	164
PRT	Phosmet	17.5425	31	57.14	77	46
DOD	Dodine (dodecylguanidine monoacetate)	17.4166	32	43.42	171	139

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
DUR	Diuron	16.7428	33	61.84	37	4
LUN	Linuron	16.1690	34	60.53	47	13
MCZ	Mancozeb	16.0804	35	40.00	184	149
DIN	Dinocap	15.6286	36	58.6	65	29
IMP	Imazethapyr	15.3565	37	48.82	135	98
PRI	Primisulfuron-methyl	13.0588	38	52.11	111	73
AZY	Azoxystrobin	9.4412	39	60.00	51	12
AME	S-Metolachlor	8.8643	40	62.50	33	7
DBR	Deltamethrin	8.3160	41	50.79	125	84
PHS	Phosalone	8.2079	42	67.89	13	29
FOL	Folpet	7.2575	43	62.14	34	9
CAP	Captan	7.1991	44	57.37	71	27
FMS	Foramsulfuron	6.4007	45	46.84	147	102
TER	Terbacil	5.2900	46	59.87	55	9
OXB	Oxamyl	4.9571	47	58.57	66	19
BAX	Metribuzin	4.7929	48	61.84	38	10
MEX	Tribenuron methyl	4.6426	49	40.15	183	134

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
AMI	Amitrole	4.6380	50	44.87	161	111
IMI	Imidacloprid	4.3815	51	50.71	128	77
MML	Methomyl	4.3796	52	63.82	26	26
MAL	Malathion	4.3761	53	71.43	4	49
MET	Methoxychlor	4.0256	54	64.29	21	33
MOR	Chinomethionat	3.3904	55	57.37	72	17
EFR	Ethalfluralin	3.3250	56	51.32	121	65
BET	Bensulide	3.2600	57	61.32	40	17
ATR	Atrazine	3.1516	58	65.79	18	40
SMZ	Simazine	3.0067	59	57.37	73	14
FLM	Flumetsulam	2.8837	60	57.37	74	14
DYR	Anilazine	2.8626	61	48.57	141	80
SLF	Sulfosulfuron	2.5699	62	55.53	92	30
CSL	Chlorsulfuron	2.5659	63	45.53	155	92
FOM	Formetanate (form not specified)	2.5517	64	58.57	67	3
DIK	Dichloran	2.3153	65	52.86	109	44
FAD	Famoxadone	1.9664	66	65.79	19	47

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
PYA	Pyraclostrobin	1.4465	67	70.53	5	62
MEI	Dimethenamid	1.3730	68	61.18	44	24
MAA	MCPA (acid)	1.1791	69	44.87	162	93
MAE	MCPA (unspecified ester)	1.1452	70	45.53	156	86
PEN	Pendimethalin	1.0806	71	68.42	10	61
TFS	Triflusulfuron methyl	1.0794	72	53.42	103	31
TRL	Triallate	1.0790	73	56.05	83	10
PSF	Prosulfuron	0.9642	74	56.05	84	10
DIC	Dicamba (form not specified)	0.9462	75	42.37	173	98
FAA	N-Decanol	0.8985	76	55.71	88	12
IPD	Iprodione	0.8766	77	49.47	132	55
PYZ	Pyrazon (chloridazon)	0.8594	78	39.74	185	107
QTZ	Quintozene	0.7126	79	57.14	78	1
DCF	Dicofol	0.6985	80	59.21	58	22
MAN	Maneb	0.6792	81	48.15	143	62
PIR	Pirimicarb	0.6712	82	62.86	30	52
ZOX	Zoxamide	0.6539	83	48.68	138	55

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
ETS	Ethofumesate	0.6529	84	61.97368	36	48
MTL	Metolachlor	0.6521	85	61.18	45	40
TRF	Trifluralin	0.5615	86	68.42	11	75
BRY	Bromoxynil (octanoate)	0.5521	87	51.32	122	35
MBS	MCPB (sodium salt)	0.4233	88		N/A	
TZL	Thiabendazole	0.4129	89	60	52	37
FRA	Florasulam	0.3785	90	46.84211	148	58
BTL	Desmedipham	0.3744	91	53.42105	104	13
FOF	Fomesafen	0.2872	92	64.07407	22	70
FLR	Fluroxypyr 1-methylheptyl ester	0.2872	93	63.94737	24	69
IDO	Iodosulfuron-methyl-sodium	0.2785	94	53.28947	107	13
TPR	Triclopyr	0.2774	95	55.52632	93	2
TCM	2-(Thiocyanomethylthio)benzothiazole	0.2739	96	58.68421	61	35
KRB	Propyzamide	0.2570	97	66	16	81
IMZ	Imazamox	0.2564	98	50.78947	126	28
FLZ	Fluazinam	0.2508	99	61.31579	41	58
EPT	EPTC	0.2429	100	56.05263	85	15

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
ZIN	Zineb	0.2424	101	44.44444	166	65
TFY	Trifloxystrobin	0.2408	102	60.52632	48	54
DXA	2,4-D (acid)	0.2344	103	48.68421	139	36
PAQ	Paraquat (form not specified)	0.2222	104	51.42857	120	16
TFZ	Tebufenozide	0.2198	105	67.10526	14	91
MTR	Metiram	0.1769	106	18.33333	197	91
DPY	Rimsulfuron	0.1671	107	42.36842	174	67
DIQ	Diquat (form not specified)	0.1646	108	59.25926	56	52
SOD	Sethoxydim	0.1628	109	51.44737	119	10
PFN	Picolinafen	0.1585	110	57.89474	69	41
CNQ	Clomazone	0.1534	111	58.68421	62	49
PIC	Picloram (form not specified)	0.1357	112	56.71053	79	33
DIH	Dichlorprop (form not specified)	0.1325	113	52.10526	112	1
CHL	Chlorthal (form not specified)	0.1257	114	35.65789	195	81
VIL	Vinclozolin	0.1257	115	48.15789	142	27
KRS	Kresoxim-methyl	0.1255	116	59.21053	59	57
TPM	Thiophanate-methyl	0.1243	117	45.52632	157	40

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
IXF	Isoxaflutole	0.1192	118	50.78947	127	9
ENT	Endothall (form not specified)	0.1186	119	59	60	59
PMP	Phenmedipham	0.1085	120	41.42857	178	58
NBP	Napropamide	0.1006	121	62.14286	35	86
DPP	Diclofop-methyl	0.0922	122	54.28571	97	25
CYP	Cyprodinil	0.0892	123	57.36842	75	48
CHH	Boscalid	0.0870	124	52.10526	113	11
MXF	Methoxyfenozide	0.0861	125	60	53	72
NXI	Acetamiprid	0.0786	126	39.60526	186	60
PON	Propiconazole	0.0774	127	63.94737	25	102
MAS	MCPA (potassium salt)	0.0678	128	46.31579	151	23
TEU	Tebuconazole	0.0631	129	69.09091	6	123
MAB	MCPA (dimethylammine salt)	0.0618	130	44.86842	163	33
GLG	Glufosinate ammonium	0.0597	131	40.92105	179	48
FAB	N-Octanol	0.0530	132		N/A	
DPB	2,4-DB (form not specified)	0.0509	133	51.31579	123	10
FEX	Fenhexamid	0.0508	134	44.86842	164	30

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
DAZ	Dazomet	0.0452	135	62.63158	32	103
FED	Fenamidone	0.0425	136	65.26316	20	116
PYR	Pyrethrins	0.0394	137		N/A	
CYO	Cymoxanil	0.0384	138	46.18421	153	15
GPT	Glyphosate (trimethylsulfonium salt)	0.0382	139	45	159	20
DPA	Diphenylamine	0.0322	140	44.28571	167	27
QUC	Quinclorac	0.0316	141	54.21053	99	42
QPE	Quizalofop p-ethyl	0.0298		61.3	42	42
COD	Clothianidin	0.0280	143	48.81579	136	7
MYC	Myclobutanil	0.0279	144	61.31579	43	101
BZN	Bentazon (form not specified)	0.0273	145	42.14286	177	32
CUZ	Copper (copper hydroxide)	0.0246	146		N/A	
AMZ	Amitraz	0.0219	147	49.34211	134	13
DXB	2,4-D (unspecified amine salt)	0.0191	148	43.68421	169	21
ACP	Acephate	0.0171	149	47.14286	146	3
DFF	Diflufenzopyr (form not specified)	0.0163	150	46.18421	154	4
FBZ	Indar	0.0137	151	53.4	105	46

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
VIT	Carbathiin	0.0126	152	48.81579	137	15
GPI	Glyphosate (isopropylamine salt)	0.0124	153	51.66667	115	38
MPR	(S)-Methoprene	0.0099	154	55.71429	89	65
NAP	Naptalam (form not specified)	0.0089	155	40.85714	181	26
FLS	Flucarbazone-sodium	0.0088	156	58.48485	68	88
TRA	Tralkoxydim	0.0081	157	49.47368	133	24
MFN	Metalaxyl-m (mefenoxam)	0.0074	158	48.68421	140	18
MAH	Maleic hydrazide (form not specified)	0.0073	159	42.36842	175	16
FZA	Fluazifop-p-butyl	0.0068	160	45.39474	158	2
CLE	Clethodim	0.0065	161	55.14286	94	67
MEA	Mecoprop (potassium salt)	0.0063	162	39.3	187	25
AVG	Difenzoquat (methyl sulphate salt)	0.0061	163	55.71429	90	73
MEW	Mecoprop d-isomer (potassium salt)	0.0058	164	39.3	188	24
GPS	Glyphosate (acid)	0.0053	165	43.55263	170	5
CYZ	Cyromazine	0.0052	166	56.44737	82	84
TRR	Triforine	0.0052	167	34.21053	196	29
MEC	Mecoprop (form not specified)	0.0047	168	39.3	189	21

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
DME	Dimethomorph	0.0046	169	53.94737	100	69
ACA	Acifluorfen (form not specified)	0.0041	170		N/A	
DPI	Clopyralid	0.0041	171	45	160	11
TLL	Triadimenol	0.0034	172	56.05263	86	86
ETF	Ethephon	0.0034	173	36.97368	193	20
FPF	Fenoxaprop-p-ethyl	0.0033	174	46.84211	149	25
MEZ	Mecoprop d-isomer (amine salt)	0.0032	175	39.3	190	15
FOR	Formaldehyde	0.0030	176		N/A	
GPP	Glyphosate (potassium salt)	0.0028	177	51.7	116	61
CUS	Copper (copper sulphate)	0.0026	178		N/A	
BMS	Flusilazole	0.0025	179	58.6	64	115
DFZ	Difenoconazole	0.0023	180	62.85714	31	149
CCC	Chlormequat (form not specified)	0.0023	181	51.66667	117	64
SPI	Spinosad	0.0023	182	50	129	53
MER	Mesotrione	0.0022	183	42.36842	176	7
PHY	Propamocarb hydrochloride	0.0022	184	52.28571	110	74
CFP	Clodinafop-propargyl	0.0017	185	53.42105	106	79

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
ASS	Imazamethabenz (form not specified)	0.0016	186	50.85714	124	62
MTA	Metalaxyl	0.0014	187	47.23684	145	42
ETM	Ethametsulfuron (form not specified)	0.0011	188	44.86842	165	23
CFZ	Clofentezine	0.0010	189	53.94737	101	88
THE	Thiamethoxam	0.0010	190	50	130	60
TRT	Triticonazole	0.0010	191	60	54	137
BAD	6-Benzyladenine	0.0010	192	44.16667	168	24
PID	Picloram (triisopropanolamine salt)	0.0008	193	63.28947	27	166
SUL	Sulphur	0.0006	194		N/A	
CUY	Copper (copper oxychloride)	0.0006	195		N/A	
CLM	Cloransulam (form not specified)	0.0006	196	48.02632	144	52
CHE	Chlorimuron-ethyl	0.0006	197	52.10526	114	83
GPM	Glyphosate (mono-ammonium salt)	0.0004	198	51.7	118	80
PZN	Pymetrozine	0.0004	199	38.15789	191	8
FLD	Fludioxonil	0.0003	200	58.68421	63	137
TPA	Tepraloxydim	0.0002	201	40.92105	180	21
HEC	Hexaconazole	0.0001	202	54.73684	96	106

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of ranking differences
AMN	Aminoethoxyvinylglycine	0.0001	203	37.63158	192	11
NIO	Nicosulfuron	0.0000	204	46.84211	150	54
FAL	Fosetyl-al	0.0000	205	46.31579	152	53
NAA	1-Naphthalene actetic acid (form not specified)	0.0000	206	40.85714	182	24

APPENDIX E: Top 20 rankings with fumigants included (fumigants are marked in red).

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of differences
TEL	Tefluthrin	8714.887647	1	71.84	4	3
PHR	Phorate	5738.024881	2	61.43	43	41
MTM	Metam (form not specified)	3161.8889	3	68.30	13	10
DIM	Dimethoate	2856.56897	4	55.71	89	85
KMC	Potassium n-methyldithiocarbamate	2531.307825	5			
MIS	Methyl isothiocyanate	1807.438531	6	62.6	36	30
CPN	Chloropicrin	681.6054479	7	39.4	186	179
MOM	Methamidophos	662.965777	8	57.14	78	70
DIA	Diazinon	380.4886148	9	66.58	17	8
TRI	Trichlorfon	312.8779009	10	68.57	8	2
DSG	1,3-Dichloropropene	256.6707435	11	55.9	88	77
DUB	Chlorpyrifos	204.2788294	12	75.79	1	11
MBR	Methyl bromide	156.6945153	13	64.3	23	10
PFL	Permethrin	154.8135853	14	62.86	31	17

AI Code	AI Accepted Name	Weighted community risk	Rank of Weighted community risk	APPLES tox/fate	Rank of weighted APPLES tox/fate	Absolute value of differences
THI	Thiram	153.6834457	15	49.47	130	115
MMM	Thifensulfuron-methyl	137.4786064	16	42.89	171	155
FLT	Flufenacet	137.3049674	17	56.58	82	65
GOO	Azinphos-methyl	133.1950191	18	68.57	9	9
CYM	Cypermethrin	125.9592649	19	60.00	52	33
CAF	Carbofuran	98.00169233	20	62.86	32	12

GENEEC output: estimated environmental concentrations (ug/L) for the 6 fumigants analyzed

AI Code	AI Accepted Name	96-hour concentration
MTM	Metam (form not specified)	21956.02
KMC	Potassium n-methyldithiocarbamate	39852.60
MIS	Methyl isothiocyanate	7179.108
CPN	Chloropicrin	1564.402
DSG	1,3-Dichloropropene	15008.56
MBR	Methyl bromide	11530.50

NOTE: When running the GENEEC model for all of the active ingredients, six runs returned outputs of "******" rather than the usual water concentrations. The six compounds with this result were: Chloropicrin, 1,3-Dichloropropene, Potassium n-methyldithiocarbamate, Methyl bromide, Methyl isothiocyanate, and Metam (form not specified). All of these compounds are fumigants. Analyzing the physical/chemical input values necessary to run GENEEC revealed that the 'maximum rate of the active ingredient (kg a.i./ha)' for each of the six compounds was much higher than that of the other compounds. Closer examination revealed that GENEEC was not capable of generating a concentration output that is 1000 ppb or greater. It was possible to reduce the 'maximum rate of the active ingredient (kg/ha)' for the six compounds to a level that resulted in a 96-hour concentration below the 1000 ppb threshold. In order to obtain a value, we tested the linearity of model outputs with fractions of the application rate and were able to extrapolate to the higher water residue levels.

APPENDIX F: Comparison of GENEEC outputs with measured river concentrations of pesticides: The San Joaquin watershed in California as a case study

Introduction

There are no appropriate datasets with which we can compare the outputs from the GENEEC model with actual end of field residue levels. The only reasonably comprehensive datasets are for water samples taken from second or third order streams, often a long way downstream from some of the application sites and always after a great deal of dilution. As mentioned in the text, Urban (1998) established that GENEEC peak concentrations were usually 2-3X higher than values predicted with more sophisticated PRIZM/EXAMS modeling – but that is not proper field validation.

Even though we cannot verify the actual GENEEC predictions, we decided to at least asses whether the relative among-chemical GENEEC end of field predictions were reflected in downstream measured residue levels. In order to carry out this validation, we chose a jurisdiction which has both water quality monitoring as well as comprehensive pesticide use information – California.

Methods

North American Water-Quality Assessment (NAWQA) Database

We obtained information on pesticide concentrations in stream water from the National Water-Quality Assessment (NAWQA) Program of the United States Geological Survey (USGS). Their database, based on results from studies completed during 1992–2004, provides the most comprehensive national (U.S.)-scale analysis to date of pesticide occurrence and concentrations in streams and ground water. In their first decadal assessment (Gilliom *et al.* 2006), they found that pesticides are frequently present in streams and

ground water and that, while they do not occur at concentrations harmful to humans, they do occur in many streams at concentrations that may have effects on aquatic life or fish-eating wildlife.

The San Joaquin basin in California fulfilled the criteria we were looking for: discrete sample points downstream from a series of well defined agricultural watersheds for which pesticide use data could be obtained. Gronberg et al. (1998) thoroughly described the San Joaquin-Tulare Basin. It covers around 8080762 hectares in central California. The basin includes the Sierra Nevada to the east, the San Joaquin Valley, and the Coast Ranges to the west. The San Joaquin Valley has an arid-to-semiarid climate that is characterized by hot summers and mild winters. Mean annual precipitation in the valley runs from less than 13 cm in the south to 38 cm in the north, while high in the Sierra Nevada mountains precipitation can run from 50-203 cm. Total mean annual runoff from the Sierra Nevada drainage to the San Joaquin Valley is 10.9 cubic kilometres/year.

Almost the entire San Joaquin Valley floor is agricultural, and the foothills of the Sierra Nevada's and the Coast Range are rangeland. In 1987, around 10.2 percent of the total value of agricultural production in the United States came from California, 49 percent of which, or $6.82 billion (USD), was from the San Joaquin Valley (Dubrovsky et al. 1998). The sampling locations are on the Merced River and the San Joaquin River at the boarder between Merced and Stanislaus counties. At this location, annual discharge ranges from 3-24 cubic meters/second (Gronberg et al. 1998). Mean monthly discharge ranges from 1.5 cubic meters/second in September and October to 34 cubic meters/second in March.

Over 100 different chemicals were sampled from 1992-2001 in the San Joaquin basin, including 9 breakdown products, and their parent pesticides. We only used chemicals that were applied upstream of the sampling site in the year sampled (see PUR database description below). Most breakdown products have been removed from our analysis because they consist of less than 5% of the parent compound detected in stream waters. The exception is 2-Hydroxy-4-isopropylamino-6-ethylamino-s-triazine, which is 11% of its parent compound, atrazine. This degrade was excluded because of the long half life of atrazine and our inability to match residue to annual use. Some pesticides were also not included in our analysis due to their persistent nature and 'legacy status'. These included lindane, alpha-HCH, DDT derivatives, dieldrin, and aldrin.

For each pesticide entry in the NAWQA database, the sample location, date and time, and concentration (either concentration detected, estimated concentration, or the detection limit) is given. Each chemical was sampled on a different schedule, and not all chemicals were sampled in the same year. For example in the San Joaquin Basin, the year 2001 was the most extensively sampled (57 chemicals examined), and sampling took place approximately every two weeks from February through September. However, in the same basin, in 1995, only 41 chemicals were analysed (all in a single day in March), and in 1996 no samples were taken. Therefore, we did not include the years 1995 and 1996. Additionally, 18 chemicals were not included in our analysis because they were sampled fewer than 5 times, including: Aldicarb, Benomyl, Bensulfuron, Bentazon, Bromacil, Bromoxynil, Chlorothalonil, Clopyralid, Cycloate, Dicamba, Imazethapyr, Imidacloprid, Metalaxyl, Oryzalin, Oxamyl, Nicosulfuron, Propiconazole, and Triallate. Our intent was not to comment on pesticide use in the San Joaquin Basin or on the appropriateness of the chosen analytes – what we were after is the cleanest possible

dataset with which to relate use to water contamination levels.

The NAWQA database indicates when the exact chemical concentration could not be given, but could be estimated. The estimated value is often close to the detection limit. In the San Joaquin Basin for the years under consideration, there were 13 chemicals detected fewer than 20 times. For these chemicals, the detected and estimated values were combined. They included: Azinphos-methyl, Benfluralin, Carbaryl, Carbofuran, Dinoseb, Linuron, Methomyl, Methyl parathion, Norflurazon, Permethrin, Prometon, Propanil, and Triclopyr.

Several pesticides detected in stream waters were applied to crops in several different forms. Many of these include salts, or contain methyl side chains which quickly breakdown to the detected generic form. We used the pesticide manual (Tomlin 2003) to determine the main forms in which different products are applied. Often, the forms in which the products were applied did not differ greatly – e.g. different salts of the same herbicide. However, the pesticides 2,4,5-T, 2,4-D, MCPA, MCPB, Silvex, and dichloroprop were applied both as salts and esters with wildly varied physico-chemical properties. These also were excluded from the analysis. The final list of chemicals used in our analysis is given in Table F1.

Table F1. Pesticides included in this analysis, their number of detects or non-detects, peak concentrations detected as well as relevant physicochemical data*. Note that chosen values may differ from those listed in Appendix 2 because the order in which various sources were consulted varied slightly.

detect chem name	Detected N	count of non-detects	minimum detection limit (ug/L)	Peak Detected (ug/L)	95% CI (ug/L)	weight applied (kg)	log Kow*	Soil DT50* (days)	Koc*	vapour pressure* (mmHg)
Alachlor	44	16	0.002	0.8600	0.4263	31605				
Atrazine	35	10	0.001	0.0470	0.0417	15677				
Azinphos-methyl	89	24	0.001	1.0000	0.3666	361599				
Benfluralin	6	11	0.002	0.0070	0.0090	31039				
Butylate	23	14	0.002	0.0600	0.0986	109589				
Carbaryl	168	28	0.003	0.7000	0.2268	669076				
Carbofuran	61	22	0.002	0.9820	0.3978	123131				
Chlorpyrifos	197	16	0.004	0.4000	0.1252	3096023				
cis-Permethrin	4	17	0.005	0.0070	0.0087	145179				
Cyanazine	109	20	0.004	1.3000	0.3726	418115				
DCPA	71	9	0.002	0.3640	0.1662	27701				
Diazinon	273	13	0.002	3.8000	0.4928	515487				
Dinoseb	1	4	0.012	0.003		2020				
Disulfoton	0	12	0.017			83967				
Diuron	24	2	0.02	1.9000	1.8769	398655				
EPTC	242	15	0.002	4.7300	0.6408	489433				

Table F1. Pesticides included in this analysis, their number of detects or non-detects, peak concentrations detected as well as relevant physicochemical data*. Note that chosen values may differ from those listed in Appendix 2 because the order in which various sources were consulted varied slightly.

detect chem name	Detected N	count of non-detects	minimum detection limit (ug/L)	Peak Detected (ug/L)	95% CI (ug/L)	weight applied (kg)	log Kow*	Soil DT50* (days)	Koc*	vapour pressure* (mmHg)
Ethalfluralin	70	16	0.004	0.3600	0.2589	39849				
Ethoprop	16	17	0.003	0.1160	0.0673	24954				
Fonofos	53	11	0.003	0.2770	0.2235	14552				
Linuron	5	24	0.002	0.2900	0.9233	71522				
Malathion	39	20	0.005	1.1400	0.2797	304819				
Methiocarb	0	105	0.008			1				
Methomyl	9	3	0.017	0.6700	2.6278	294641				
Methyl parathion	14	17	0.005	0.0897	0.1041	185674				
Metolachlor	304	13	0.002	1.7700	1.0478	350797				
Metribuzin	66	20	0.004	0.6720	0.1223	18404				
Molinate	91	23	0.0016	4.0000	0.3339	48926				
Napropamide	82	18	0.003	1.2200	0.1261	113369				
Norflurazon	6	3	0.024	0.4400	0.7729	139864				
Parathion	0	19	0.004			4190				
Pebulate	66	16	0.0016	2.3000	0.6434	244462				
Pendimethalin	62	23	0.004	0.6790	0.6280	646885				
Phorate	0	20	0.002			152174				
Prometon	1	14	0.002	0.020		2				

Table F1. Pesticides included in this analysis, their number of detects or non-detects, peak concentrations detected as well as relevant physicochemical data*. Note that chosen values may differ from those listed in Appendix 2 because the order in which various sources were consulted varied slightly.

detect chem name	Detected N	count of non-detects	minimum detection limit (ug/L)	Peak Detected (ug/L)	95% CI (ug/L)	weight applied (kg)	log Kow*	Soil DT50* (days)	Koc*	vapour pressure* (mmHg)
Propanil	7	17	0.004	0.0133	0.0185	77481				
Propargite	116	17	0.013	3.7000	2.3112	2907733				
Propyzamide	22	18	0.003	0.1100	0.0531	44262				
Simazine	323	3	0.005	20.0000	0.9922	1225219				
Thiobencarb	38	14	0.002	0.6080	0.3507	39821				
Triclopyr	2	3	0.0224	0.0412	0.0571	422				
Trifluralin	230	17	0.002	1.7400	0.3371	1512301				

**NOTE: Some of these values are from the PMRA database and may be considered proprietary in Canada. The data have therefore been removed from the table until the provenance of each data point can be established with certainty.*

California Pesticide Use Reporting

In California, most commercial pesticide applications are reported to the California Department of Pesticide Regulation (DPR) to the nearest square mile as part of a comprehensive pesticide use reporting (PUR) system. Other jurisdictions (e.g. other states in the U.S. namely Oregon and New York) are starting similar systems. It is useful to point out that Canada does not even have comprehensive national sales or use survey, although a few jurisdictions produce fragmentary information (Brimble et al. 2005). The California database includes a total of 2-3 million records annually, with 192 million pounds of pesticide active ingredients applied in 2000. The

database includes information on the type of crop, the type of spray (aerial, ground, or integrated), the area treated, the total weight of chemical applied, and the location to which it was applied. We used the total area treated, and the total weight of chemical applied from agricultural crops only.

The PUR database gives a location for each pesticide application within each county. Maps of the basins were examined to determine which counties were upstream of the NAWQA sampling points. This led to the exclusion of some counties within the basin, because they were located downstream of the sampling locations. The counties used in our analysis of the San Joaquin Basin included: Mariposa, Merced, Madera, Fresno, Kings, Tulare and Kern.

We only used pesticides that were applied in the year when water samples were tested for that pesticide. For example, Bromacil was sampled in 1993, 94, 97 and 2001. The total quantity treated (area treated and weight applied) was the sum of all years that were sampled. The application rate was calculated from the weight applied and area treated. The PUR database includes the crop to which each pesticide was applied. About 80% of the pesticides were applied primarily to one crop (70% of the pesticide applications were made to that crop). Therefore, we used the application rate of the major crop as the chosen application rate for our analysis.

Physicochemical data

We used the physicochemical data for the parent compound (the non-salt, non-ester). The data are more complete for these chemicals, especially in the case of soil DT_{50}. We obtained the vapour pressure, log P (log K_{ow}), molecular weight, K_{oc}, soil DT_{50}, and water solubility were from the PMRA pesticide properties database (courtesy of EAD, PMRA – see note about proprietary nature of some of

these data). If there were missing data, we went to several other sources, including the Pesticide Manual (Tomlin 2003), the USDA toxicology database, the USEPA's GLEAMS database (Leonard *et al.* 1987; Leonard *et al.* 2002), and the Oregon State University pesticide database. In cases where one source disagreed with another, we preferentially took them in the order listed above.

In addition to the individual physico-chemical constants, we computed Groundwater Ubiquity Scores (GUS) for each pesticide using the following equation:

$$GUS = \log(\text{soil } DT_{50}) \times (4 - \log(K_{oc}))$$

GENEEC output

The GENeric Estimated Environmental Concentration (GENEEC) model was described in the main report. This model was designed as a screening level tool to mimic the more sophisticated PRIZM/EXAMS and AGDRIFT models but without any requirement for specific physiographic data. The model requires water solubility, K_{oc}, soil half life, aerobic water half life, and chemical photolysis in water half life. The majority of the pesticides were missing the aerobic water half lives and the suggested default of twice soil DT50 valued was used often. Chemical photolysis rates were also missing frequently and assumed to be 0. Inspection of the model outputs showed this parameter to have minimal influence on the results. The model also includes information about the chemical application, including: application rate (we used that of the major crop), the number of applications (we used 1 application), the interval between applications (since there was only one application, the interval would be zero), if the chemical was wetted in (we assumed not), a

measure of how deeply the chemical was incorporated into the soil (we assumed it was not), and the buffer zone (zero for our calculations). The spray drift percentage is also based on the spray quality: we assumed medium to course sprays. The California applications are made primarily with ground applications and aerial applications. We ran the model twice, with each type of spray, and found no significant difference in the two models.

Statistics

All of the chemicals with sufficient data for distributional analysis had detection values that were log-normally distributed (Kolmogorov-Smirnov $p>0.05$). Therefore we assumed that chemicals with small sample sizes (listed above) also approximated a log-normal distribution. Non-detect samples were excluded from this distributional analysis. The proportion of samples that are 'detects' is not necessarily a significant measure per se. In order to judge the significance of a 'non-detect' sample, the timing of this sample relative to upstream pesticide applications must be considered on a case by case basis. This was not possible here. For each pesticide, the maximum concentration detected, and the upper 95% confidence bound of the distribution (mean+1.96*standard deviation) were determined. We computed 95% upper confidence intervals in order to exclude exceptionally high values, which could be due to spill or abnormally heavy rain fall. We did not calculate 95% confidence bounds for dinoseb and prometon, which were only detected once.

The factors log Kow, and molecular weight (mw), were normally distributed. The other factors including K_{oc}, vapour pressure, soil DT_{50}, and water solubility were all log transformed to achieve normal distributions. Several variables were correlated; correlated variables were removed from models under consideration *a priori* (Table 2). The largest correlations were between area, weight

applied, and application rate. Additionally, K_{oc}, and solubility were correlated with the K_{ow}.

Table F2: Correlations observed between the variables included in analysis. All data for chemicals listed in table 1 were included.

	log area ha	**log K_{ow}**	**log soil DT_{50}**	**log K_{oc}**	**log vp**	**log S**	**log HLC**	**log appl rate**
log weight (kg)	.9366	.1975	-.2977	.2153	.0901	-.1882	.2049	.4752
	p=0.00	p=.216	p=.059	p=.176	p=.575	p=.239	p=.199	p=.002
log area (ha)		.1720	-.1814	.2433	.0207	-.2033	.1012	.1723
		p=.282	p=.256	p=.125	p=.898	p=.202	p=.529	p=.281
log K_{ow}			.0433	.8439	.3446	-.7995	.7583	.0998
			p=.788	p=.000	p=.027	p=.000	p=.000	p=.535
log soil DT_{50}				-.0864	-.0601	-.1359	-.1026	-.5445
				p=.591	p=.709	p=.397	p=.523	p=.000
log K_{oc}					.1302	-.8272	.5996	.0140
					p=.417	p=.000	p=.000	p=.931
log vp						-.0127	.6329	.1573
						p=.937	p=.000	p=.326
log S							-.4936	-.0251
							p=.001	p=.876
log HLC								.2755
								p=.081

vp = vapour pressure (mmHg)

S = water solubility (mg/L)

HLC = Henry's law constant

area = total area treated (ha)

weight = total chemical applied to the area treated (kg a.i.)

appl. rate = application rate of the major crop to which that chemical was applied. (kg a.i./ha)

In analyzing predictive models with multiple dimensions, we selected the best model by the best subset method, an iterative method based on maximum likelihood estimation, and Akaike's Information Criterion (AIC). The AIC assesses a penalty for the number of independent variables in the model. Because our sample size was small, we used the correction for small sample size (AIC_c; Burnham and Anderson 2002). The relative difference between models was assessed using a ratio of the Akaike weights of each model with the best fit (smallest AIC_c). We only show the best (most parsimonious) models identified although in some cases, several other models were also possible; i.e. they had Akaike weight ratios of <2, a commonly used cut-off. The significance of these models was found using the R^2 and p value for each of the model types using the STATISTICA (v.6) software.

Results

Our goal was to predict measured water concentrations (the dependent variable) form a combination of use statistics and physico-chemical variables (the predictors).

When the 95% confidence intervals were chosen as dependent variable, the best predictor model included total weight of chemical applied, log K_{ow}, the soil half life, and the vapour pressure (R^2=0.56 p=0.000045; Table 3 and Figure 1). There is considerable support for adopting this model, since the Akaike weight ratio between the best and second best model was greater than 3. The formula for this model is:

$$\log \text{chemical concentration} = -2.49 + 0.51 \times \log \text{weight} - 0.25 \times \log K_{ow} + 0.38 \times \log \text{soil } DT_{50} + 0.09 \times \log \text{vapour pressure}$$

The best model using the ground water ubiquity score (GUS) rather than the component physicochemical variables had an AIC weight ratio of 12677, indicating that it is better to try fitting the individual physico-chemical properties in preference to derived combined estimates of run-off potential.

Table F3: AIC table using the top 95% confidence interval as the dependant variable. N=35 pesticides

K	Variable 1	Variable 2	Variable 3	Variable 4	AIC_c	ΔAIC_c	Akaike weight ratio	R^2	p
6	log weight	log Kow	log soil	log vp	48.31	0.00	1.00	0.56	0.000045
5	log weight	log soil	log S		50.85	2.54	3.57	0.48	0.00012
5	log weight	log Kow	log soil		51.97	3.66	6.25	0.47	0.00019
6	log weight	log soil	log vp	log S	52.22	3.92	7.09	0.51	0.00022

vp = vapour pressure (mmHg)

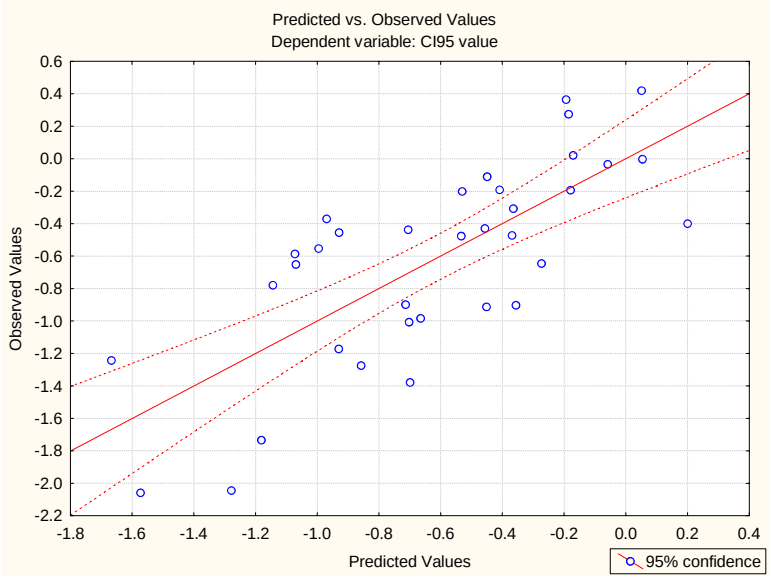
S = water solubility (mg/L)

soil = soil DT_{50}

area = total area treated (ha)

weight = total chemical applied to the area treated (kg)

Figure F1: Best model using upper 95% confidence interval as the dependant variable.



When peak chemical detected was used as the dependant variable (Table 4, Figure 2), results were almost identical suggesting that our concern about outlier or atypical values were unfounded.

log peak chemical concentration = -2.72 + 0.61×log weight – 0.29×log K_{ow} + 0.45×log soil DT_{50} + 0.09×log vapour pressure

Table F4. AIC table using the peak amount detected as the dependant variable. N=37

K	Variable 1	Variable 2	Variable 3	Variable 4	AIC_c	ΔAIC_c	Akaike weight ratio	R^2	p
6	log weight	log Kow	log soil	log vp	78.26	0.00	1.00	0.55	0.00003
4	log weight	GUS			78.30	0.04	1.02	0.47	0.00002
5	log weight	log Kow	log soil		78.43	0.17	1.09	0.51	0.00003
5	log weight	log soil	log S		78.53	0.28	1.15	0.51	0.00003
5	log weight	log soil	log Koc		78.74	0.48	1.27	0.51	0.00003

vp = vapour pressure (mmHg)

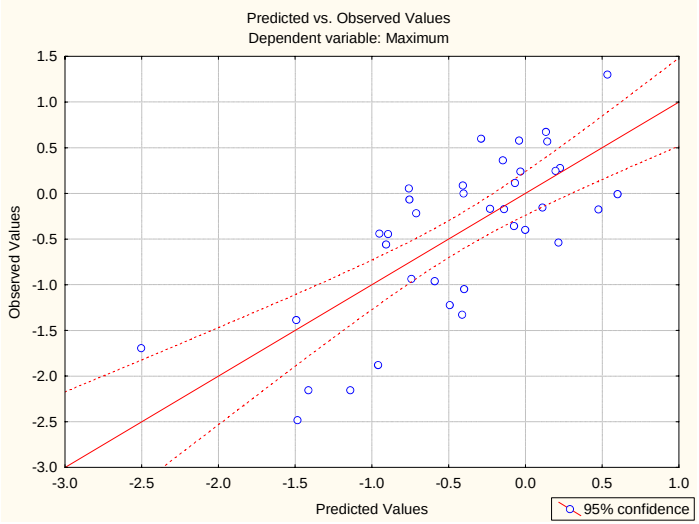
S = water solubility (mg/L)

soil = soil DT_{50}

area = total area treated (ha)

weight = total chemical applied to the area treated (kg)

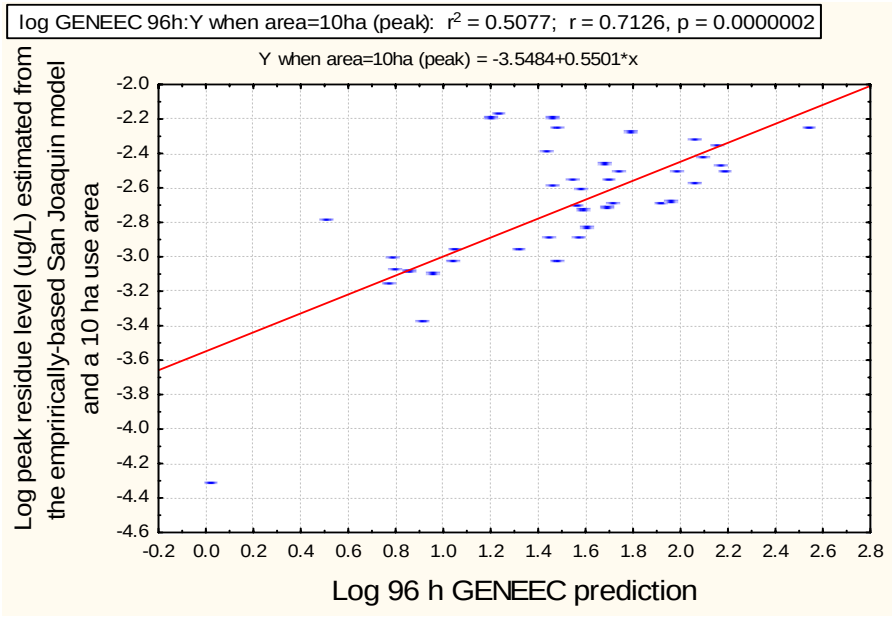
Figure F2: The best model when peak chemical concentration is used as dependant variable.



In order to compare GENEEC outputs to the empirical models developed for the San Joaquin basin, weight of chemical applied was calculated based on the 'common' application rate and a 10 ha application area. This is the size of field that GENEEC uses in predicting end of field water concentrations. Figure 3 shows the best log-log relationship – that between peak measured residue levels and GENEEC-predicted 96 hour concentrations. The regression is highly significant and reasonable predictive (R^2=0.51 $p<0.00001$). It is important to note that GENEEC predicts a much higher concentration than was observed in the San Joaquin dataset (by approximately 3.5 orders of magnitude). However, the reasonably good fit suggests that those same chemical characteristics that

influenced end of field estimates in GENEEC were also at play downstream after much dilution.

Figure F3: Comparison between GENEEC predicted concentration 96 hours after pesticide application and predicted peak concentration.



Discussion

Based on the San Joaquin basin data, empirically-based models to predict peak residue concentrations in our waterways will require knowledge of pesticide quantities applied. This will be difficult to obtain with any precision in Canadian watersheds. We found that the soil half life, octanol/water partitioning coefficient (log Kow) and vapour pressure could be used to predict peak pesticide levels in large streams, without direct knowledge of when the pesticide was applied, or how it was applied. (One has to assume that water

sampling regimes used by the USGS were roughly adapted to local pesticide use conditions.) A similar empirical model was created for an agricultural basin in southern Sweden (Kreuger and Tornqvist 1998). Like our model, the weight of chemical applied in the catchment was very important in predicting chemical concentration in stream water. Their best fit model included the K_{oc}, solubility and vapour pressure. Since the soil binding constant (K_{oc}) is closely related to the soil half life, and K_{ow} and water solubility are closely correlated, this model is comparable to our best model.

A reasonable (although far from perfect) linear fit between output from this empirical model and GENEEC lends support for the use of GENEEC in ranking the relative exposure potential of pesticides and our aquatic risk ranking strategy.

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APPENDIX G: Technical and formulated Log HC5 values for ranked pesticides in ug/L.

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
ABM	Abamectin	0.425	3.895	-1.243	-0.772	0.843		3.837		2.428	
ACA	Acifluorfen (sodium salt)	3.736	4.038	3.679	3.819			4.252	1.318		1.398
ACA	Acifluorfen (acid)										
ACA	Acifluorfen (form not specified)	3.736	4.038	3.679	3.819			4.252	1.318		1.398
ACP	Acephate	4.136	4.530	3.167	2.622	3.825	3.288	4.182			
ALM	d-trans Allethrin	0.389		1.082		0.434					
ALP	Aluminum phosphide		1.107								
AME	S-Metolachlor	2.754		2.482				0.165		0.209	
AMI	Amitrole	4.768	4.368	2.557	3.587			1.287		2.235	
AMN	Aminoethoxyvinyl glycine	4.279		3.715							
AMZ	Amitraz	2.629	2.622	2.530	1.232			2.916			

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
ARP	Arsenic pentoxide	3.445		0.563							
ARS	Imazapyr	3.784	4.254	3.930						0.217	
ASS	Imazamethabenz-methyl	4.492		3.963				3.941			
ASS	Imazamethabenz (acid)										
ASS	Imazamethabenz (form not specified)	4.492		3.963				3.941			
ATR	Atrazine	3.094	3.750	3.231	1.725	2.134		1.080	0.860	1.092	
AVG	Difenzoquat (methyl sulphate salt)	4.378	4.150	2.204					1.347		
AZN	Azaconazole										
AZY	Azoxystrobin	2.385		1.159		2.539		-0.892		2.369	
BAD	6-Benzyladenine	3.557		2.993				3.837	3.569		
BAX	Metribuzin	4.096	3.960	3.350	3.393	3.733	4.041	0.615		1.066	
BAY	Propoxur	3.049	3.167	1.191	1.282	1.510	1.390				

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BBU	Bromacil (acid)	3.584		3.169				0.319			
BBU	Bromacil (lithium salt)										
BBU	Bromacil (dimethylamine salt)										
BBU	Bromacil (form not specified)	3.584	4.229	3.169				0.319			
BDC	Bendiocarb	2.017	2.057	-0.330		1.703					
BDX	Cyanazine	3.755	3.946	2.914	3.682			0.524		1.164	
BET	Bensulide	2.380	2.590	1.560	2.360			1.994	2.343	1.012	
BMS	Flusilazole	2.291		2.116				2.643			
BNS	Borax	4.598									
BOA	Boracic acid (Boric acid)	4.611	3.856	5.219							
BOC	Disodium octaborate tetrahydrate										
BRY	Bromoxynil (octanoate)	1.179	1.366	0.674	0.350			1.355		1.159	

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BTL	Desmedipham	2.226		1.756				1.443		1.954	
BTS	Bis(trichloromethyl)sulfone	0.749	2.619	0.823							
BZN	Bentazon (sodium salt)	4.491	4.257	3.889	4.032				2.709		2.549
BZN	Bentazon (acid)	4.809	4.580	3.692	3.990			3.444	2.856	2.570	2.549
BZN	Bentazon (form not specified)	4.809	4.580	3.692	3.990			3.444	2.856	2.570	2.549
CAB	Carbaryl	2.970	3.170	0.285	0.744	0.797	-2.749	2.759			
CAF	Carbofuran	1.859	1.876	-0.746	0.382	0.006	-2.003	4.273			
CAP	Captan	1.396	1.803	1.880	3.405	1.940		1.854		2.941	
CAZ	Carbendazim	1.486	1.491	1.100	2.965			2.839			
CCC	Chlormequat chloride		5.419	3.961	3.427						
CCC	Chlormequat ion	5.462		2.812				5.593			
CCC	Chlormequat (form not specified)	4.635	5.419	3.961	3.427			5.593			

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CFP	Clodinafop-propargyl	1.807		3.173				3.150		2.217	
CFZ	Clofentezine	2.835	3.319		3.232			3.342			
CHE	Chlorimuron-ethyl	2.837		2.792							
CHH	Boscalid	2.602		1.865				2.031		2.131	
CHL	Chlorthal (dimethyl ester)	2.594	3.971		3.081		3.845			2.879	
CHL	Chlorthal (acid)										
CHL	Chlorthal (form not specified)	2.594	3.971		3.081	3.792	3.845			2.879	
CIP	Chlorpropham	3.659	3.283	2.344				2.024		2.060	
CLE	Clethodim	3.842		3.871	3.150			3.172	3.531	1.964	4.041
CLM	Cloransulam-methyl	4.340		3.940				2.746		3.942	
CLM	Cloransulam (acid)										
CLM	Cloransulam (form not specified)	4.340		3.940				2.746		3.942	

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CNB	Chloroneb	3.288		2.376							
CNQ	Clomazone	3.528		2.187				2.034		3.482	
COD	Clothianidin	4.023		1.590				3.643		3.920	
COY	Terbufos	0.151	0.936	-0.745	-0.916	0.146					
CPN	Chloropicrin	0.755		0.070							
CRO	Chromic acid		3.689		1.850						
CSL	Chlorsulfuron	4.451		4.051				1.240	0.281	-1.429	1.374
CUB	Copper (tribasic copper sulphate)										
CUO	Cupric oxide										
CUP	Copper (cuprous oxide)	2.620		0.306				-0.076			
CUQ	Copper 8-quinolinolate	1.057	1.267	0.547				-0.064			
CUR	Copper (mixed copper ethanolamine complexes)										

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CUS	Copper (copper sulphate)	1.886	3.321	1.738	2.021			0.449		2.199	
CUY	Copper (copper oxychloride)	1.900	3.191	0.865	-0.521						
CUZ	Copper (copper hydroxide)	2.561		2.397				3.381			
CXF	Cyfluthrin	-1.245	-1.285	-2.746	-2.893	-1.759	-0.863	2.837			
CYH	Cyhalothrin-lambda	-1.742	-1.086	-3.227	-2.768			1.489			
CYM	Cypermethrin	-0.141	-0.440	-2.176	-2.499	-1.823	-1.869	2.837			
CYO	Cymoxanil	4.176		2.872				1.561		1.736	
CYP	Cyprodinil	2.757		1.521		2.158		2.569	2.229	2.724	
CYZ	Cyromazine	3.973	0.575	2.930		4.668					
DAM	Daminozide	4.542		3.548							
DAZ	Dazomet	1.898	3.278	1.620	2.075			1.249		2.193	
DBR	Deltamethrin	-0.595	-0.678	-2.834	-3.746	-1.915	-2.507	3.817			

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DCB	Dichlobenil	3.785	3.455	3.193	2.446	2.915	4.001	2.937		0.314	
DCF	Dicofol	1.862	1.554	1.527		2.013		0.712			
DEB	Denatonium benzoate										
DFB	Diflubenzuron	2.086	4.740	-0.506	-1.561		-1.000	1.192	3.914	1.116	
DFF	Diflufenzopyr (sodium salt)	4.323		3.018				0.901		1.381	
DFF	Diflufenzopyr (acid)	4.323		3.018				0.879			
DFF	Diflufenzopyr (form not specified)	4.323		3.018				1.929		1.381	
DFZ	Difenoconazole	2.212		1.666				1.916			
DIA	Diazinon	1.755	1.854	-0.718	-0.662	0.475	0.009	2.837			
DIC	Dicamba (potassium salt)		4.397		4.720						
DIC	Dicamba (isopropylamine salt)				1.020						
DIC	Dicamba (diethanolamine salt)										

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DIC	Dicamba (acid)	3.484	4.414		3.485			1.418	1.236	1.764	1.163
DIC	Dicamba (sodium salt)	4.971	5.010		3.426			3.398		3.837	
DIC	Dicamba (diglycolamine salt)		4.814		4.447						
DIC	Dicamba (form not specified)	3.509	4.702		3.384			1.491	1.236	2.801	1.163
DIE	Dieldrin	0.496	0.053	0.240	0.337	-0.313		2.944			
DIG	Dichlorprop (dimethylamine salt)	3.411	2.609	3.792	3.270			4.106			
DIH	Dichlorprop (ethylhexyl ester)	3.117									
DIH	Dichlorprop (butoxyethyl ester)	2.665	2.387								
DIH	Dichlorprop (isooctyl ester)	3.429	3.835	1.968				1.252			
DIH	Dichlorprop (form not specified)	2.406	2.813	1.968				1.252			
DIK	Dichloran	2.897	2.858	2.090							
DIM	Dimethoate	1.100	3.378	-2.000	1.156	1.169	0.166	3.525			

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DIN	Dinocap										
DIQ	Diquat dibromide	3.480	3.989	1.910	2.781			0.907	-0.206	0.092	-1.059
DIQ	Diquat	3.514	3.205	2.546			3.719				-0.577
DIQ	Diquat (form not specified)	3.797	3.715	2.190	2.297		3.719	0.907	-0.206	0.092	-1.029
DIR	Dithiopyr	2.114		2.289	2.561			0.138			
DIS	Disulfoton	1.717	2.457	1.249	0.507	0.002					
DME	Dimethomorph	3.164	1.850	3.037	1.818			3.218	0.100		3.164
DNB	Dinoseb	1.824	1.040	2.238	1.213	2.207					
DOD	Dodine (dodecylguanidine monoacetate)	2.842	2.892	0.964	1.006			-1.357			
DOM	Dodemorph-acetate	3.738		2.108							
DPA	Diphenylamine	2.600		1.548				2.174			
DPB	2,4-DB (isooctyl ester)										

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DPB	2,4-DB (butyl ester)										
DPB	2,4-DB (acid)	2.989	2.756	3.190							
DPB	2,4-DB (form not specified)	2.989	2.756	3.190		3.161					
DPI	Clopyralid	4.281		4.151		4.695		2.676		3.787	
DPP	Diclofop-methyl	2.016	1.960	1.339	1.997						
DPY	Rimsulfuron	4.632		4.202				2.079		-0.299	
DSG	1,3-Dichloropropene	2.730		1.323		2.224		2.745		2.159	
DUB	Chlorpyrifos	-0.015	0.707	-1.301	-1.301	-0.456	-0.778	1.973			
DUR	Diuron	3.163	3.913	2.403		1.965		0.741		0.232	
DVP	Dichlorvos	2.396	2.102	-1.324	0.296	0.465	1.037	3.880			
DXA	2,4-D (acid)	3.888	2.911	2.248	2.663	3.080		2.615		2.822	
DXB	2,4-D (diethanolamine salt)		4.290		3.844				3.568		1.464

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DXB	2,4-D (triisopropylamine salt)		4.816		4.757				3.791		2.196
DXB	2,4-D (isopropylamine salt)		5.311		4.619				3.458		
DXB	2,4-D (dimethylamine salt)	5.115	4.854		3.350		3.845		3.565		1.584
DXB	2,4-D (unspecified amine salt)	5.115	4.802		3.487		3.845		3.657		1.748
DXF	2,4-D (butoxyethyl ester)	2.655		2.487	2.613		1.949	1.252		-1.402	
DXF	2,4-D (isooctyl ester)	3.396	3.492	0.983	0.341			2.076		1.536	
DXF	2,4-D (ethylhexyl ester)	2.030	3.461	1.519	1.030			1.662		1.536	
DXF	2,4-D (unspecified ester)	2.345	3.301	2.233	3.036		1.949	1.227		0.067	
DXS	2,4-D (sodium salt)	4.312	3.942	4.764	2.972	3.394					
DYR	Anilazine	1.177	1.882	0.863							
EFR	Ethalfluralin	1.325	1.534	1.058	0.103			-0.209			
END	Endrin	-0.699	-0.416	-1.791	-0.362	-1.867	-0.151				

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ENT	Endothall	4.067	2.069	4.453	1.102		2.481				
ENT	Endothall	2.455	2.113	1.875	1.453		2.357	2.013	0.713		2.312
ENT	Endothall (form not specified)	3.741	2.036	2.732	1.719		2.481	2.013	0.713		2.312
EPT	EPTC	4.228	3.696	2.733			3.719	2.675		2.649	
ESF	Endosulfan	-0.444	-0.189	-0.865	-1.864	-0.338	1.172	1.585			
ETF	Ethephon	4.584	4.466	3.893	3.830	3.802		3.342	2.029		2.025
ETM	Ethametsulfuron-methyl	4.852		3.928				2.252			
ETM	Ethametsulfuron (acid)										
ETM	Ethametsulfuron (form not specified)	4.852		3.928				2.252			
ETO	Ethylene oxide	3.999		3.743							
ETS	Ethofumesate	2.375	2.468								
ETY	Ethoxyquin	3.391		1.886							

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FAA	N-Decanol	2.862	2.704	2.448	2.327						
FAB	N-Octanol	4.122		3.279				2.817			
FAD	Famoxadone	0.441		-0.582				0.139			
FAL	Fosetyl-al	4.182		3.323				2.690		3.662	
FBT	Fenbutatin oxide	-0.289	0.299	-0.416	-0.126			2.916			
FBZ	Indar										
FDR	Pyridate	2.337		2.350	2.425			2.138		2.138	
FED	Fenamidone	2.554		1.562				1.526		1.782	
FEM	Fenitrothion	2.823	2.977	-0.862	-0.986	0.242	-0.195	2.888			
FER	Ferbam	1.265	2.546	0.140	2.729	1.512		2.217			
FEX	Fenhexamid	2.698	2.554	2.553	3.546			2.541	2.249	2.199	
FLB	Flamprop-m-methyl										

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FLB	Flamprop-m (acid)										
FLB	Flamprop-m (form not specified)										
FLD	Fludioxonil	2.428		0.847				1.132		1.837	
FLM	Flumetsulam	5.449		4.289				1.854		-0.671	
FLR	Fluroxypyr 1-methylheptyl ester	1.683	4.011	0.972				1.572		3.026	1.967
FLS	Flucarbazone-sodium	4.216		3.830				3.315		1.438	
FLT	Flufenacet	2.772		2.563				-1.455		-0.775	
FLZ	Fluazinam	1.078		0.533				1.115			
FMS	Foramsulfuron	4.219		3.778				3.285		-1.455	
FOF	Fomesafen	4.929	5.154	4.286	3.965			0.820			
FOL	Folpet	1.403	1.295	1.308	0.506			1.452			
FOM	Formetanate hydrochloride	3.135		1.258				2.013			

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FOM	Formetanate										
FOM	Formetanate (form not specified)	3.135		1.258				2.013			
FOR	Formaldehyde	4.030	4.377	4.508	2.520		4.414				
FPF	Fenoxaprop-p-ethyl	2.546		2.122				1.639			
FRA	Florasulam	4.253		4.064				0.488		-1.091	
FZA	Fluazifop-p-butyl	2.352		2.612				1.910			
GAR	Tetrachlorvinphos	1.910	1.743	-0.395							
GIA	Gibberellic acid A3	4.312		3.740							
GIB	Gibberellins										
GLG	Glufosinate ammonium	5.476	3.609	3.654	3.457			2.729		2.005	
GOO	Azinphos-methyl	0.093	0.119	-0.854	-1.849	0.182					
GPI	Glyphosate (isopropylamine salt)	3.201	3.599	3.667	3.757	3.365	4.410	2.705	2.779	2.886	2.122

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GPM	Glyphosate (mono-ammonium salt)										
GPP	Glyphosate (potassium salt)										
GPS	Glyphosate (acid)	4.633	3.127	3.534	3.678	3.533	3.341	3.842	2.231	3.146	2.506
GPT	Glyphosate (trimethylsulfonium salt)	3.160	4.547	2.871	3.090			2.433	2.691	1.837	1.666
HEC	Hexaconazole	2.864		2.275				2.592			
HQB	Oxine benzoate										
IDO	Iodosulfuron-methyl-sodium	4.209		3.777				0.214		-1.367	
IMI	Imidacloprid	4.204		-0.152	0.328	0.145		2.837			
IMP	Imazethapyr	4.738		4.792				3.610		-0.254	
IMZ	Imazamox	4.270		3.835				0.996		-0.121	
IPB	Iodocarb	2.031		1.180				0.837			
IPD	Iprodione	3.381	3.021	1.554	1.081			1.049		1.837	

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ISX	Isoxaben	2.220		2.321				3.837			
IXF	Isoxaflutole	3.147		2.128				1.122		0.603	
KMC	Potassium n-methyldithiocarbamate	1.891	3.178	0.840	1.793						
KRB	Propyzamide	2.650	4.620	2.462				2.700		1.946	
KRE	Fosamine ammonium	4.826	4.212	4.450	3.845		3.845	3.072	4.821	3.159	
KRS	Kresoxim-methyl	1.989		1.091				1.381		1.319	
LUN	Linuron	3.124	3.106	1.623	1.527	2.923	2.478	0.540		0.282	
MAA	MCPA (acid)	3.261	3.212	3.923		4.317		4.012		1.068	
MAB	MCPA (dimethylammine salt)	4.174	4.425		4.324			3.513	1.634	2.548	1.219
MAE	MCPA (buyl ester)										
MAE	MCPA (iso-octyl ester)	2.837		1.093				2.138			
MAE	MCPA (2-ethylhexyl ester)										

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MAE	MCPA (unspecified ester)	2.837		1.093				2.138			
MAH	Maleic hydrazide	4.286	4.778	3.814	4.845			4.364	2.814	3.894	
MAH	Maleic hydrazide (potassium salt)	5.225	5.212	4.792				3.829		3.894	
MAH	Maleic hydrazide (form not specified)	4.325	4.778	4.056	4.845			4.364	2.814	3.894	
MAL	Malathion	1.683	1.347	-0.380	-1.013	0.518	0.665				
MAN	Maneb	2.216	1.850	1.703	2.729			1.556			
MAS	MCPA (potassium salt)										
MBR	Methyl bromide	2.098		1.551				2.367			
MBS	MCPB (sodium salt)	3.550	3.102	3.533	3.544			1.721	1.937	1.342	1.183
MCZ	Mancozeb	2.907	2.449	0.559	0.629			0.143	0.431		2.563
MEA	Mecoprop (potassium salt)		4.273		3.784						
MEC	Mecoprop (dimethylamine salt)		4.259						1.494		2.100

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MEC	Mecoprop (diethanolamine salt)										
MEC	Mecoprop (form not specified)		4.259						1.494		2.100
MEE	Mecoprop acid (MCPP)	4.751	3.242	4.204				4.030	2.821	2.623	
MEI	Dimethenamid	2.917		2.735				0.944	0.076		0.025
MEM	Metsulfuron-methyl	4.438		3.968				0.415		-1.581	
MER	Mesotrione	4.436		3.326				3.452		2.996	
MET	Methoxychlor	0.891	1.052	-0.189	-0.448	0.048	0.134				
MEU	1-Methylcyclopropene										
MEW	Mecoprop d-isomer (potassium salt)										
MEX	Tribenuron methyl			4.649				1.711	2.511	-0.540	
MEZ	Mecoprop d-isomer (amine salt)								2.268		
MFN	Metalaxyl-m (mefenoxam)	4.177	1.498	3.225				3.622		3.724	

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
MGK	N-Octyl bicycloheptene dicarboximide	2.035		1.560							
MGP	Magnesium phosphide										
MIS	Methyl isothiocyanate	1.241		0.160				1.450		1.608	
MML	Methomyl	2.786	2.595	1.157	1.315	0.794	0.404	3.615			
MMM	Thifensulfuron-methyl			4.628				-0.233		-1.155	
MOM	Methamidophos	4.205	3.153	-1.708	-2.078			4.088			
MOR	Chinomethionat	1.173	2.082	-0.298				0.384			
MPR	(S)-Methoprene	3.146	3.239	1.549	-0.572						
MSM	Arsenic (monosodium methane arsonate)	4.523	4.203	4.139	3.072				2.636		3.912
MTA	Metalaxyl	4.032	3.355	2.731	1.835			3.471		3.767	
MTB	Metobromuron	3.874		3.436				1.252			
MTL	Metolachlor	3.597	1.388	2.876	3.154	2.372	2.488	1.520		1.741	

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
MTM	Metam (sodium salt)	2.147	2.627	0.440	1.500						
MTM	Metam (sodium, dihydrate)										
MTM	Metam (acid)										
MTM	Metam (form not specified)	2.147	2.627	0.440	1.500						
MTR	Metiram	2.936	2.640	2.183	1.201			0.826	2.076		
MXF	Methoxyfenozide	2.569		1.539				2.369			
MYC	Myclobutanil	2.694		1.795				1.999			
NAA	1-Naphthalene actetic acid	3.600	4.069	3.990							
NAA	1-Naphthalene actetic acid (ammonium salt)								2.994		2.569
NAA	1-Naphthalene actetic acid (form not specified)	3.600	4.069	3.990					2.994		2.569
NAD	Naphthaleneacetamide										
NAL	Naled	1.220	2.219	-0.812	-1.244	0.167		0.428		2.092	

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NAP	Naptalam (sodium salt)										
NAP	Naptalam (acid)	4.248	3.520	3.866							
NAP	Naptalam (form not specified)	4.037	3.520	3.866							
NBP	Napropamide	3.341	3.276	3.100					2.380		
NIO	Nicosulfuron	4.679		4.269				4.145			
NXI	Acetamiprid	4.027		1.457				1.889		1.837	
OXA	Oxadiazon	2.727	2.795	1.626	2.100			-0.519		0.522	
OXB	Oxamyl	3.252	2.989	0.791	1.816	1.019	0.967	2.356			
OXR	Oxyfluorfen	1.730	1.600	2.228	1.938			-1.672	-1.717		
PAQ	Paraquat	3.377	3.605	3.427	2.465				1.403		
PAQ	Paraquat dichloride	3.983	3.198	2.234	2.906		3.845	0.107	0.181	0.475	0.812
PAQ	Paraquat (form not specified)	3.693	3.310	3.150	3.016	3.766	3.845	0.107	0.319	0.475	0.812

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PAZ	Paclobutrazol	3.584		3.341	3.818			3.327			
PBU	Piperonyl butoxide	2.813	-0.176	1.892	-0.825	2.202					
PCP	Pentachlorophenol	1.542	1.474	1.732	2.127	2.710	1.666	1.592		1.419	
PEN	Pendimethalin	2.289	2.523	1.676	2.719			-0.123	2.239	-0.075	
PFL	Permethrin	0.265	0.041	-1.850	-0.886	-0.943	-0.122	0.774	3.469		
PFN	Picolinafen	1.923		1.512				-0.611		0.593	
PHI	Phosine (phosacetim)	0.002		0.499							
PHR	Phorate	-0.195	-0.004	-2.184	-1.266	-0.370	0.272	1.951			
PHS	Phosalone	1.831	1.616	-0.468							
PHY	Propamocarb hydrochloride	4.896		3.808				4.489			
PIC	Picloram (potassium salt)	3.943	3.225	3.792	4.318				2.997		3.801
PIC	Picloram (acid)	3.504	3.834	2.461	4.642		3.750	3.446			

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
PIC	Picloram (form not specified)	3.548	3.480	2.449	4.318	2.710	3.750	3.446	2.997		3.801
PID	Picloram (triisopropanolamine salt)	4.180	4.095	4.146	4.373			4.226	4.046	3.970	3.954
PIR	Pirimicarb	3.854	4.257	1.169	-0.727	3.118		3.983			
PMP	Phenmedipham	2.921	3.584	2.097				0.779	2.935	1.199	
PON	Propiconazole	3.291	2.862	2.936	1.781		1.535	1.051		2.792	
PRI	Primisulfuron-methyl	4.079		3.658				1.070		-1.731	
PRL	Propanil	3.300	3.491	2.648	2.845		3.076	1.019		0.879	
PRO	Prometryne	3.136	3.141	1.726				0.026		0.209	
PRT	Phosmet	1.167	1.752	-0.101	-0.503	1.987	2.415	0.682			
PSF	Prosulfuron	4.371		3.920				-0.188		-1.073	
PTH	Parathion	1.287	2.445	-1.256	-2.070	-0.036	-0.660	1.536			
PTX	Oxycarboxin	3.510	3.503	3.424	3.364			3.116			

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PYA	Pyraclostrobin	0.424		-0.508				-0.077		2.073	
PYD	Pyridaben	-0.282	0.550	-1.991	-1.399			1.749		0.047	
PYR	Pyrethrins	0.661	0.931	0.182	-1.330	-0.590	-0.662				
PYZ	Pyrazon (chloridazon)	4.055		4.142				1.522		2.500	
PZN	Pymetrozine	4.976		3.080				3.015		3.875	
QAC	N-alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride										
QAK	Didecyl dimethyl ammonium chloride	1.070	1.232	0.454	0.711	2.340		0.866	1.165		
QAO	N-alkyl (67% C12, 25% C14, 7% C16, 1% C18) dimethyl benzyl ammonium chloride										
QPE	Quizalofop p-ethyl										
QTZ	Quintozene	1.822	1.895	0.638							
QUC	Quinclorac	4.607	4.134	3.628				3.477		1.536	

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
REZ	Resmethrin	-0.282	-0.419	-1.839	-0.813	-1.018					
SDD	Sodium dimethyldithiocarbamate	2.203	2.885	0.847	0.301			1.740			
SLF	Sulfosulfuron	3.151		3.789				2.146		-1.172	
SMZ	Simazine	3.460	4.095	3.360	3.495	2.894		1.392		1.161	
SOD	Sethoxydim	3.102	2.488	3.814	2.004	2.679		1.319		1.284	
SPI	Spinosad	3.050		2.181				1.592		2.863	
SUL	Sulphur	4.554	3.153	4.466							
SUS	Lime sulphur or calcium polysulphide		3.345	2.219	2.859				2.970		
TCM	2-(Thiocyanomethylthio)benzothiazole	0.507	0.199	-0.081						1.242	
TCS	TCA (sodium salt)			4.061							
TCS	TCA (trichloroacetic acid)	5.962	5.513	3.707	5.146						
TCS	TCA (form not specified)	5.249	5.513	2.023	5.146	5.533					

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
TEL	Tefluthrin	-1.996	-0.083	-3.017	-2.606						
TER	Terbacil	4.166		3.737				0.760		0.983	
TET	Chlorothalonil	1.257	1.162	0.142	0.440	2.019		0.578		1.637	
TEU	Tebuconazole	3.699		1.892				2.053		1.018	
TFS	Triflusulfuron methyl	5.084		4.774				0.659		-0.713	
TFY	Trifloxystrobin	1.160		0.317				0.471		2.123	
TFZ	Tebufenozide	1.936		1.359	1.852	1.334		1.364			
THE	Thiamethoxam	4.036		2.630				3.824		3.791	
THI	Thiram	0.281	-0.350	-0.358		1.725		1.529		2.041	
TLL	Triadimenol	4.125		1.983				2.374			
TPA	Tepraloxydim	4.213	2.953	3.871	2.308				1.503		1.504
TPM	Thiophanate-methyl	3.564	2.366	2.043	2.803			2.596		2.509	

AI Code	AI Accepted Name	Fish Log HC5 technical	Fish Log HC5 formulation	Crustacea Log HC5 technical	Crustacea Log HC5 formulation	Aquatic insects Log HC5 technical	Aquatic insects Log HC5 formulation	Algae Log HC5 technical	Algae Log HC5 formulation	Macrophyte Log HC5 technical	Macrophyte Log HC5 formulation
TPR	Triclopyr	3.034	2.408	3.916	1.924	2.578		2.812		2.751	
TRA	Tralkoxydim	3.255		3.934				3.255		2.252	
TRB	Etridiazole	2.547		1.985				0.920		2.747	
TRF	Trifluralin	1.663	0.594	1.349	1.889	2.926	2.583	0.835		0.772	
TRI	Trichlorfon	2.667	3.127	-0.890	0.367	0.360	-0.498				
TRL	Triallate	2.542	2.421	0.854	0.601	1.831	2.018	1.693	-0.258	2.837	
TRR	Triforine		3.487	3.174	2.956			4.316	3.620		
TRS	Triasulfuron			3.458				1.320		-2.177	
TRT	Triticonazole	3.045		2.077				2.388		2.013	
TXP	Trinexapac-ethyl	4.392		3.068				2.206		1.288	
TZL	Thiabendazole	2.900	3.172	0.852	1.843			2.791			
VIL	Vinclozolin	3.294	3.912	1.993				1.881		2.004	

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VIT	Carbathiin	2.366	2.753	3.039	3.192			1.718		1.732	
VPR	Hexazinone	5.010	5.540	4.163	3.774			-0.096		0.695	
ZIN	Zineb	3.282	3.887	2.147	2.428	3.366					
ZIR	Ziram	0.939	1.783	0.759				1.499			
ZNO	Zinc oxide	3.636		2.712							
ZOX	Zoxamide	2.199		0.968				0.860		0.092	

APPENDIX H: Ranking of all 206 compounds for their risk to fish with the associated number of ecological incidents.

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
TEL	Tefluthrin	1870.4120	1	7		
PHR	Phorate	185.3049	2	10		[1]
THI	Thiram	82.0759	3			
ESF	Endosulfan	53.5757	4	58	9	13
GOO	Azinphos-methyl	33.1168	5	98	11	[1]
DUB	Chlorpyrifos	31.2321	6	26		[1]
ZIR	Ziram	21.9956	7			[2]
COY	Terbufos	10.9610	8	67		[1]
CAP	Captan	10.7813	9			
TET	Chlorothalonil	10.2010	10	6	3	
FER	Ferbam	10.1540	11			
DIM	Dimethoate	7.2523	12	1		[1]
FOL	Folpet	6.8724	13			
DIA	Diazinon	4.0699	14	7		[1]

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
DIN	Dinocap	3.9651	15			
PFL	Permethrin	3.7503	16	4		[3]
CYM	Cypermethrin	3.6644	17	2		[3]
PRT	Phosmet[1]	2.5568	18			[1]
CYH	Cyhalothrin-lambda	2.3097	19	5		
PYD	Pyridaben	2.2048	20			
DYR	Anilazine	2.0325	21			
NAL	Naled	1.5670	22			[1]
CAF	Carbofuran	0.7754	23	5	1	[2]
MET	Methoxychlor	0.7682	24			
DIK	Dichloran	0.7513	25			
ETS	Ethofumesate	0.6529	26			
FAA	N-Decanol	0.5573	27	1		
DXF	2,4-D (unspecified ester)	0.5188	28	9		
FAD	Famoxadone	0.4713	29			
BET	Bensulide	0.4703	30			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
EFR	Ethalfluralin	0.4440	31			
PYA	Pyraclostrobin	0.3842	32			
CAB	Carbaryl	0.3312	33	2		[2]
BRY	Bromoxynil (octanoate)	0.3256	34			
MOR	Chinomethionat	0.3112	35			
MAN	Maneb	0.2858	36	1		
TRI	Trichlorfon	0.2777	37			[1]
TRF	Trifluralin	0.2157	38			
CHL	Chlorthal (form not specified)	0.2030	39			
DCF	Dicofol	0.1828	40			
TPR	Triclopyr	0.1582	41	1		
TCM	2-(Thiocyanomethylthio)benzothiazole	0.1571	42			
DBR	Deltamethrin	0.1522	43			
BTL	Desmedipham	0.1463	44			
FLZ	Fluazinam	0.1419	45			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
MML	Methomyl	0.1406	46	1		
ATR	Atrazine	0.1386	47	26		
KRB	Propyzamide	0.1332	48			
FLR	Fluroxypyr 1-methylheptyl ester	0.1223	49			
AME	S-Metolachlor	0.1200	50			
LUN	Linuron	0.1150	51			
QTZ	Quintozene	0.1099	52			
PHS	Phosalone	0.1064	53			[1]
DUR	Diuron	0.1011	54	3		
MAL	Malathion	0.0970	55	11		[1]
FOM	Formetanate (form not specified)	0.0962	56			
MCZ	Mancozeb	0.0899	57		2	
TFZ	Tebufenozide	0.0897	58			
PRO	Prometryne	0.0844	59			
NBP	Napropamide	0.0782	60			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
SMZ	Simazine	0.0771	61	2		
MEI	Dimethenamid	0.0738	62	1		
TFY	Trifloxystrobin	0.0669	63			
TRL	Triallate	0.0633	64			[2]
MAE	MCPA (unspecified ester)	0.0610	65			
DCB	Dichlobenil	0.0606	66			
DPB	2,4-DB (form not specified)	0.0582	67			
OXB	Oxamyl	0.0537	68			[2]
DIC	Dicamba (form not specified)	0.0466	69	2		
OXR	Oxyfluorfen	0.0437	70			
FLT	Flufenacet	0.0434	71			
MAA	MCPA (acid)	0.0395	72			
DPP	Diclofop-methyl	0.0377	73	1		
FEX	Fenhexamid	0.0332	74			
DIH	Dichlorprop (form not specified)	0.0329	75			
KRS	Kresoxim-methyl	0.0326	76			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
ZIN	Zineb	0.0316	77			
CHH	Boscalid	0.0300	78			
PIC	Picloram (form not specified)	0.0291	79	2		
AZY	Azoxystrobin	0.0262	80			
CUZ	Copper (copper hydroxide)	0.0250	81	**		**
DAZ	Dazomet	0.0235	82			[2]
MTL	Metolachlor	0.0232	83	18		
AMZ	Amitraz	0.0222	84			
ZOX	Zoxamide	0.0219	85			
PEN	Pendimethalin	0.0216	86	2		
MXF	Methoxyfenozide	0.0207	87			
CYP	Cyprodinil	0.0145	88			
IPD	Iprodione	0.0142	89			
EPT	EPTC	0.0140	90	1		
MBS	MCPB (sodium salt)	0.0136	91			
PYZ	Pyrazon (chloridazon)	0.0133	92			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
DXA	2,4-D (acid)	0.0133	93			
SOD	Sethoxydim	0.0119	94	2		
CNQ	Clomazone	0.0116	95	2		
TZL	Thiabendazole	0.0116	96			
TER	Terbacil	0.0110	97			
VIL	Vinclozolin	0.0108	98			
GPI	Glyphosate (isopropylamine salt)	0.0096	99	*		
TPM	Thiophanate-methyl	0.0096	100			[2]
VIT	Carbathiin	0.0090	101			
ENT	Endothall (form not specified)	0.0087	102			
BAX	Metribuzin	0.0084	103	1		
FAB	N-Octanol	0.0082	104			
FED	Fenamidone	0.0076	105			
GPT	Glyphosate (trimethylsulfonium salt)	0.0076	106	*		
MAS	MCPA (potassium salt)	0.0075	107			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
NAP	Naptalam (form not specified)	0.0075	108			
AMI	Amitrole	0.0075	109			
MYC	Myclobutanil	0.0071	110			
DPA	Diphenylamine	0.0071	111			
MAB	MCPA (dimethylammine salt)	0.0069	112			
MTR	Metiram	0.0067	113			
QPE	Quizalofop p-ethyl	0.0065	114			
DOD	Dodine (dodecylguanidine monoacetate)	0.0058	115			
FZA	Fluazifop-p-butyl	0.0057	116	1		
FBZ	Indar	0.0054	117			
PYR	Pyrethrins	0.0053	118			3
ACP	Acephate	0.0048	119	2		1
MAH	Maleic hydrazide (form not specified)	0.0046	120			
ACA	Acifluorfen (form not specified)	0.0045	121			
PIR	Pirimicarb	0.0044	122			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
GPP	Glyphosate (potassium salt)	0.0043	123	*		
DME	Dimethomorph	0.0042	124			
FOR	Formaldehyde	0.0041	125			
PMP	Phenmedipham	0.0038	126			
TRA	Tralkoxydim	0.0033	127			
MMM	Thifensulfuron-methyl	0.0031	128			
CFP	Clodinafop-propargyl	0.0029	129			
MOM	Methamidophos	0.0026	130			[1]
PFN	Picolinafen	0.0024	131			
BMS	Flusilazole	0.0024	132			
PON	Propiconazole	0.0023	133			
MEA	Mecoprop (potassium salt)	0.0023	134			
MEW	Mecoprop d-isomer (potassium salt)	0.0021	135			
MFN	Metalaxyl-m (mefenoxam)	0.0019	136			
IXF	Isoxaflutole	0.0017	137			
MEC	Mecoprop (form not specified)	0.0017	138			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
CFZ	Clofentezine	0.0013	139			
DFZ	Difenoconazole	0.0012	140			
FPF	Fenoxaprop-p-ethyl	0.0012	141	1		
CCC	Chlormequat (form not specified)	0.0012	142			
MEZ	Mecoprop d-isomer (amine salt)	0.0011	143			
TRR	Triforine	0.0011	144			
CYZ	Cyromazine	0.0011	145			
VPR	Hexazinone	0.0009	146			
IMP	Imazethapyr	0.0008	147			
DXB	2,4-D (unspecified amine salt)	0.0008	148			
BZN	Bentazon (form not specified)	0.0007	149			
ASS	Imazamethabenz (form not specified)	0.0007	150			
SLF	Sulfosulfuron	0.0007	151			
MPR	(S)-Methoprene	0.0006	152			
IMI	Imidacloprid	0.0006	153			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
ETF	Ethephon	0.0006	154			
TEU	Tebuconazole	0.0006	155	1		
BAD	6-Benzyladenine	0.0006	156			
SUL	Sulphur	0.0006	157			
NXI	Acetamiprid	0.0005	158			
CHE	Chlorimuron-ethyl	0.0005	159			
GPS	Glyphosate (acid)	0.0005	160	*		
DPI	Clopyralid	0.0005	161			
CYO	Cymoxanil	0.0005	162			
PHY	Propamocarb hydrochloride	0.0005	163			
CLE	Clethodim	0.0004	164			
CUS	Copper (copper sulphate)	0.0004	165	3		
GPM	Glyphosate (mono-ammonium salt)	0.0004	166	*		
COD	Clothianidin	0.0003	167			
PAQ	Paraquat (form not specified)	0.0003	168			
SPI	Spinosad	0.0003	169			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
MER	Mesotrione	0.0002	170			
MTA	Metalaxyl	0.0002	171	1		
TRT	Triticonazole	0.0002	172			
DIQ	Diquat (form not specified)	0.0002	173	2		
MEM	Metsulfuron-methyl	0.0002	174			
QUC	Quinclorac	0.0001	175			
CUY	Copper (copper oxychloride)	0.0001	176	**		**
TPA	Tepraloxydim	0.0001	177			
FOF	Fomesafen	0.0001	178			
THE	Thiamethoxam	0.0001	179			
PRI	Primisulfuron-methyl	0.0001	180			
AVG	Difenzoquat (methyl sulphate salt)	0.0001	181			
GLG	Glufosinate ammonium	0.0001	182			
DFF	Diflufenzopyr (form not specified)	0.0001	183			
FLS	Flucarbazone-sodium	0.0001	184			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
PID	Picloram (triisopropanolamine salt)	0.0001	185			
FMS	Foramsulfuron	0.0001	186			
HEC	Hexaconazole	0.0001	187			
CLM	Cloransulam (form not specified)	0.0001	188			
TLL	Triadimenol	0.0001	189			
TRS	Triasulfuron	0.0001	190			
IMZ	Imazamox	0.0001	191			
AMN	Aminoethoxyvinylglycine	0.0001	192			
MEX	Tribenuron methyl	0.0000	193			
NIO	Nicosulfuron	0.0000	194			
FLD	Fludioxonil	0.0000	195			
PSF	Prosulfuron	0.0000	196			
CSL	Chlorsulfuron	0.0000	197			
ETM	Ethametsulfuron (form not specified)	0.0000	198			
FLM	Flumetsulam	0.0000	199			

AI Code	AI Accepted Name	Fish ETR	Rank	US EPA EIIS Fish Incident Data	PEI Fish Incident Data	California Fish Incident Data 1984-2003
DPY	Rimsulfuron	0.0000	200			
PZN	Pymetrozine	0.0000	201			
TFS	Triflusulfuron methyl	0.0000	202			
FRA	Florasulam	0.0000	203			
IDO	Iodosulfuron-methyl-sodium	0.0000	204			
FAL	Fosetyl-al	0.0000	205	1		
NAA	1-Naphthalene actetic acid (form not specified)	0.0000	206			

[1] = generic organophosphates (see note below)

[2] = generic carbamates

[3] = generic pyrethroids/synthetic pyrethroids

** = generic glyphosate records*

*** = generic copper records*

In the California Fish Incident Data 1984-2003 dataset, there were 3 recorded incidents for organophosphates, 2 for carbamates, and 4 for pyrethroids/synthetic pyrethroids. Since no distinction was made as to which specific compound or compounds were responsible for the fish kills, all organophosphates are marked with a [1] in the table, all carbamates are marked with a [2] in the table, and all

pyrethroids/synthetic pyrethroids are marked with a [3] in the table (the marked compounds are ones that do not already have a specified number of fish kills). Because the generic form was given in these cases we were unable to incorporate the information into the current analysis. It is however important to note the occurrence of these incidents because of their negative impact to fish. Likewise, copper has a similar situation. Three forms of copper exist in the list of 206 pesticides: copper hydroxide, copper sulphate, and copper oxychloride. The recorded incidents for copper sulphate were specific. Yet there were 8 investigations involving copper in the California Fish Incident Data 1984-2003 dataset, and 2 in the US EPA EIIS database. Copper is marked with ** to signify that there are reported incidents for copper, yet only in the generic context. Since the form of copper was unidentified, we were unable to use the data in our analysis. Once again, it is important to take note of these numbers because of the adverse effect to fish. Finally, the same situation arose for glyphosate. There were 5 incidents in the EIIS database that were unable to be used because the specific form of glyphosate that caused the fish kills was not reported. These are signified with * in the table.