A Comparative Analysis of Ecological Risks from Pesticides and Their Uses: Background, Methodology & Case Study

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I. INTRODUCTION

A. Purpose

This document describes a proposed approach and methodology, which is under development, for comparing the ecological risk of pesticides and their uses in the Environmental Protection Agency's (EPA or the Agency) Office of Pesticide Programs (OPP). Risk assessors are often asked to compare the ecological risks posed by different pesticides registered (or being considered for registration) for use on a specific crop. Comparative analyses can help to ensure consistency in risk management decisions and to focus more significant ecologically-based risk management decisions on those pesticides that pose the greatest risk to fish and wildlife. Therefore, OPP seeks to define standard methods for comparative ecological risk assessment that are scientifically sound and capable of being implemented using currently available data and resources. We would expect to update or replace these methods as additional data and probabilistic assessment tools become available.

Methods will be presented for comparing the potential ecological risk of pesticides used on similar crop sites. Risk indices or risk quotients (RQs)[1] are calculated and the results are compared to established levels of concern (LOCs)[2]. In addition, since numerous RQ calculations are made using a range of use rates and ecotoxicity values, pesticides and their use sites are compared based on frequency (%) of LOC exceedances. The resultant exceedances and frequencies are used to rank pesticides used on the similar use sites according to risk. The comparisons include acute and chronic endpoints for terrestrial and aquatic organisms, as well as incident reports and information on extent of use. Pesticide specific ecotoxicology data and environmental fate and transport data are used in the analysis. Screening models such

[1]A risk quotient is the ratio of the estimated environmental concentration of a chemical to a toxicity test effect level for a given species. It is calculated by dividing an appropriate exposure estimate (e.g. EEC) by an appropriate toxicity test effect level (e.g. LC50).

[2]Levels of Concern (LOC's) are criteria used to indicate potential risk to non-target organisms and the need to consider regulatory action. The criteria indicate that a pesticide, when used as directed, has the potential to cause adverse effects on non-target organisms. Since the issuance of a 1992 policy by OPPTS [1 and 2], OPP has generally pursued ecological risk mitigation whenever these levels of concern are exceeded.

as GENEEC[3] and FATE[4] are used here to estimate pesticide exposure, but results from more sophisticated models such as PRZM/EXAMS[5] also could be used.

B. Background

Risk managers in EPA's Office of Pesticide Programs have had a longstanding desire to better understand the relative ecological risk posed by pesticides so that this information can be factored into decisions regarding priorities for risk management and decisions regarding degrees of needed risk mitigation. With the passage of FQPA and its mandate for EPA to conduct cumulative human health risk assessments for pesticides with common mechanisms of toxicity, risk managers are even more interested in understanding which pesticides pose the greater or lesser ecological risk. Simply stated, risk managers understand that the purposeful release of biological poisons into the environment will result in impacts to exposed non-target aquatic and terrestrial species; what risk managers most desire is to focus the more significant ecological risk mitigation actions on those pesticides and pesticide use patterns which result in the greatest threat to non-target species. Although EFED is undertaking a major multi-year effort to improve its risk assessment methods (an effort which will likely lead to the use of probabilistic risk assessment methods and the collection of some different data than has been historically required for registration and reregistration), a major challenge for scientists in EFED today is to effectively use the data which are currently and typically provided to support registration and reregistration and current risk assessment methods in order to provide risk managers with an accurate sense of relative risk.

For a typical food-use pesticide, EPA requires and generally has available the following ecotoxicological data:

1. Mammalian Acute Toxicity (Rat LD_{50})
2. Avian Acute Toxicity (one species - Oral LD_{50}; two species - Dietary LC_{50}'s)
3. Avian Chronic Toxicity (two species, avian reproduction - NOAEC)

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[3]GENEEC is a PC - based computer program which is designed to allow the user to quickly calculate a set of generic (non-site specific) estimated environmental concentrations (EEC's) given limited environmental fate data and pesticide label information [21].

[4]FATE model is PC - based computer program designed to allow the user to quickly calculate conservative, non-site specific, exposure values for avian and mammalian risk assessments [Appendix 31].

[5]PRZM/EXAMS is a combination of a runoff model (PRZM2, Pesticide Root Zone Model) [26 and 27] and a surface water receiving model (EXAMS, EXposure Analysis Modeling System) [28] designed to provide a distribution of EEC values, in time and space, for the crop area in which the pesticide has been applied.

4. Honey Bee Contact or Residue Toxicity
5. Terrestrial Plant Toxicity (vegetative vigor & seedling emergence - 10 species - EC_{50}'s)
6. Fish Acute Toxicity (two species, coldwater & warmwater - LC_{50}'s)
7. Fish Chronic Toxicity (one species - NOAEC)
8. Aquatic Invertebrate Acute Toxicity (one species - EC_{50})
9. Aquatic Invertebrate Chronic Toxicity (one species - NOAEC)
10. Estuarine/Marine Acute Toxicity (three species, fish, shrimp, crustacean, mollusc - EC_{50}'s)
11. Aquatic Plant Toxicity (5 species - EC_{50}'s)

For a typical food-use pesticide, EPA requires and generally has available the following exposure/fate and transport data:

1. Solubility in water
2. Volatility (vapor pressure)
3. Octanol/Water Partition Coefficient (as Log K_{ow})
4. Hydrolysis at pH 5 , 7, and 9; (when applicable, dissociation constant)
5. Photolysis in water (half-life)
6. Photolysis on soil (half-life)
7. Aerobic/Anaerobic soil metabolism (half-life) (includes information on soil type)
8. Aerobic/Anaerobic aquatic metabolism (half-life)
9. Mobility in soil data for parent & major degradates (includes information on soil type)
10. Field dissipation studies, according to use pattern (includes brief description of study sites)
11. Soil Adsorption/desorption with K_d and K_{oc} sorption coefficients, values (range & median) for parent and environmental degradates
12. Bioaccumulation in fish

Field studies for investigating terrestrial and/or aquatic effects are not required for all pesticides, but only those whose labeled use raised concern for high risk. Such pesticides usually have high risk quotients for acute or chronic effects to birds, fish or aquatic invertebrates. In addition, some other information characterizing the risk is often available such as kill incident reports, data on environmental persistence, multiple applications, or a pattern of widespread use.

This is not the first attempt by EPA’s Office of Pesticide Programs (OPP) to develop an approach for comparing the ecological risks posed by different pesticides in a regulatory context. In March, 1992, EPA’s Office of Pesticide Programs published a document titled "Comparative Analysis of Acute Avian Risk from Granular Pesticides"[3]. It described OPP's approach for screening granular formulation pesticides to identify those that may pose acute lethal risk to birds. That document focused on granular pesticides because of the particular acute risk they pose to birds. The analysis was based on the calculation of an acute risk quotient and a weight-of-evidence approach to characterize the ecological risk, considering confirmatory field studies and bird kill incident reports. The analysis found that 14 granular pesticides pose potentially high risk to birds due to their high acute toxicity and availability in the environment. The report was released to the public and the regulated community.

Based on written technical comments provided by the registrants, the Agency developed a series of generic risk assessment issues that could benefit from further research [4]. Such issues as the effect of granular substrate, avian preference, the efficiency of various incorporation methods, the effect of watering in granules, and insecticide/fertilizer mixes on risk of granular pesticides to birds were identified. The registrants have already submitted data that have been useful in refining Agency risk assessment for granular pesticides.

Given the limitations of the data generally available to EPA and the limitations of available EPA resources, EFED recognizes it is necessarily limited in its ability to use relative risk methods to make "fine" distinctions between the ecological risk posed by particular pesticides. That is, given the nature of the available data and the amount of time and effort that can be routinely dedicated to completing ecological risk assessments[6], OPP cannot expect to rank all active ingredients with precision. However, EFED does believe that it is possible to use available data and current risk assessment methods to identify those pesticides and pesticide uses which pose significantly less ecological risk than others, so that EFED can answer the very real questions that risk managers ask every day. EFED believes that the proposed risk-based methodology for comparing pesticides may provide us with an appropriate tool to distinguish between pesticides that are greatly different from one another.

The document provides two basic approaches to aid decision-making: the first is a graphical presentation consisting of a series of bar charts comparing pesticides based on risk functions; the second is a tabular presentation with a summarized ranking of the same pesticides based on decision analysis of the risk functions. Ideally, both would be used concurrently and would complement one another.

A series of questions are being posed to the SAP based on the two approaches. Where the panel may conclude that an approach or method is inappropriate, the

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[6]EFED technical staff of 78 scientists has responsibility for conducting ecological risk assessments and water resource assessments for over 400 registered pesticide active ingredients and 10 to 20 new active ingredients (per year).

Agency is very interested in suggestions for alternative approaches and/or methods that can be adopted within the constraints of available data and available resources. .

First, the fundamental question:

> Based on the typical sets of studies, data, and information provided for pesticide risk assessment purposes in the regulatory context and the use of OPP's current risk assessment methods, is this approach useful/meaningful for evaluating the relative potential risk of pesticides and pesticide uses, especially for ascertaining large distinctions between the risk posed by pesticides?

Second, concerning the graphical presentation:

> Is this approach useful/meaningful for comparing the relative potential risk of pesticides and pesticide uses?
>
> In the previous comparative analysis of granular insecticides the Agency compared the pesticides based on calculated risk quotients. In this analysis, the Agency sought to incorporate more of the available information into the comparison. Thus, there are a number of new calculations for expressing potential risk, such as the % contribution to the RQ sum, the frequency of RQ exceedance, the % contribution to the Time to RQ=1 sum, and % risk. Are these useful parameters for comparing the potential risk of pesticides?
>
> The graphs are presented in order of decreasing percent of acres treated. Otherwise, the extent of use is not factored into the risk calculations. Is this appropriate?
>
> The use of granular formulations is likely to present chronic risk to birds; however, OPP currently has no method to calculate this risk. Therefore the proposed approach addresses chronic risk to birds only for sprayable formulations. Does the Panel agree that the avian chronic risk should be included for sprayable formulations despite the Agencies inability to include this risk element for granular formulations? Should the Agency explore ways to use the avian chronic risk quotient for sprayable formulations as a surrogate to address this risk factor when comparing granular formulations?

Third, concerning the tabular presentation based on decision analysis:

> Is this approach useful/meaningful for comparing the relative potential risk of pesticides and pesticide uses?
>
> One of the simplifications of the methodology used in the decision analysis

software is that there are no uncertainties. This is certainly not the case in comparative ecological risk analysis. However, one of the ways the software permits the user to deal with some uncertainty is by running multi-scenarios. This was done for the case study. These runs show how sensitive the differences between pesticides are to change in the importance of the criteria. The results can add confidence to overall conclusions. Does the panel agree that his approach is useful and can increase the confidence of conclusions derived from the results?

Incidents were treated as important when they exist; however, when there were no incident reports this element was given zero weight in the analysis. Is this an appropriate use of incident data for this comparative analysis?

C. Scope and Methods

This comparative analysis builds upon the earlier comparative risk document. The Comparative Analysis of Acute Avian Risk from Granular Pesticides was focused solely on one kind of formulation (granular) and one endpoint (acute risk to birds). In order to present the approach and methods for this more expansive and complex analysis, we chose to present a case study of 17 insecticide chemicals and four use sites, alfalfa, corn, cotton, and peanuts. In order to maintain the focus of this analysis on the methodology and not on individual pesticides, the 17 insecticides were designated as Chemical A through Q.

In this new analysis eleven endpoints were selected for comparing both at-plant granular formulations and post-emergent sprays. They include both acute and chronic risk for birds, fish and aquatic invertebrates. The aquatic endpoints covered exposure in both the freshwater and marine/estuarine environments. In addition, the analysis incorporates the standards of ecological risk assessment and management, the Levels Of Concern (LOCs), provided in the 1992 Agency policy document [2]. Consequently, risk comparisons can be made in a more equitable fashion for all pesticides included in this analysis.

EPA calculated risk quotients for acute and chronic risk to birds, fish and aquatic invertebrates. These risk indices are based upon estimates of pesticide exposure and ecotoxicity. In turn, these estimates are based on available pesticide label information, ecotoxicity and environmental fate data, as well as widely accepted models.

The risk quotient methodology described in this analysis has previously been available for both public and scientific review. It has become common in ecological risk assessment to present potential risk in terms of a ratio of the estimated environmental exposure or EEC, divided by the hazard of toxicity such as the LC_{50}, EC_{50} or No

Observed Adverse Effects Concentration (NOAEC). EPA first presented this risk index method in the Standard Evaluation Procedure for Ecological Risk Assessment in 1986 [4]. These ratios are used to express potential acute and chronic risk to birds, fish and aquatic invertebrates.

Ecological risk assessment is an evolving field. EPA sponsors research and works with industry and other agencies in a continuing effort to refine the Agency's ecological risk assessment methodologies. Of particular note is the Ecological Committee on FIFRA Risk Assessment Methods (ECOFRAM) which was formed in June 1997. Its purpose is to develop tools and processes within the FIFRA framework for predicting the magnitude and probabilities of adverse effects to non-target aquatic and terrestrial species resulting from the introduction of pesticides into their environment. ECOFRAM was convened in response to a review of OPP's ecological risk assessments and guidelines in May of 1996 by the FIFRA Scientific Advisory Panel (SAP). While recognizing and generally affirming the utility of the current assessment process and methods for screening risk assessment purposes, the SAP noted that OPP has relied on deterministic methods of assessing the ecological effects of pesticides and strongly encouraged OPP to develop and validate tools and methodologies to conduct probabilistic assessments of ecological risk. This resulted in the formation of ECOFRAM. As tools for probabilistic ecological risk assessments become available and are implemented in OPP/EFED, this comparative analysis of ecological risk assessments will need to be revised and updated.

As noted previously, the risk quotients in this screening analysis are used to indicate potential ecological risk. They find their greatest utility when used as the basis for comparing the potential acute and chronic risk to birds, fish and aquatic invertebrates posed by different pesticides used on the same sites, under similar exposure scenarios. When used with additional information such as reports of bird and fish kill incidents, refined estimates of exposure, common practice mitigatory measures, unique site characteristics, etc. this analyses is useful for identifying those pesticides which pose comparatively higher or lower risk. However, it is important to clarify the limitations of this approach.

This analysis is similar to a predictive model. It is based on data inputs such as laboratory eco-toxicity data, fate data from laboratory and/or field studies, computer generated model exposure estimates, and use data from the pesticide labels. The quality of the results from any model reflect the quality of the input data and the adequacy of the models used to accurately represent the most significant processes affecting a pesticide's fate and biological effects in the environment, and the dependence of those behaviors on the selected input parameters. The limitations of the approaches used here are discussed more fully in Section VIII of this paper. Nevertheless, the Agency believes that the choices of input data and risk calculations are useful for comparing potential and relative risks among pesticides used as alternatives on the same site.

The current analysis is intended only to compare the potential acute and chronic risk to birds, fish and aquatic invertebrates posed by these insecticides used on these four crop sites. A complete ecological risk assessment of any of these pesticides would include an evaluation of other information including acute and chronic risk to other non-target organisms such as wild mammals and non-target plants, consideration of exposure refinements based on site-specific use data, an account of the extent, location and ecological sensitivity of the areas treated and a comprehensive assessment of available field effects data (terrestrial field studies and mesocosms), including detailed incident reports. These factors were not included as part of the current analysis.

EPA recognizes the potential risk to wild mammals and non-target plants from these and other highly toxic pesticides and will address those risks in future comparative assessments. Additionally, the results of this analysis could change if the input data changes. New eco-toxicity or environmental fate data, or updated use information will result in changes in the quotients, their LOC exceedance, and the relative comparisons. As such, the results of the analysis and the conclusions drawn are dynamic. The Agency recognizes that as additional information is made available, both the results and conclusions are subject to change.

This analysis is valuable in that it identifies and compares pesticides and uses presenting the relative acute and chronic potential risk to birds, fish and aquatic invertebrates. The scope of this analysis is considerably expanded over the previous analysis for granular pesticides. However, it is still incomplete. Despite this, the analysis presents an interesting approach for comparing ecological risk based on sound data and a well documented methodology.

D. Approach - Case Study Using Selected Insecticides & Use Sites

Four major crop sites were selected for analysis - alfalfa, corn, cotton and peanuts. Current pesticide labels for insecticides commonly used on these sites were reviewed . Based on this review, 17 pesticides were selected and designated as Chemical A through Q. For this case study, we will assume that these 17 pesticides were all of the same chemical class, with similar modes of action. This resulted in a total of 38 pesticide-use site combinations (See Table 1). Hypothetical usage data was generated and is found in Appendix 1. Appendix 2 lists the information collected from selected pesticide labels. This included various formulations, timing, types, and methods for application for each pesticide-use combination.

This case study analysis is not intended to characterize all the risks of the chemicals in the analysis or serve as the sole basis for decision-making. Rather, it is provided as an illustrative example demonstrating how pesticides used as alternatives on the same site can be compared based on ecological risk and the results used to aid decision-making.

Table 1. Chemicals & Uses Chosen for Comparative Ecological Risk Analysis (17 Chemicals & 4 Uses)

	Chemical Names	***Selected Use Sites***				***# of Use Sites per Chemical***
		Alfalfa (10)*	***Corn (8)***	***Cotton (14)***	***Peanuts (6)***	
1	**A**					2
2	**B**					2
3	**C**					3
4	**D**					3
5	**E**					3
6	**F**					1
7	**G**					3
8	**H**					2
9	**I**					4
10	**J**					1
11	**K**					2
12	**L**					3
13	**M**					2
14	**N**					2
15	**O**					3
16	**P**					1
17	**O**					1

* The Number of Chemicals per use Site

II. AVIAN EFFECTS AND EXPOSURE ASSESSMENT

A. Effects

EPA typically receives the following required laboratory studies to use in performing avian risk assessments: acute bird LD_{50}[7] (mg/kg) and LC_{50}[8] (ppm) studies, and chronic bird reproduction studies, providing a NOAEC[9] (ppm). The Agency evaluates the studies and classifies them as either core[10], supplemental[11] or invalid[12], as well as indicating whether the supplemental and invalid studies are upgradable[13]. The toxicity values from the core and supplemental studies are used in risk assessment.

This analysis used core and supplemental eco-toxicity data in the Eco Tox data base [5] to characterize the effects of the selected pesticides on birds. All the data used in this analysis has been updated and verified. However, some errors in this analysis could result from entry errors. In addition, the data used in this analysis reflects the status of the data base as of July, 1998. It does not include data available after that date. More recent data could change the results of this analysis.

Avian LD_{50} (mg/kg) and LC_{50} (ppm) values and chronic NOAEC (ppm) values for the most sensitive species tested (the lowest values) were selected from the data base. In addition, the median LD_{50} (mg/kg) and LC_{50} (ppm) values were calculated. These median values provided a less conservative estimate of the toxicity values (compared to the lowest) and provided additional values for determining a range of toxicity values for a particular endpoint.

Since relatively few species are used in standard toxicity testing, it is likely that the species most sensitive to each pesticide has not been tested. The few species that are tested often provide a range of toxicity values, reflecting the combined effects of measurement error, variability in sensitivity among individuals within a species, and

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[7] Median lethal dose necessary to affect (kill) 50% of the test population.

[8] Median lethal concentration in the diet necessary to affect (kill) 50% of the test population.

[9] The highest concentration tested in the study where no adverse effects were observed.

[10] Scientifically sound study which also meets EPA published guideline requirements.

[11] Scientifically sound study with some deviations from published EPA guideline requirements.

[12] Study has flaws that make it's results unreliable to use in risk assessment.

[13] Additional data (e.g., sample storage stability data) could make a study useable for risk assessment.

species-to-species variation in sensitivity to the pesticide being tested. Because of this variation in sensitivity, it is unlikely that this analysis will show the worst case risk for each pesticide considered. Rather, based on the calculated toxicity values, the analysis will provide a range of risk values for purposes of comparison and identification of those pesticides that are more likely to cause adverse effects in actual use.

1. Acute Toxicity to Birds

Based on years of experience in preparing risk assessments, EPA/OPP has found that the LD_{50} value, compared to the LC_{50} value, is often a better indicator of acute toxicity to birds [5]. This seems to be true especially for pesticides with LD_{50} values less than or equal to 50 mg/kg. Alternately, the LC_{50} value may be a better indicator of acute toxicity to birds if their LD_{50} values are greater than 50 mg/kg and they persist in the environment with a half-life greater than one day. For this analysis, however, both the avian acute oral LD_{50} value and the avian subacute dietary LC_{50} value were included and used in the risk calculations.

The avian LD_{50} value is usually expressed in mg/kg of body weight. However, it is well established that the body weight of a bird is a very important consideration when determining how sensitive any individual bird will be to acute pesticidal effects, Therefore, the LD_{50} value was adjusted by multiplying it by the weight of a bird to arrive at an LD_{50} per bird value. For this analysis, EPA chose 20 gm to represent small birds (e.g., songbirds); 100 gm to represent medium size birds such as small upland game birds (e.g., quail) ; and 1000 gm to represent large upland game birds and waterfowl (e.g., pheasants and geese).

EPA ranked the 17 pesticides in order of their lowest acute oral LD_{50} toxicity values (Appendix 3) and their lowest acute dietary LC_{50} toxicity values (Appendix 4). The median of the data including data on all bird species tested for each pesticide was included.

2. Chronic Toxicity to Birds

The NOAEC are typical values resulting from the avian reproduction test. Typically, two species, bobwhite quail and mallard ducks, are tested. Common reproductive effects found in these tests are egg thinning, cracked eggs, reduced hatchability, decreased survival rate, reduced growth of F_1 generation and reduced egg production.

EPA ranked the 17 pesticides in order of their lowest chronic toxicity, that is NOAECs (Appendix 5). For chemicals lacking data on chronic effects to birds, a value was estimated by applying an acute to chronic ratio value. This was calculated based on a regression analysis (Table 2) of acute toxicity values over long-term exposure effect values for the all the pesticides in this class. This regression equation was used to predict missing values. Although r^2-values for the regression suggested that they were not predictive over the entire range of the regression, the regression coefficient was significant ($P<0.05$) and residuals were minimal for acute toxicity values requiring the regression analysis.

Table 2. Linear regression parameter estimates following the format: Dependent Variable = Slope (Independent Variable) + y-intercept. Regression analyses were conducted using toxicity estimates from studies involving > 50% active ingredient.

Dependent Variable[1]	slope	y-intercept	Independent Variable	r^2
avian chronic NOAEC	0.03081	6227.22	median acute avian LC_{50} [2]	0.39
freshwater fish chronic NOAEC	0.157	-24.5931	median freshwater fish acute LC_{50} [3]	0.27
freshwater fish chronic NOAEC	0.05933	-6.809434	median freshwater fish acute LC_{50} [3]	0.79
marine/estuarine fish acute LC_{50}	0.076924	458.1463	median freshwater fish acute LC_{50} [3]	0.99
freshwater crustacean NOAEC	0.0127	2.372717	median freshwater crustacean acute EC_{50}	0.57
marine/estuarine crustacean acute EC_{50}	0.599898	7.282905	median freshwater crustacean acute EC_{50} [4]	0.97
marine/estuarine mollusc acute EC_{50}	2.489109	47.852861	median marine/estuarine crustacean acute EC_{50}	0.79

[1]estimate expressed as parts per billion (ppb).
[2]regression equation developed using Guideline 71-2 median toxicity (LC_{50}) estimates.
[3]regression equation developed using Guideline 72-4 toxicity estimates of 4,000 ppb.
[4]regression equation developed using Guideline 72-3 median toxicity estimates excluding estimate of 43 ppb.

B. Exposure

Both granular and non-granular formulations are being considered in this analysis. The amount of toxicant a bird is likely to consume in the diet or by preening, ingest as a single dose, inhale, or absorb via the eye or through the skin, is currently not quantified as it is for human exposure. Research has begun, but is limited at this time [6]. Among bird species, there are tremendous differences in feeding, mating, migration, and other behaviors. These and other factors explain why a definitive avian exposure model is not currently available.

Environmental exposure has two components: the frequency and duration of contact with the pesticide; and, the amount or concentration of a pesticide in the environment and available to non-target organisms. The Comparative Analysis of Acute Avian Risk from Granular Pesticides provided an in-depth discussion showing that birds are present in fields treated with pesticides; that the pesticide is available to birds in the fields; and, birds can and do ingest pesticide granules, contaminated plant material, insects, and soil.

Only limited data are currently available to determine to what extent ingestion of pesticide granules or food items with pesticide residues is incidental, accidental, selected for, avoided or some combination of these possibilities. Birds may inadvertently ingest granules along with other material, may mistake the granules for seeds, grit, or other food items, or may actively select or avoid contaminated insects, plant material or pesticide granules. With accidental or incidental exposure, both dietary consumption and oral ingestion are assumed to be proportional to availability.

Since the amount of pesticide actually consumed or ingested by birds is difficult to quantify, the Agency used two simple exposure models to estimate exposure in terms of availability of the pesticide active ingredient: one to estimate avian acute oral dose exposure, and one to estimate avian dietary exposure, both acute and chronic.

1. Acute Exposure to Granular Pesticides via Oral Dose (mg a.i./ ft^2 available)

For granular pesticides, a simple exposure model for avian oral dose exposure assumes that the amount of toxicant available to birds per unit area of the treated field provides an indication of the actual amount of pesticide available that birds could ingest. It is important to note that the Agency is not attempting to estimate the actual number of birds that would receive a lethal dose, nor the probability of a given bird consuming a lethal dose. Estimates of that sort would depend on the number of acres treated, the species and numbers of birds present in a given area and many factors of bird behavior, that have not yet been adequately documented.

Methods and timing of applications vary with the specific product, the crop, and reason for treatment. Further, preferred application methods also vary with crop and location. Though some application-incorporation regimes are more effective than others at reducing exposure, wildlife exposure to pesticides can result from all pesticide application methods including ground spray, aerial spray, band, in-furrow, drill, shanked-in, broadcast, side-dress and aerial broadcast.

For the purposes of this analysis, the Agency assumed that applications requiring soil incorporation of the pesticide would result in only 15% of the pesticide being available to birds. For in-furrow applications the Agency assumed that only 1% of the pesticide would be available to birds. If labels did not specify any incorporation, no reduction in exposure was calculated. Further, the Agency calculated the exposure using the maximum application rate and one-half that rate. The latter was included to provide a range of exposure estimates. An exposure at one-half the maximum is not intended to represent any particular label rate. Since this is a screening analysis, it is assumed that information on typical rates would not be readily available for all the pesticides included in the comparison.

The Agency is using 15% and 1% as a representative values, recognizing that specific application methods provide more or less efficient incorporation. In previous product-specific assessments, the Agency has used a range of incorporation efficiency values, reflecting the range of application methods. Erbach and Tollefson [7] and other published data document the efficiency of various incorporation methods.

Field study and incident data confirm that birds can and do consume sufficient amounts of the pesticide formulations examined in this analysis to cause mortality. Furthermore, multiple lethal doses are readily available to birds in the relatively small area of one square foot.

Birds may ingest pesticide granules or food items contaminated by pesticides remaining on or just below the soil surface after a pesticide application. These granules or contaminated food items may be consumed while a bird is foraging for seed, grit or insects on the surface or probing below the surface of the soil. Furthermore, subsurface granules and contaminated food items may also have exposure potential via routes other than direct ingestion (e.g., dermal exposure via contaminated water after irrigation or rainfall). Data are not available to estimate the amount of pesticide ingested by birds probing below the soil surface. Therefore, for this analysis, the Agency has considered only the amount of pesticide on the surface of the soil after a pesticide application. See equation (1).

$$(1)\quad \frac{\text{\#Pounds Active Ingredient/Acre}}{43{,}560\ \text{ft}^2\text{/Acre}} \times 453{,}600\ \text{mg/lbs} = \frac{\text{\#mg Active Ingredient}}{\text{ft}^2}$$

which equals

$$\frac{\underline{\text{\#Pounds Active Ingredient/Acre x 10.4132 mg/lbs}}}{\text{ft}^2\text{/Acre}} = \frac{\underline{\text{\#mg Active Ingredient}}}{\text{ft}^2}$$

This analysis, like the Comparative Analysis of Acute Avian Risk from Granular Pesticides, uses one square foot as the unit for calculating toxicant availability, although any constant unit area could be used. DeWitt [8] suggested this unit for calculating environmental exposure when he related quantities of toxic pesticides ingested by birds to quantities of toxic pesticide deposited per square foot using several laboratory and field studies. Felthousen [9] proposed Agency risk criteria for granular pesticides related to the amount of toxic pesticide per square foot available to an animal. Current EPA ecological risk assessment procedures for pesticides use a similar approach for determining the amount of toxicant available [10 and 11].

Appendix 6 gives the results of the calculations of amount of toxicant available on the major use sites in terms of milligrams per square foot.

2. Acute Exposure to Sprayed Pesticides via Diet (ppm available in diet)

In the Standard Evaluation Procedures for Ecological Risk Assessment [10, Table 5], EPA presented a generalized table for estimating pesticide residues on avian food items based on the data compiled by Hoerger and Kenaga [12]. The pesticide residues in the table (all 0-day residues for 1 lb a.i./acre application) have been used to estimate maximum residues likely to be found in avian diets such as 240 ppm for small grasses, estimate ranges from maximum to typical such as 240 to 125 for small grasses or 58 to 33 ppm for forage crops, and to estimate residues in diets of specific species. These estimates have been recently updated based on Fletcher et al [13]. These estimates, ranging from maximum to average, are 240 to 85 ppm for small grasses, 110 to 36 ppm for long grasses, 135 to 45 ppm for broadleaf plants, and 15 to 7 ppm for fruits.

Since this is a screening analysis, the Agency chose to keep the acute exposure simple and use the maximum residue value for small grasses adjusted by the maximum single application rate on the label and one-half this value for comparison purposes. This residue value was input to the FATE Model as well as the aerobic soil metabolism half-life value (see Table 3). The aerobic soil metabolism half-life value is used here as an estimate of foliar dissipation[14]. Run for 30-days, the model out-put provided the

[14]The aerobic soil metabolism (ASM) half-life value is almost always a conservative estimate of foliar dissipation. For many pesticides, a more refined estimate may be found in Willis and McDowell [14]. ASM values greater than 30 days are very rare. Where the ASM value is greater than 30-days, the data in

maximum and average estimated residues on avian food items in ppm. Appendix 7 shows the results for spray formulations.

this reference may provide a better estimate of foliar dissipation. Since this is a screening analysis, only the ASM value was used to estimate the foliar dissipation.

Table 3. Environmental Fate Parameters for Inputs into Terrestrial FATE Model & GENEEC Surface Water Model

Chemical Name	***Water Solubility***	***Hydrolysis Half-life (days @ pH 7)***	***Photolysis Half-life (days)***	***Aerobic Soil Metabolism (days)***	***Anaerobic Soil Metabolism (days)***	***Aerobic Aquatic Metabolism (days)***	***GENEEC Koc***
A	80.1 g/l	163	stable	2.3	NA	NA	2.73
B	25.1 mg/l	37	3.2	95.6	NA	NA	725
C	2 mg/l	72	29.6	180	NA	NA	3680
D	32000 mg/l	68	175	27	NA	54	10
E	15 mg/l	323	3.87	19.39	NA	NA	386
F	843 mg/l	stable	stable	300	300	NA	108
G	24 mg/l	stable	30	174	NA	5.2	232
H	400 mg/l	706	0.218	13.29	NA	NA	106
I	145 mg/l	6.2	94	3	NA	3.3	151
J	200 g/l	27	90	1.75	NA	NA	0.88
K	250 mg/l	48	11	9	NA	NA	113
L	2000 mg/l	0.64	stable	3	NA	NA	89
M	miscible	40	137	9.6	10.5	NA	2
N	60 mg/l	40	2.04	11.25	NA	NA	230
O	50 mg/l	3	1	9	96	NA	150
P	25 mg/l	0.39	Stable	9	45	NA	1260
Q	15 mg/l	15	1.2	81	216	NA	633

3. Chronic Exposure via Diet (ppm available in diet)

The Agency has noted that the chronic exposure is the weakest point in the avian risk assessment [10]. It noted that Hoerger and Kenaga [12] even adjusted by Fletcher et al [13] data are of minimal value since the values presented are generally those found immediately after application. Further, in the past, the residues likely to be found over time have been estimated on a case-by-case basis and used for the chronic avian EEC's.

Fletcher et al. [13] looked at pesticide persistence by examining residue-decay curves of pesticides administered at rates between 0.5 and 1.5 lb/acre. All the data fit exponential decay curves except systemic pesticides applied as either granules or dust. For such pesticides, "no apparent exponential decay curve occurred over the first 30 to 40 days." The residues that remained were generally "below the 0-day levels predicted by the Kenaga nomogram." More research is needed to expand this prediction.

Further, the findings of Rattner et al. [15], Bennett and Bennett, [16], and Bennett et al. [17] have shown that pesticide effects on avian reproduction for some pesticides are not simply a function of chronic exposure. They found that exposure of breeding bobwhite quail and mallard ducks to organophosphate compounds can negatively impact reproduction with exposure periods as short as 8-10 days. Again, this research needs to be expanded to more accurately predict when short exposure periods can lead to reproductive impairment.

Considering all of the above, the Agency chose to use the acute exposure EEC's as estimates in Appendix 7 to be compared with chronic test endpoints for this analysis of 17 insecticides.

III. AVIAN RISK QUOTIENTS AND ECOLOGICAL LEVELS OF CONCERN

The Agency currently uses the quotient method to express ecological risk. The quotient method compares the estimated environmental concentration of a pesticide to the toxicity test effect level for a given species. The result is a risk quotient (RQ). An RQ is calculated by dividing an appropriate exposure estimate (e.g. EEC) by an appropriate toxicity test effect level (e.g. LC_{50}, LD_{50}, NOAEC). We assume that the higher the specific risk quotient for an endpoint, generally, the greater the relative risk. Equation (2) is a general statement of this relationship:

$$(2)\quad \frac{\text{Estimated Environmental Concentration (e.g.EEC)}}{\text{Toxicity Test Effect Level (e.g., } LC_{50})} = \text{Risk Quotient}$$

The risk quotients are intended to be used as rough indicators of comparative risk, and cannot be used to predict how many birds will actually die or experience impaired reproduction. Further, they are not intended to predict the probability of a bird receiving a lethal or chronic dose. Site-specific considerations such as the attractiveness of the treated fields, the species distribution, the species density, as well as the number of acres treated would affect the number of these organisms actually exposed.

Furthermore, the quotient does not provide a definitive value for the amount of pesticide that will be available to birds. The actual amount of pesticide available will vary depending on the application method, configuration and calibration of equipment, wind speed and other field conditions.

In order to provide industry and the public with clear standards for ecological risk assessment and management that can be applied in an equitable fashion and to facilitate ecological risk comparisons, the Agency established levels of concern (LOC's) for ecological effects of pesticides on non-target organisms [2]. These LOC's are criteria used by the Agency to indicate potential risk to non-target organisms and the need for a regulatory action. If the criteria are exceeded, it indicates that a pesticide, when used as directed, has the potential to cause adverse effects on non-target organisms.

There are two general categories of LOC's for avian species, acute and chronic. In order to determine if an LOC has been exceeded, first a risk quotient must be calculated and then compared to the appropriate LOC. When the risk quotient exceeds the LOC for a particular endpoint, risk for that endpoint is presumed to exist. The LOC's for birds used in this analysis plus the corresponding risk presumptions are as follows:

ENDPOINT	LOC	PRESUMPTION
Acute Dietary RQ≥	0.5	High Acute Risk
Acute Oral Dose RQ≥	0.5[13]	High Acute Risk
Chronic RQ≥	1.0	High Chronic Risk

The specific equations used to calculate the risk quotients for acute and chronic

[13] In 1992, the Agency announced the selection of 1 LD_{50}/ft^2 as the cutoff level of concern based upon field study data submitted to the Agency at that time which indicated that pesticide applications resulting in environmental concentrations of at least 1 LD_{50}/ft^2 have resulted in avian mortality. Since that time, the Agency proposed changing the level of concern (LOC) to 0.5 LD_{50}/ft^2 primarily to add a level of safety to the risk estimate [2]. This proposal has generated considerable discussion both within and outside the Agency.

risk to birds used in this analysis follow. Calculations using these equations were conducted for the 17 pesticides used on the seven use sites. Maximum and average exposure values as well as one-half these residues were used as numerators; the lowest toxicity value and the median toxicity value (where calculated) were used as denominators. Avian acute (LD_{50}/ft^2) RQs calculations were limited to granular formulations typically applied pre- or at-plant, while avian dietary (EEC/LC_{50}) RQs, avian acute bird per day (EEC x %Food Ingestion per Day/ LD_{50}) RQs, and avian chronic (EEC/NOAEC) RQs were limited to spray formulations, primarily applied post-emergent. Twelve acute avian dose risk quotients were calculated for each granular pesticide/use combination; four avian dietary risk quotients were calculated for each spray pesticide/use combination; twenty-four acute bird per day risk quotients were calculated for each spray pesticide/use combination; and, four avian chronic risk quotients were calculated for each spray pesticide/use combination.

A. Calculation of the Acute Avian Risk Quotients

In U.S. EPA 1986 [10], the avian dietary LC_{50} was presented as the primary acute toxicological endpoint to be compared to the acute exposure. However, Hill [18] points out that "ingestion is believed to be the most common route of pesticidal exposure in birds and therefore th[e] oral tests of lethality [LD_{50}] provide a sound basis for preliminary screening." Further, he states that "when used in combination and judiciously, the two tests of lethality are invaluable tools for preliminary evaluation of potential hazard of pesticides to wild birds."

The Agency chose to estimate acute risk to birds for these pesticides by using both the avian acute oral LD_{50} test and the avian dietary LC_{50} test in the risk assessment.

1. Avian Acute Risk via Dose Ingestion - Granular Formulations

The *avian acute risk via dose ingestion* is calculated for *granular formulations* using equation (3).

$$(3) \quad \frac{\text{EEC (mg ai/ft}^2\text{)}}{LD_{50}\text{ (mg/kg) x Bird Weight (kg)}} = \frac{\text{\# of }LD_{50}\text{s}}{\text{ft}^2} = \text{RQ (Risk Quotient)}$$

This equation describes acute avian risk as a quotient of the amount of toxicant readily available to birds within a square foot (a rough indicator of exposure) of treated area, to the avian acute oral toxicity (expressed as an LD_{50} per bird). General bird body weights used were 1.000 kg (1000 gm) to represent large birds such as mallard ducks and pheasants, 0.100 kg (100 gm) to represent medium size birds such as doves and quail, 0.020 kg (20 gm) to represent small birds such as songbirds. The result is an expression of acute risk to birds in terms of the number of LD_{50}s per square foot.

Appendix 9 lists all acute avian risk quotient calculations for the granular formulation pesticide use site combinations. The results are presented in order of descending risk quotients for the pesticides on each use site. The greater the number, the greater the potential acute dose risk to birds.

2. Avian Dietary Risk - Spray Formulations

The *avian acute risk via the diet* is calculated for *spray formulations* using equation (4).

$$(4)\quad \frac{\text{EEC (ppm in the diet)}}{LC_{50}\text{ (ppm)}} = \text{Risk Quotient}$$

This equation describes acute avian dietary risk as a quotient of the concentration of toxicant likely to be available in bird diets, to the subacute avian dietary toxicity (expressed as an LC_{50}). The result is an expression of acute risk to birds in terms of concentration exposed to concentration tested.

Appendix 10 lists all avian dietary risk quotient calculations for the spray formulation pesticide use site combinations. The results are presented in order of descending risk quotients for the pesticides used on each use site. The greater the number, the greater the potential acute dietary risk to birds.

3. Avian Acute Bird per Day Risk - Spray Formulations

The *avian acute bird per day ingestion risk* is also calculated for *spray formulations* using equations (5) and (6).

$$(5)\quad \frac{\text{EEC x (Food Ingestion}^{14}\text{/bird weight)}}{LD_{50}} = \text{Risk Quotient}$$

This equation describes acute avian bird per day ingestion risk as a quotient of the

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[14] Bird food ingestion rates (in grams dry matter per day) were calculated using an equation developed by Nagy [19] and referenced by EPA [20],

$$\text{Food Ingestion (g/day)} = 0.648 \text{ x bird weight}^{0.651}\text{ (g)}$$

The Agency selected the general equation for all birds over other more specific equations for passerines, non-passerines, and seabirds. We assumed that the lowest and median toxicity values used in the risk quotients represented all birds. Thus, we chose the generalized food ingestion rate for all birds.

quantity of toxicant likely to be ingested daily [20] by a bird, to the acute oral avian dose toxicity (expressed as an LD_{50} expressed as mg/kg). The result is an expression of acute risk to birds in terms of daily acute dose from ingestion of contaminated food items.

As previously noted, EPA/OPP has found that the LD_{50} value is often a better indicator of acute toxicity to birds especially for pesticides with acute LD_{50} values less than or equal to 50 mg/kg. Appendix 3 shows that 14 out of the 17 Chemicals considered here have LD_{50} values less than 50 mg/kg. Also, comparing the toxicity rankings in Appendix 3 and 4, a number of the most toxic insecticides via the oral dose are less toxic via the diet, e.g., Chemical O, Chemical G, Chemical E. Thus, the Agency decided that a risk quotient using the LD_{50} toxicity values should be included for spray formulations.

Appendix 11 lists all avian acute bird per day ingestion risk quotient calculations for the spray formulation pesticide use site combinations. The results are presented in order of descending risk quotients for the pesticides used on each use site. The greater the number, the greater the potential acute bird per day risk to birds.

B. Calculation of the Chronic Avian Risk Quotients

1. Avian Chronic Risk - Spray Formulations

The *avian chronic quotient* is calculated for *spray formulations* using equation (6).

$$(6)\quad \frac{\text{EEC (ppm in the diet)}}{\text{NOAEC (ppm)}} = \text{Risk Quotient}$$

This equation describes chronic risk to birds as a quotient of the concentration of toxicant likely to be available in bird diets, to the no observed adverse effect concentration (NOAEC) in the avian reproduction test. The result is an expression of chronic risk to birds in terms of concentration exposed to concentration tested.

Appendix 12 contains a list of avian chronic risk quotient calculations for all spray formulation pesticide use site combinations. The results are presented in order of descending risk quotients for the pesticides used on each use site. The greater the number, the greater the potential avian chronic risk to birds.

Granular formulations may also present a chronic risk to birds. However, the Agency dose not presently have a method to evaluate this risk.

2. Number of Days to Reach the Avian Chronic Level of Concern (RQ=1) - Spray Formulations

In addition to using an RQ approach for estimating potential avian chronic risk, the Agency elected to use a risk index that better reflected pesticide persistence. This was accomplished by calculating the total number of days post-application required for estimated pesticide concentrations in avian food items to be degraded/dispersed to a point of equivalence with the avian long-term exposure toxicity endpoint (reproduction NOAEC)[15].

The *Avian Chronic Time to RQ=1* calculation was performed for *spray formulations* using the equation (7):

$$\text{(7)}\quad \frac{\text{Ln ((NOAEC (ppm)/EEC (ppm in the diet))}}{-K} = \text{Time (days)}$$

where, the EEC (starting food item concentration) is the Agency standard short-grass estimated concentration based on 1 lb a.i./A (240 ppm) [13] adjusted by the application rate on the label. K is the foliar degradation rate constant as estimated by aerobic soil metabolism half-life and an assumption of first-order degradation kinetics (See Appendix 8).

Appendix 13 contains a list of avian chronic Time to RQ=1 calculations for all spray formulation pesticide use site combinations. The results are presented in order of descending number of days for the pesticides used on each use site. The greater the number of days, the greater the potential avian chronic risk to birds.

C. The Avian Risk Column - % Pesticide Contribution to RQ Sum for Each Endpoint on Each Site (Crop)

When comparing pesticides using RQs, the RQ scales for each endpoint are an important consideration. As shown below, the scales for the four avian endpoints vary widely (pesticide and use site for the highest values are presented parenthetically):

Acute Dose (LD_{50}/ft^2)	0 to 2519	[Chemical O on Peanuts]
Acute Dietary (EEC/LC_{50})	0 to 131	[Chemical L on Cotton]
Acute Bird per Day ($EECx\%FI/LD_{50}$)	0 to 2940	[Chemical G on Cotton]
Chronic Bird (EEC/NOAEC)	0 to 206	[Chemical B on Cotton]

[15] Note that the Agency is not suggesting that avian exposures occurring after this time are inconsequential; only that new exposures starting after that point are not expected to present significant risk to birds.

These differences raise many questions. For example: Should we be more concerned with acute bird per day risk and avian acute dose risk than acute dietary risk and chronic bird risk? Is the magnitude of the avian acute dose risk approximately 24 times greater than the dietary risk for pesticides used on potatoes? Do these differences reflect inherently different ranges of toxicities for the different endpoints? Additional analyses and perhaps research is needed to answer these questions. Not having adequate answers at present, the Agency decided that it would be easier to compare avian risk between pesticides without having to deal with these scale differences.

With the above information in mind, the Agency focused on each crop site. It assumed that all the potential risk for a particular endpoint on a particular crop site could be represented by the sum of the RQ values that exceeded the LOC for all the pesticides used on that crop site. If the RQ values for that endpoint for each pesticide used on that crop site were summed, then the quotient of the sum of the individual pesticide RQs over the sum of all the RQs for all the pesticides, would represent the percent (%) contribution of each pesticide to the total risk for that endpoint on that site. See equation (8).

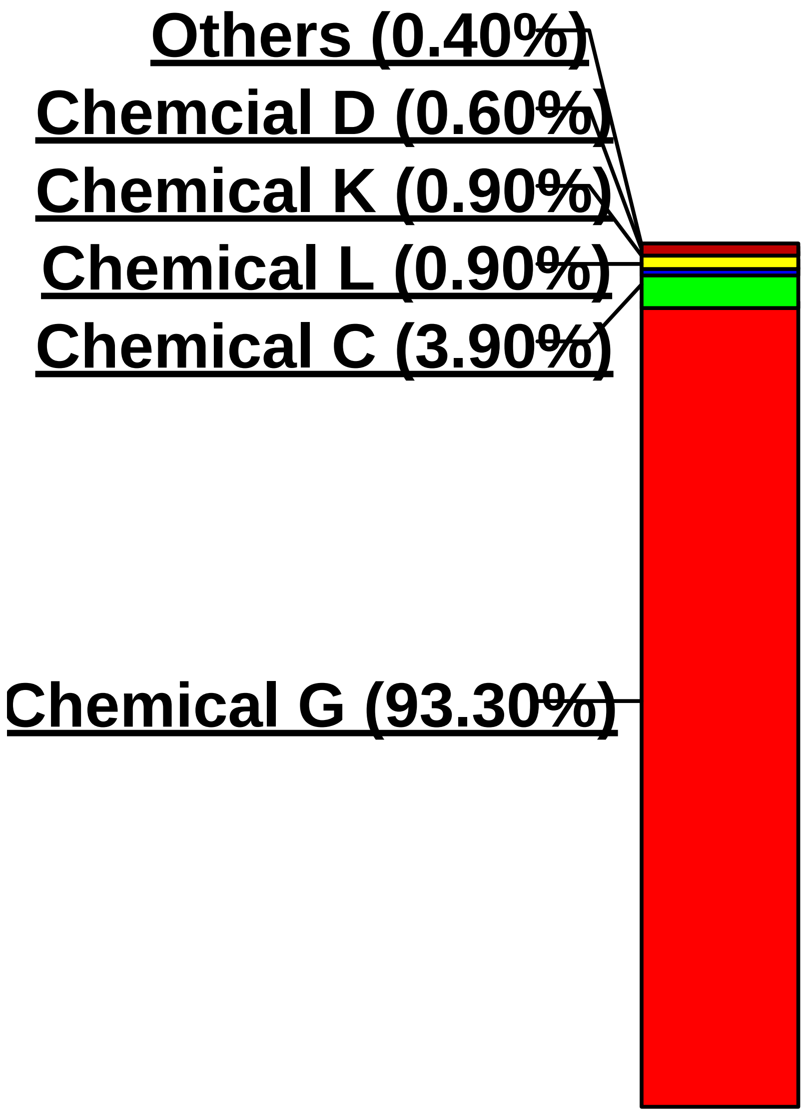
(8) $$\frac{\sum \text{endpoint RQ values/pesticide/crop site}}{\sum \text{endpoint RQ values for all pesticides/crop site}} \times 100 = \frac{\text{\% Pesticide Contribution to RQ}}{\text{Sum on Each Crop Site}}$$

This calculation provides a relative estimate of potential avian risk per pesticide per avian endpoint by which the pesticides can be compared on a crop site basis. The comparison is relative to the total risk for each endpoint and on each crop, represented by the sum of the RQ values which exceed the LOCs. It eliminates the problem of widely varying scales. Appendices 9a, 10a, 11a and 12a show these calculations for avian acute dose risk, avian dietary risk, acute bird per day risk and avian chronic risk, respectively.

If all the avian risk per endpoint can be represented by the sum of all the RQ values exceeding the LOC for that endpoint, the total risk can be viewed as column. Each pesticide used on that site contributes a certain percentage toward filling the column. The major contributors to the total risk can be determined by showing the individual percentages (See example in Figure 1).

Figure 1. Avian Risk

Acute Bird per Day Risk on Alfalfa



In this example, Chemical G contributes the greatest and a majority of the potential acute bird per day risk on alfalfa. Chemical C is a distant second, while the other pesticides used on alfalfa contribute less than 1%.

D. Frequency of LOC Exceedance (%)

Where the risk quotients can provide an estimate of the magnitude of potential avian risk, considering how often a risk quotient exceeds an LOC can provide an estimate of the frequency of the potential risk. Twelve avian acute dose risk quotients were calculated for each granular pesticide/use combination (See Appendix 9); four avian dietary risk quotients were calculated for each spray pesticide/use combination (See Appendix 10); twenty-four acute bird per day risk quotients were calculated for each spray pesticide/use combination (See Appendix 11); and, four avian chronic risk quotients were calculated for each spray pesticide/use combination (See Appendix 12). The lowest and median toxicity values were included in all calculations except the avian chronic, where the lowest value was the only value available. The maximum residue values and one-half these values were included in all calculations. In the bird per day RQ calculations and the avian chronic calculations, the average residue values, as determined using the FATE model were also included. Both the avian acute dose and the acute bird per day RQ calculations included LD_{50} values adjusted for 20, 100, and 1000 gram birds.

Appendices 9b, 10b, and 11b show how often (%) the calculated acute risk quotients exceeded the LOC's for pesticide/use combination and each endpoint analyzed. The pesticides in each appendix were ordered by crop site and by decreasing summed RQ values exceeding the LOC. The higher the frequency (%), the more times the RQ's exceeded the LOC's. This shows the relative frequency with which a pesticide/use combination is likely to exceed an LOC. The frequency of exceedance was not calculated for avian chronic risk because (1) greater than 93% [9/124; see Appendix 12] of the chronic RQ calculations exceeded the LOC for chronic avian risk, and (2) the Time to RQ=1 (# of days) calculation along with the RQ calculation were thought to be risk indices that together better reflected pesticide persistence.

IV. EFFECTS AND EXPOSURE CHARACTERIZATION FOR AQUATIC ORGANISMS

A. Effects

EPA typically reviews the following laboratory studies in performing aquatic risk assessments: acute freshwater LC_{50} (ppb) studies, acute marine/estuarine fish LC_{50} (ppb) studies, acute freshwater invertebrate EC_{50} (ppb) studies, marine/estuarine crustacean EC_{50} (ppb) studies, marine/estuarine mollusc EC_{50} (ppb) freshwater fish chronic (partial fish life-cycle) study providing a NOAEC (ppm), and freshwater invertebrate life-cycle providing a NOAEC. The Agency evaluates the studies and classifies them as either core, supplemental or invalid, as well as indicating whether the supplemental and invalid studies are up gradable. The results of the core and supplemental studies, the toxicity values, are used in risk assessment.

Core and supplemental eco-toxicity data in the EcoTox Data Base [9] were used to characterize the effects on fish and aquatic invertebrates. EPA updated and verified all the data used in this analysis. However, some errors in this analysis could result from entry errors. In addition, the data used in this analysis reflects the status of the data base as of July, 1998. It does not include data entered after that date. More recent data could change the results of this analysis.

Freshwater fish LC_{50} (ppb), marine/estuarine fish LC_{50} (ppb), freshwater invertebrate EC_{50} (ppb), marine/estuarine crustacean EC_{50} (ppb), marine/estuarine mollusc EC_{50} (ppb) acute values as well as freshwater fish and aquatic invertebrate life-cycle NOAEC (ppb) values for the most sensitive species tested (the lowest values) were selected from the data base. In addition, the median fish and aquatic invertebrate LC_{50} (ppb) and EC_{50} (ppb) values were calculated. These median values provided a less conservative estimate of the acute toxicity (compared to the lowest) and provided additional values for determining a range of toxicity values for a particular endpoint.

Since relatively few species are used in standard toxicity testing, it is likely that the species most sensitive to each pesticide has not been tested. Because of this variation in sensitivity, it is unlikely that this analysis will show the worst case risk for each pesticide, but rather will provide a range of risk values for purposes of comparison and identification of those pesticides that are more likely to cause adverse effects in actual use.

1. Acute Toxicity to Freshwater Fish

EPA typically requires 96-hour acute LC_{50} toxicity studies on two fish species, one cold water fish such as a rainbow trout, and one warm water fish such as a bluegill sunfish. These toxicity data are used to assess the pesticide's potential to cause acute lethality in freshwater fish.

EPA ranked the 17 pesticides in order of their lowest acute freshwater fish LC_{50} toxicity values (Appendix 14). The median values were also calculated.

2. Acute Toxicity to Marine/Estuarine Fish

EPA typically requires 96-hour acute LC_{50} toxicity studies on one marine/estuarine fish species such as the sheepshead minnow when the use of the pesticide is likely to contaminate marine/estuarine environments. These toxicity data are used to assess acute effects on marine/estuarine fish. For pesticides lacking data on this endpoint, a value was estimated based on a regression analysis (Table 2) of median freshwater fish acute values over median marine/estuarine fish for all the pesticides in the class. Median values are not presented for this endpoint because EPA typically receives data on only one marine/estuarine fish species.

EPA ranked the 17 pesticides in order of their lowest acute marine/estuarine fish LC_{50} toxicity values (Appendix 15).

3. Acute Toxicity to Freshwater Invertebrates

EPA typically requires one 48-hour EC_{50} study on *daphnia spp*. These data are used by OPP to assess acute effects on freshwater invertebrates.

EPA ranked the 17 pesticides in order of their lowest acute EC_{50} toxicity values (Appendix 16). The median value is also included since there were sufficient data for each pesticide in the analysis to calculate this value.

4. Acute Toxicity to Marine/Estuarine Crustaceans

EPA typically requires 96-hour acute EC_{50} toxicity studies on one marine/estuarine crustacan species such as the mysid when the use of the pesticide is likely to contaminate marine/estuarine environments. These toxicity data are used to assess acute effects on marine/estuarine crustaceans. For pesticides lacking data on this endpoint, a value was estimated based on a regression analysis (Table 2) of median freshwater crustacean acute values over median marine/estuarine crustacean values for all the pesticides in this class. Median values are not presented for this endpoint because EPA typically receives data on only one marine/estuarine crustacean species.

EPA ranked the 17 pesticides in order of their lowest acute marine/estuarine crustacean EC_{50} toxicity values (Appendix 17).

5. Acute Toxicity to Marine/Estuarine Molluscs

EPA typically requires 96-hour acute EC_{50} toxicity studies on one marine/estuarine mollusc species such as the eastern oyster when the use of the pesticide is likely to contaminate marine/estuarine environments. These toxicity data are used to assess acute effects on marine/estuarine molluscs. For pesticides lacking data on this endpoint, a value was estimated based on a regression analysis (Table 2) of median marine/estuarine crustacean acute values over median marine/estuarine mollusc values for all the pesticides in this class. Median values are not presented for this endpoint because EPA typically receives data on only one marine/estuarine crustacean species.

EPA ranked the 17 pesticides in order of their lowest acute marine/estuarine mollusc EC_{50} toxicity values (Appendix 18).

6. Chronic Toxicity to Freshwater Fish

The NOAEC is the typical value resulting from the partial or full life-cycle fish test. Typically, one species is tested, often the fathead minnow. Common life-cycle effects found in these tests are reduced hatchability, reduced juvenile survival, reduced growth of F_1 generation, etc. For pesticides lacking data on this endpoint, a value was estimated based on a regression analysis (Table 2) of median freshwater acute fish values over freshwater fish chronic values for all the pesticides in this class.

EPA ranked the 17 pesticides in order of their lowest chronic toxicity NOAECs (Appendix 19).

7. Chronic Toxicity to Freshwater Invertebrates (crustaceans)

The NOAEC is the typical value resulting from the aquatic invertebrate life-cycle test requirement in the regulations. Typically one species such as *Daphnia, spp*. is tested. Common life-cycle effects found in these tests are reduced number of young per female, reduced juvenile survival, reduced growth of F_1 generation, etc. For pesticides lacking data on this endpoint, a value was estimated based on a regression analysis (Table 2) of median freshwater crustacean acute values over freshwater invertebrate chronic values for all the pesticides in this class.

EPA ranked the 17 pesticides in order of their lowest chronic toxicity NOAECs (Appendix 20).

B. Exposure

1. Acute and Chronic Exposure Modeling

To provide a basis for comparison, EPA used the GENEEC [21] to estimate the concentration of the 17 pesticides in ponds adjacent to pesticide applications on the four use sites using both the maximum use rates and one-half the maximum use rates. The GENEEC is a screening model that mimics the PRZM-EXAMS model behavior. In the model, the number of days between treatment and rain-induced runoff is set at 2. It assumes runoff from a 10-hectare field to a standard 1 hectare pond two meters deep. Further, it assumes 10% runoff of a total annual pesticide application. A Generic Estimated Environmental Concentration (GEEC) is produced and this value may be increased by adding spray drift. Spray drift for an aerial application is added at 5% application rate with 95% application efficiency. Spray drift for a ground application is added at 1% application rate with 99% application efficiency. The GEEC may be reduced by factoring in adsorption to soil using the K_{OC} value and by considering incorporation. The model calculates chronic GEEC's using aerobic aquatic, hydrolysis and/or aquatic photolysis half-life values (days). The model produces a report consisting of the peak GEEC as well as the average GEEC at 4-days, 21-days and 56-days. Following the standard procedures used in EFED Science Chapters for Registration Eligibility Documents (REDs), EPA chose to use the peak GEEC for the acute exposure, i.e., the Estimated Environmental Concentration (EEC), to fish and aquatic invertebrates; the 21-day GEEC for the chronic EEC to aquatic invertebrates; and, the 56-day GEEC for the chronic EEC to fish. Table 3 in Section II provides a listing of the environmental fate parameters for each of the 17 pesticides used to load the GENEEC model. Table 4 below provides the report format for the model.

Appendix 21 gives the results of the GENEEC model runs for the 38 pesticide/use combinations for the maximum label rates and one-half the maximum label rates.

Table 4. GENEEC Model Report Format

RUN No. 1 FOR [name of pesticide] INPUT VALUES

RATE (#/AC) ONE(MULT)	APPLICATIONS NO.-INTERVAL	SOIL KOC	SOLUBILITY (PPM)	% SPRAY DRIFT	INCORP DEPTH(IN)
0.0(0.000)	0 0	0.0	000.0	0 .0	0.0

FIELD AND STANDARD POND HALFLIFE VALUES (DAYS)

METABOLIC (FIELD)	DAYS UNTIL RAIN/RUNOFF	HYDROLYSIS (POND)	PHOTOLYSIS (POND-EFF)	METABOLIC (POND)	COMBINED (POND)
0.00	0	000.00	.00- .00	.00	000.00

GENERIC EECs (IN PPB)

PEAK GEEC	AVERAGE 4 DAY GEEC	AVERAGE 21 DAY GEEC	AVERAGE 56 DAY GEEC
00.00	00.00	00.00	00.00

V. AQUATIC RISK QUOTIENTS AND LEVELS OF CONCERN

As noted previously, the Agency currently uses the quotient method to express ecological risk. The quotient method compares the estimated environmental concentration of a chemical to the toxicity test effect level for a given species. The result is a risk quotient. A risk quotient is calculated by dividing an appropriate exposure estimate (e.g. EEC) by an appropriate toxicity test effect level (e.g. LC_{50}). We assume that the higher the specific risk quotient, the greater the relative risk. Once again equation (2) is presented as a general statement of this relationship:

$$\frac{\text{Estimated Environmental Concentration (e.g.EEC)}}{\text{Toxicity Test Effect Level (e.g., } LC_{50})} = \text{Risk Quotient}$$

The acute aquatic effect levels typically are: LC_{50} for fish, and the EC_{50} for aquatic invertebrates. The aquatic chronic effect level for both fish and aquatic invertebrates is the NOAEC.

The risk quotients are intended to be used as rough indicators of comparative risk, and cannot be used to predict how many fish or aquatic invertebrates will actually die or experience adverse effects on their life-cycle or reproduction. Further, the risk quotients are not intended to predict the probability of a fish or aquatic invertebrate receiving a lethal dose. Site-specific considerations such the water temperature, quality and pH, vagaries of weather especially precipitation, the species distribution, the species density, as well as the number of acres treated, would affect the number of organisms actually exposed, the concentrations and durations of the exposures, and their consequences. .

Furthermore, the quotient does not provide a definitive value for the amount of pesticide that will be available to fish or aquatic invertebrates. The actual amount of pesticide available will vary depending on application method, configuration and calibration of equipment, and specific field conditions.

In order to provide industry and the public with clear standards for ecological risk assessment and management that can be applied in an equitable fashion and to facilitate ecological risk comparisons, the Agency established levels of concern (LOC's) for ecological effects of pesticides on fish and aquatic invertebrates [2]. These LOC's are criteria used by the Agency to indicate potential risk to non-target organisms and the need for a regulatory action. Exceeding the criteria indicates that a pesticide, when used as directed, has the potential to cause undesirable effects on non-target fish and aquatic invertebrates.

There are two general categories of LOC's for fish and aquatic invertebrates, acute and chronic. In order to determine if an LOC has been exceeded, first a risk quotient must be calculated and then compared to the appropriate LOC. When the risk quotient exceeds the LOC for a particular category, risk to that particular category is presumed to exist. The LOC's for fish and aquatic invertebrates used in this analysis plus the corresponding risk presumptions are as follows:

ENDPOINT	LOC	PRESUMPTION
Acute RQ $\geq$	0.5	High Acute Risk
Chronic RQ $\geq$	1.0	High Chronic Risk

The specific equations used to calculate the risk quotients for acute and chronic risk to fish and aquatic invertebrates used in this analysis follow. Calculations using these equations were conducted for all of the pesticides use site combinations. Exposure values were modeled using the maximum and one-half the maximum use rates. Five acute RQs (acute freshwater fish RQs (EEC/LC_{50}), acute marine/estuarine fish RQs (EEC/LC_{50}), acute freshwater invertebrate RQs (EEC/EC_{50}), acute marine/estuarine crustacean RQs (EEC/EC_{50}), and acute marine/estuarine mollusc RQs (EEC/EC_{50})), and two chronic RQs (chronic freshwater fish and chronic freshwater invertebrate EEC/NOAEC)) were calculated for both granular and spray formulations. Four quotients were calculated for each pesticide use site combination for acute freshwater fish and aquatic invertebrate endpoints, reflecting the combinations of maximum and one-half the maximum use rates with the lowest and median LC_{50} or EC_{50} values. Two quotients were calculated for the other endpoints, reflecting the two use rate assumptions and the lowest LC_{50} or EC_{50} values.

A. Calculation of the Acute Fish & Aquatic Invertebrate Risk Quotients

1. Acute Freshwater Fish Risk

The *freshwater fish acute risk quotient* is calculated using equation (9).

$$(9)\quad \frac{\text{EEC (ppb in pond water; peak)}}{LC_{50}\text{ (ppb)}} = \text{Risk Quotient}$$

This equation describes acute freshwater fish risk as a quotient of the concentration of toxicant likely to occur in ponds adjacent to pesticide applications as estimated by the GENEEC model, to the acute freshwater fish toxicity value (expressed as an LC_{50}). The result is an expression of acute risk to freshwater fish in terms of concentration exposed to concentration tested.

Appendix 22 lists the freshwater fish risk quotient calculations for all pesticide use site combinations. The results are presented in order of descending risk quotients by crop.

2. Acute Marine/Estuarine Fish Risk

The *marine/estuarine fish acute risk quotient* is calculated using equation (9). This equation describes acute marine/estuarine fish risk as a quotient of the concentration of toxicant likely to occur in estuarine areas adjacent to pesticide applications as estimated by the GENEEC model, to the acute marine/estuarine fish toxicity value (expressed as an LC_{50}). The pond values are used as a rough approximation of pesticide concentrations in the estuarine environment. The result is an expression of acute risk to marine/estuarine fish in terms of concentration exposed to concentration tested.

Appendix 23 lists the marine/estuarine fish risk quotient calculations for all pesticide use site combinations. The results are presented in order of descending risk quotients by crop.

3. Acute Freshwater Invertebrate Risk

The *freshwater invertebrate acute risk quotient* is calculated using equation (10).

$$(10) \quad \frac{\text{EEC (ppb in pond water; peak)}}{EC_{50} \text{ (ppb)}} = \text{Risk Quotient}$$

This equation describes acute freshwater invertebrate risk as a quotient of the concentration of toxicant likely to occur in ponds adjacent to pesticide applications as estimated by the GENEEC model, to the acute freshwater invertebrate toxicity value (expressed as an EC_{50}). The result is an expression of acute risk to freshwater invertebrate in terms of concentration exposed to concentration tested.

Appendix 24 lists the freshwater invertebrate risk quotient calculations for all pesticide use site combinations. The results are presented in order of descending risk quotients by crop.

4. Acute Marine/Estuarine Crustacean Risk

The *marine/estuarine crustacean acute risk quotient* is calculated using equation

(10). This equation describes acute marine/estuarine crustacean risk as a quotient of the concentration of toxicant likely to occur in estuarine areas adjacent to pesticide applications as estimated by the GENEEC model, to the acute marine/estuarine crustacean toxicity value (expressed as an EC_{50}). The pond values are used as a rough approximation of pesticide concentrations in the estuarine environment. The result is an expression of acute risk to marine/estuarine crustaceans in terms of concentration exposed to concentration tested.

Appendix 25 lists the marine/estuarine crustacean risk quotient calculations for all pesticide use site combinations. The results are presented in order of descending risk quotients by crop.

5. Acute Marine/Estuarine Mollusc Risk

The *marine/estuarine mollusc acute risk quotient* is calculated using equation (11). This equation describes acute marine/estuarine mollusc risk as a quotient of the concentration of toxicant likely to occur in estuarine areas adjacent to pesticide applications as estimated by the GENEEC model, to the acute marine/estuarine mollusc toxicity value (expressed as an EC_{50}). The pond values are used as a rough approximation of pesticide concentrations in the estuarine environment. The result is an expression of acute risk to marine/estuarine molluscs in terms of concentration exposed to concentration tested.

Appendix 26 lists the marine/estuarine mollusc risk quotient calculations for all pesticide use site combinations. The results are presented in order of descending risk quotients by crop.

B. Calculation of the Chronic Fish & Aquatic Invertebrate Risk Quotients

1. Chronic Freshwater Fish Risk

The *freshwater fish chronic quotient* is calculated using equation (11).

$$(11)\quad \frac{\text{EEC (ppb in pond water; 56-day average)}}{\text{NOAEC (ppb)}} = \text{Risk Quotient}$$

This equation describes chronic freshwater fish risk as a quotient of the concentration of toxicant likely to occur in ponds adjacent to pesticide applications as estimated by the GENEEC model, to the chronic freshwater fish toxicity value (expressed as an NOAEC). The result is an expression of chronic risk to freshwater fish in terms of concentration exposed to concentration tested.

Appendix 27 lists all chronic freshwater fish risk quotient calculations for all pesticide use site combinations.

2. Chronic Freshwater Invertebrate Risk

The *freshwater invertebrate chronic quotient* is calculated using equation (12).

$$(12)\quad \frac{\text{EEC (ppb in pond water; 21-day average)}}{\text{NOAEC (ppb)}} = \text{Risk Quotient}$$

This equation describes chronic freshwater invertebrate risk as a quotient of the concentration of toxicant likely to occur in ponds adjacent to pesticide applications as estimated by the GENEEC model, to the chronic freshwater invertebrate toxicity value (expressed as an NOAEC). The result is an expression of chronic risk to freshwater invertebrates in terms of concentration exposed to concentration tested.

Appendix 28 lists all chronic freshwater invertebrate risk quotient calculations for all pesticide use site combinations.

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A. The Aquatic Risk Column - % Pesticide Contribution to RQ Sum for Each Endpoint on Each Site (Crop)

When comparing pesticides using RQs, the RQ scales for each endpoint are an important consideration. As shown below, the scales for the four aquatic endpoints vary widely (pesticide and use site for the highest values are presented parenthetically):

Acute Freshwater Fish (EEC/LC_{50})	0 to 443	[Chemical B on Cotton]
Acute Marine/Estuarine Fish (EEC/LC_{50})	0 to 50	[Chemical B on Cotton]
Acute Freshwater Invertebrate (EEC/EC_{50})	0 to 4979	[Chemical G on Cotton]
Acute Marine/Estuarine Crustacea (EEC/EC_{50})	0 to 830	[Chemical G on Cotton]
Acute Marine/Estuarine Mollusc (EEC/EC_{50})	0 to 249	[Chemical G on Cotton]
Chronic Freshwater Fish (EEC/NOAEC)	0 to 334	[Chemical B on Cotton]
Chronic Freshwater Invertebrate (EEC/NOAEC)	0 to 22494	[Chemical G on Cotton]

These differences raise many questions. For example: Should we be more concerned with chronic and acute freshwater invertebrate risk than the others, especially acute marine/estuarine fish risk? Is the magnitude of the chronic freshwater invertebrate risk approximately 450 times greater than the acute marine/estuarine fish risk for pesticides used on cotton? It would be easier to compare aquatic risk between pesticides without having to deal with these scale differences.

With the above information in mind, the Agency focused on each crop site. It assumed that all the potential risk for a particular endpoint on a particular crop site could be represented by the sum of the RQ values that exceeded the LOC for all the pesticides used on that crop site. If the RQ values for that endpoint for each pesticide used on that crop site were summed, then the quotient of the sum of the individual pesticide RQs over the sum of all the RQs for all the pesticides, would represent the percent (%) contribution of each pesticide to the total risk for that endpoint on that site. See equation (8) again.

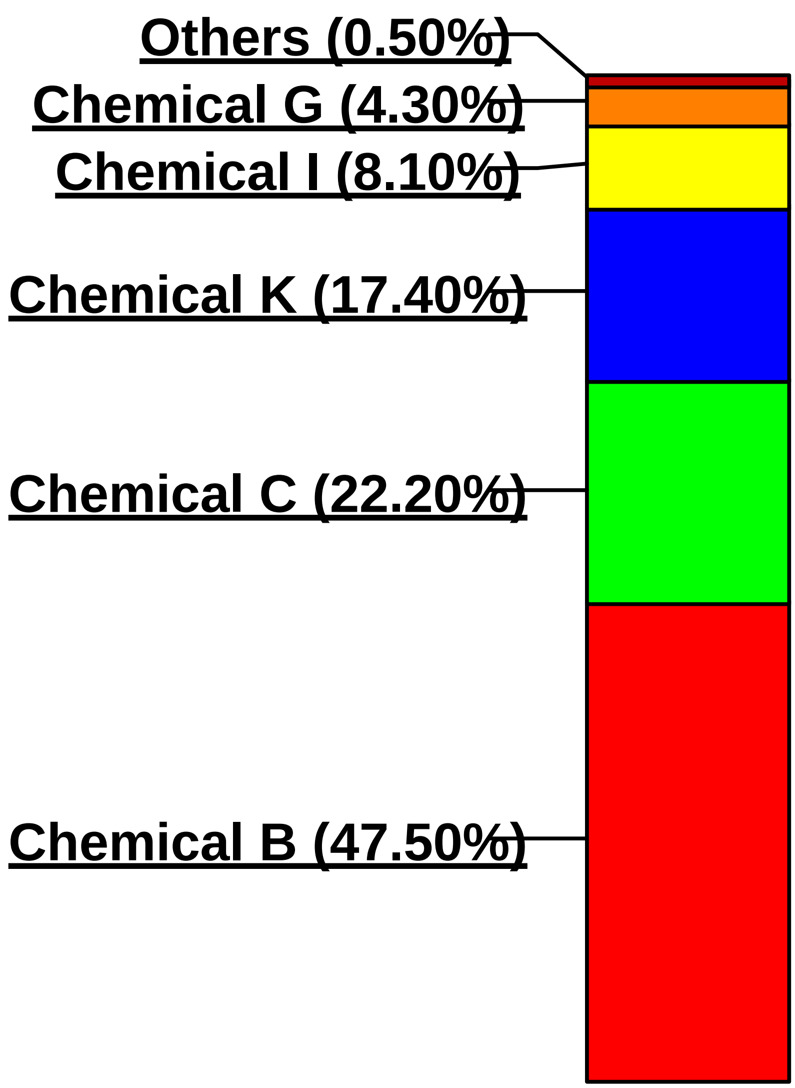
$$\frac{\sum \text{endpoint RQ values/pesticide/crop site}}{\sum \text{ endpoint RQ values for all pesticides/crop site}} \times 100 = \text{\% Pesticide Contribution to RQ Sum on Each Crop Site}$$

This calculation provides a relative estimate of potential fish or aquatic invertebrate risk per pesticide per aquatic endpoint by which the pesticides can be compared on a crop site basis. The comparison is relative to the total risk for each endpoint and on each crop, represented by the sum of the RQ values which exceed the LOCs. It eliminates the problem of widely varying scales. Appendices 22a, 23a, 24a, 25a, 26a, 27a, and 28a, show these calculations for acute freshwater fish risk, acute marine/estuarine fish risk, acute freshwater invertebrate risk, acute marine/estuarine crustacean risk, acute marine/estuarine mollusc risk, chronic freshwater fish risk, and chronic freshwater invertebrate risk, respectively.

If all the aquatic risk per endpoint can be represented by the sum of all the RQ values exceeding the LOC for that endpoint, the total risk can be viewed as a column. Each pesticide used on that site contributes a certain percentage toward filling the column. The major contributors to the total risk can be determined by showing the individual percentages (See example in Figure 2).

Figure 2. Aquatic Risk

Acute Freshwater Fish Risk on Alfalfa



In this example, Chemical B contributes the greatest potential acute freshwater fish risk on alfalfa, followed by Chemical C and Chemical K. Chemical I and Chemical G contribute a combined total of 12.4%. Other Chemicals used on alfalfa contribute less than 1%.

D. Frequency (%) of LOC Exceedance

Where the risk quotients can provide an indicator of the magnitude of potential aquatic risk, considering how often a risk quotient exceeds an LOC can provide an indicator of the frequency of the potential risk. Four acute freshwater fish risk quotients were calculated for each pesticide/use combination (See Appendix 22); two acute marine/estuarine fish risk quotients were calculated for each pesticide/use combination (See Appendix 23); four acute freshwater invertebrate risk quotients were calculated for each pesticide/use combination (See Appendix 24); and, two acute marine/estuarine crustacean risk quotients were calculated for each pesticide/use combination (See Appendix 25); two acute marine/estuarine mollusc risk quotients were calculated for each pesticide/use combination (See Appendix 26); two chronic freshwater fish risk quotients were calculated for each pesticide/use combination (See Appendix 27); and, two chronic freshwater invertebrate risk quotients were calculated for each pesticide/use combination (See Appendix 28). The lowest and median toxicity values were included in the acute freshwater fish and invertebrate risk quotient calculations. Only the lowest toxicity value was available for the other risk quotient calculations. The maximum use rate EEC values and one-half these values were included in all calculations.

Appendices 22b, 23b, 24b, 25b, 26b, 27b, and 28b show how often (%) the calculated acute and chronic risk quotients exceeded the LOC's for each pesticide/use combination and each endpoint analyzed. The pesticides in each appendix were ordered by crop site and by decreasing summed RQ values exceeding the LOC. The higher the frequency (%), the more times the RQ's exceeded the LOC's. This shows the relative frequency with which a pesticide/use combination is likely to exceed an LOC.

VI. COMPARATIVE ECOLOGICAL RISK ANALYSIS

This comparative analysis relies upon readily available data for use in estimating potential risk. Ecotoxicity [5] and environmental fate data were readily available in Agency files and used to calculate risk quotients, % contributions to RQ sums, and frequency (%) of exceeding LOCs. Use information [Appendix 1], such as the number of acres treated by pesticide and crop site, as well as bird and fish incident report data [22] can also be considered in characterizing the potential risk. Together, they can be used to compare the ecological risk of pesticides used on the same crop site.

A. Calculation of Potential Risk (% of Risk)

Up to this point in the analysis, the risk quotients for all the pesticides have been summed for each endpoint on each crop site to arrive at the total calculated risk for each endpoint and each crop site. Next, the percentage contribution of each pesticide use/combination to the total risk has been determined for each endpoint. This will be called the percentage *(%) contribution to the RQ sum*, e.g., % contribution to the RQ sum for avian acute risk, % contribution to the RQ sum for avian chronic risk, % contribution to the RQ sum for acute freshwater fish risk.

Further, the frequency that the calculated risk quotients for each pesticide use/combination exceeded the LOC for each endpoint has been calculated. This will be called the *frequency (%) of exceedance*.

The potential risk (which will be called the percentage *(%) of risk*) for a pesticide use/combination and any endpoint was assumed to be a function of both the % contribution of the RQ sum and the frequency % of exceedance. This is expressed in equation (13).

$$(13)\quad \frac{\text{\% contribution to the RQ sum}}{100\%} \times \frac{\text{frequency (\%) of exceedance}}{100\%} = \text{\% of risk}$$

Thus, the % avian acute risk for Chemical O applied at-plant to corn is equal to the product of the % contribution of the RQ sum for avian acute risk sum and the frequency (%) that the calculated risk quotients exceeded the LOC=0.5.

The avian chronic endpoint presents a slightly different situation. As for the other endpoints, the % contribution to the RQ sum for avian chronic risk was calculated. However, as described above, the Time to RQ=1 was calculated in place of the frequency of exceedance. This calculation better captured the persistence of the pesticide.

Similar to the % contribution to the RQ sum, the % contribution to the Time to RQ=1 was calculated for each pesticide use/combination. The potential avian chronic risk, % avian chronic risk, for a pesticide use/combination was assumed to be the average of the % contribution to the RQ sum and the % contribution to the Time to RQ=1. This is expressed in equation (14).

$$(14)\quad \frac{\text{\% contribution to the RQ sum/100\%} + \text{\% contribution to the Time toRQ=1/100\%}}{2} = \text{\% of avian chronic risk}$$

Most of the pesticides considered in this case study have low NOAEC values and most calculated RQs exceed the LOC=1. Equation (14) assigns greater % avian chronic risk to those pesticides with greater persistence.

B. Percentage (%) Acres Treated

When considering a practical estimate for extent of risk, the pesticide usage information in Appendix 1 provided data on number of acres treated. The acre treatments data incorporated information on multiple applications of the same pesticide on the same site during the year, and best represented the full extent of the use of the pesticide. The % acres treated per pesticide provided an estimate of the extent of the use of a pesticide on a crop site. When comparing pesticides on each crop site, those used at-plant which are primarily granular formulations, and those used as post-emergent sprays were compared separately. It was assumed that pesticides applied at-plant could not substitute for those applied post-emergent, and vice versa.

C. Incident Reports - Bird and Fish Kills

An ecological incident has been defined as an adverse effect on non-target organisms in the environment (Brassard et al., in press [23]); incidents may range from incapacitation to mortality among non-target species. Incident data have been used by the Agency in identifying and confirming ecological risk to non-target organisms. For almost two decades the OPP has collected incident data. Prior to 1991 these data were sporadically provided by state and federal agencies on a limited number of pesticides; however, in 1991 the OPP began to actively solicit data from a variety of sources that include state agencies, registrants (companies responsible for registering pesticides), U.S. Fish and Wildlife Service, the National Biological Survey, and the National Oceanic and Atmospheric Administration. As of early 1998, a total of 4,341 incidents had been reported to OPP; these data were recorded in the Ecological Incident Information System (EIIS) [22]. Incident reports are categorized (certainty index) relative to the likelihood of their being associated with a particular pesticide. Thus, an incident is classified with one of the following certainty indices: highly probable, probable, possible, unlikely, and unrelated. A classification of highly probable indicates the presence of particular chemical residues and/or evidence of a pesticide-specific effect, e.g., cholinesterase inhibition among organophosphorus pesticides. A classification of probable implies direct information linking the pesticide and incident; however, there was no residue data. A certainty index of possible implies that the pesticide was present but several other compounds may also have been implicated. The remaining two classifications, i.e., unlikely and unrelated, imply that there is little to no evidence directly linking a particular pesticide with an incident.

Appendix 29 summarizes the total number of bird and fish kill incidents reported for the 17 pesticides on all sites recorded in the Ecological Incident Information System (EIIS) as of June of 1998. The incident data base was subjected to two selection criteria: (1) that the certainty index was either probable or highly probable, and (2) that the cause of the incident was other than misuse. Incidents that have not been screened or entered into EIIS have not been included in this list. The systems reports a total of 184 bird incidents and 607 fish incidents for these 17 pesticides.

Appendix 30 shows the bird and fish incidents reported for the 17 pesticides on each of the four crop sites. No incidents were reported for peanuts. The reported number of bird incidents for alfalfa, corn and cotton were similar, but primarily due to different pesticides: Chemicals D and G for alfalfa, Chemicals O and Q for corn, and Chemicals B and G for cotton. The site with the greatest number of reported fish incidents was cotton, primarily due to one pesticide, Chemical B. Chemical Q had the greatest number for corn.

The existence of highly probable and probable incident reports tends to add a weight of certainty to the acute risk concerns indicated by the LOC exceedances for acute risk to birds and fish. Reported incidents for pesticide use\combinations with LOC exceedances tend to confirm the prediction of mortality based on the acute risk quotients calculated using laboratory eco-toxicity data and exposure estimates using models. Due to the fact that the incident data base is still in development, the lack of reported incidents does not reduce the certainty of risk for pesticide/uses with risk quotients that exceed the LOC.

D. Comparison of Potential Risk by Crop Site

The % of risk for each endpoint was calculated and compared for each pesticide used on a crop site . At-plant applications of pesticides , primarily granular formulations, were compared separately from post-emergent spray applications of pesticides. Further, it seemed best to compare avian endpoints (four) and aquatic endpoints (7) separately. It also seemed helpful to compare the pesticides in order of decreasing % acres treated to add the element of extent of use to the comparison. Finally, if any bird and/or fish incidents have been reported, the number of bird and fish incidents was indicated for each pesticide, again in order of decreasing % acres treated. In addition, the percentage (%) of the total number of incidents reported in EIIS for each site was calculated to provide some perspective on the importance of kills for a pesticide relative to crop site.

1. Alfalfa - Post-Emergent Spray Formulations

Figure 3 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for the pesticides used as post-emergent sprays on alfalfa. Table 5 shows the data included in Figure 3. There was only one granular at-plant use reported for alfalfa, and that was for Chemical C. The Chemical C label also included post-emergent sprays. Consequently, for this analysis, we assumed that most of the Chemical C was used as post-emergent sprays. Figures 3a, b, and c show individual graphs for comparative avian risk, aquatic risk and the incident reports for pesticides used as post-emergent sprays on alfalfa.

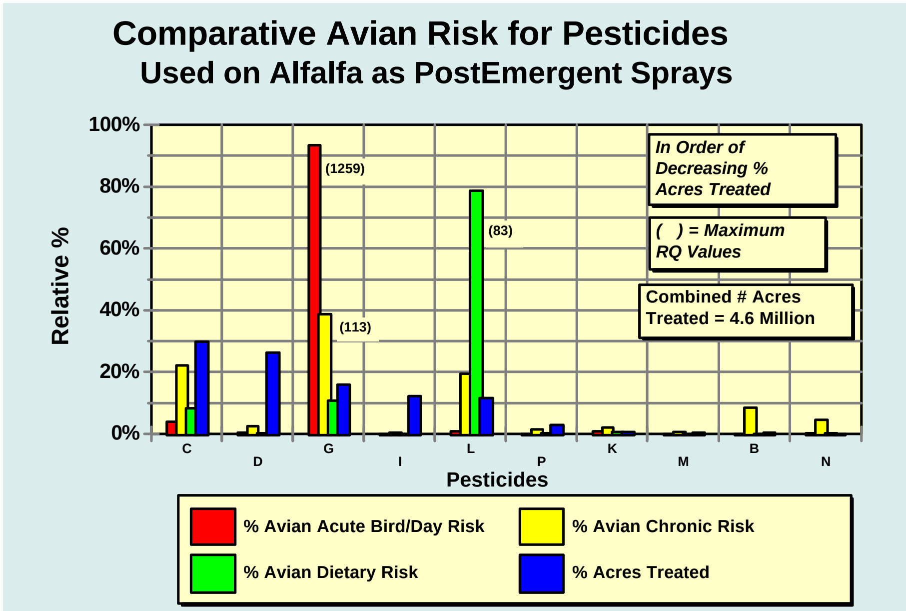
The total combined use for these pesticides is 4.6 million treated acres. Chemical C and Chemical D lead with greater than 20% each followed by Chemical G, Chemical I, and Chemical L at greater than 10% each.

Comparing avian risk, Chemical G leads with the greatest % avian acute bird/day risk and % avian chronic risk. Chemical L leads with the greatest % avian dietary risk. Similarly, Chemical G leads the comparative aquatic risk with the greatest % freshwater fish chronic risk, % freshwater invertebrate acute risk, and the % freshwater invertebrate chronic risk, % marine/estuarine crustacean acute risk, and % marine/estuarine mollusc acute risk. However, Chemical B has the greatest % freshwater fish acute risk, and Chemical C has the greatest % marine/estuarine fish acute risk.

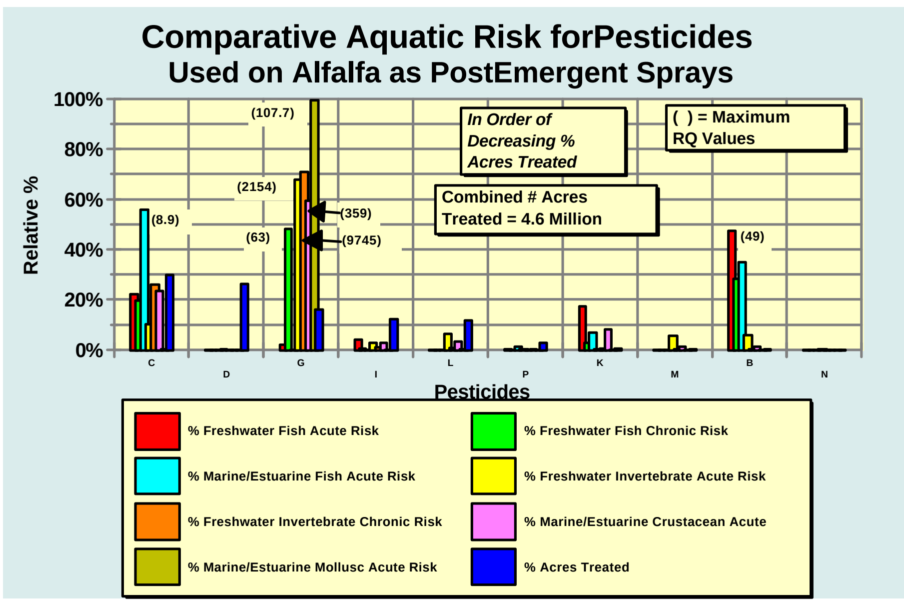
Incidents have been reported for birds only, and are limited to Chemical D and Chemical G. The one incident report for Chemical G is not surprising in view of the high % avian acute bird/day risk. However, the three incidents reported for Chemical D, representing 50% of bird incidents reported for Chemical D on all sites, is surprising. The % avian acute bird/day risk is comparatively very low. Additional information is needed to attempt to characterize these incidents.

In summary for postemergent sprays on alfalfa, Chemical G stands out as presenting the greatest potential acute and chronic risk to birds, and aquatic invertebrates, and chronic risk to fish. The acute risk to birds appears to be supported by and incident report. Chemical B presents the greatest acute risk to freshwater fish, Chemical C presents the greatest acute risk to marine/estuarine fish, and Chemical L presents the greatest dietary risk to birds. The bird incident reports raises a question concerning the comparatively low risk of Chemical D to birds. Overall, Chemical N, Chemical M, and Chemical P appear to be comparatively less risky than the others.

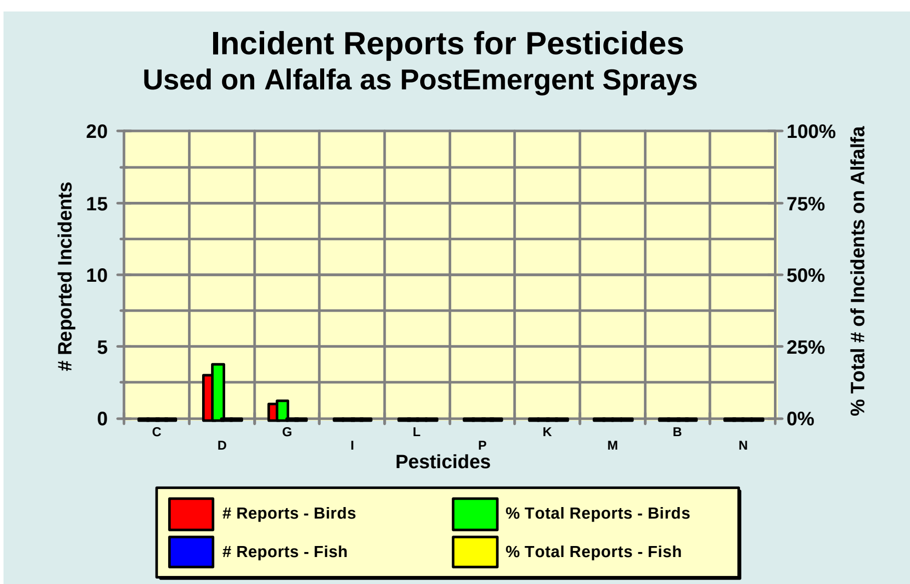
Figure 3



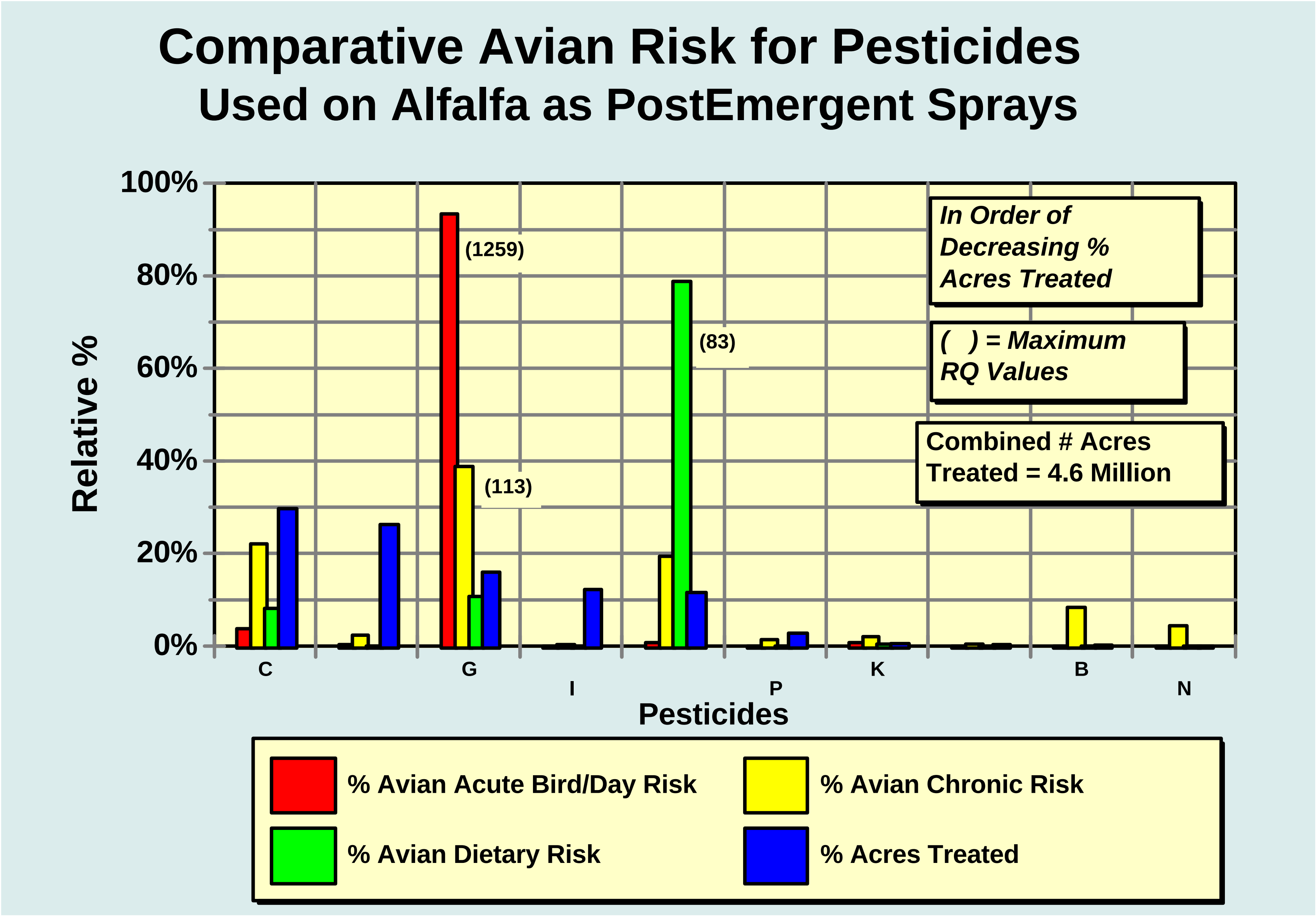
Comparative Avian Risk for Pesticides
Used on Alfalfa as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
(1259)
(113)
(83)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 4.6 Million
C
D
G
I
L
P
K
M
B
N
Pesticides
% Avian Acute Bird/Day Risk
% Avian Chronic Risk
% Avian Dietary Risk
% Acres Treated



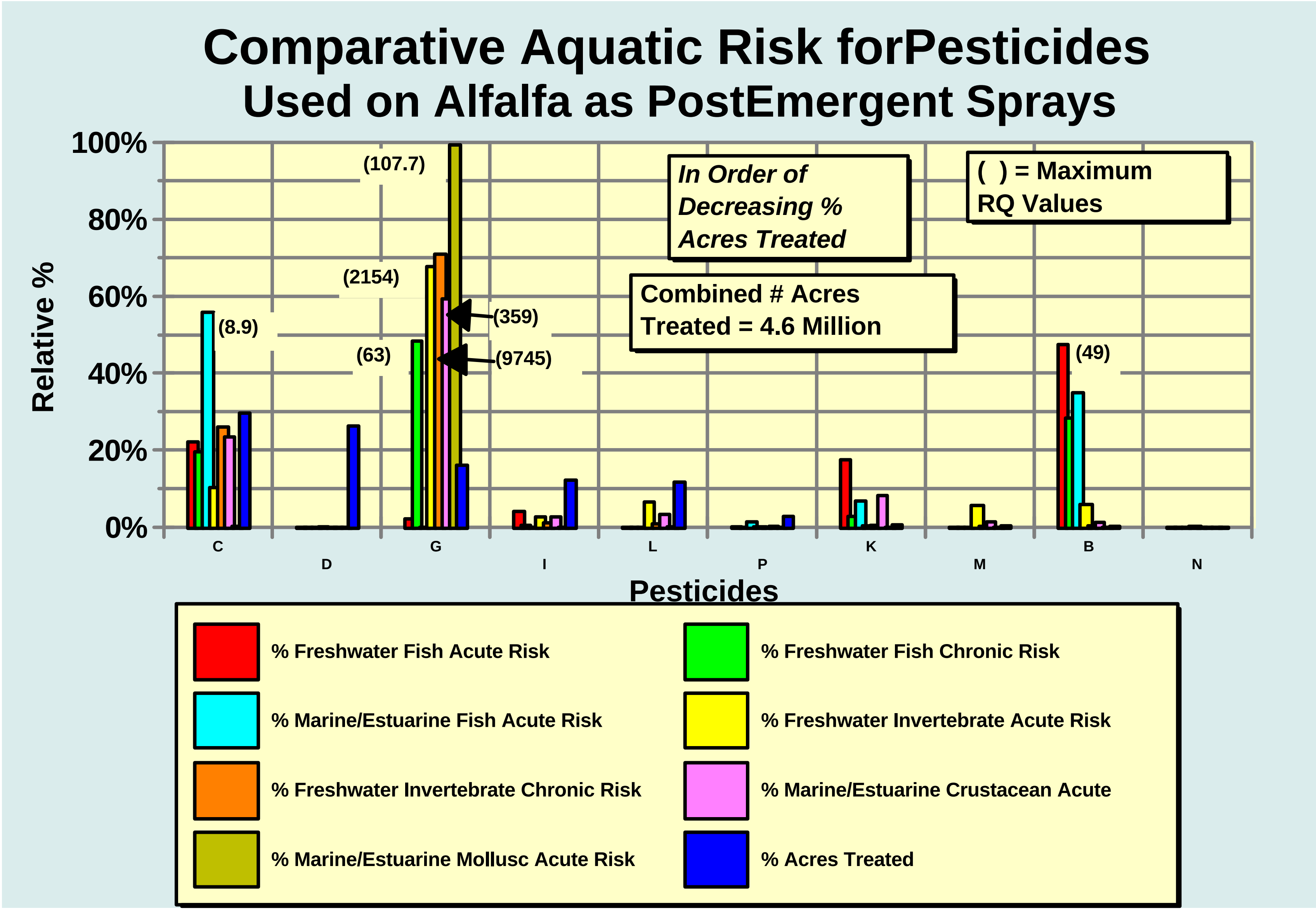
Comparative Aquatic Risk forPesticides
Used on Alfalfa as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
(107.7)
(2154)
(8.9)
(63)
(359)
(9745)
(49)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 4.6 Million
C
D
G
I
L
P
K
M
B
N
Pesticides
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Risk
% Marine/Estuarine Crustacean Acute
% Marine/Estuarine Mollusc Acute Risk
% Acres Treated



Incident Reports for Pesticides
Used on Alfalfa as PostEmergent Sprays
Reported Incidents
20
15
10
5
0
% Total # of Incidents on Alfalfa
100%
75%
50%
25%
0%
C
D
G
I
L
P
K
M
B
N
Pesticides
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish



Comparative Avian Risk for Pesticides
Used on Alfalfa as PostEmergent Sprays
100%
80%
60%
40%
20%
0%
Relative %
(1259)
(113)
(83)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 4.6 Million
C
G
I
P
K
B
N
Pesticides
% Avian Acute Bird/Day Risk
% Avian Chronic Risk
% Avian Dietary Risk
% Acres Treated


Comparative Aquatic Risk forPesticides
Used on Alfalfa as PostEmergent Sprays
100%
80%
60%
40%
20%
0%
Relative %
(107.7)
(2154)
(8.9)
(63)
(359)
(9745)
(49)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 4.6 Million
C
D
G
I
L
P
K
M
B
N
Pesticides
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Risk
% Marine/Estuarine Crustacean Acute
% Marine/Estuarine Mollusc Acute Risk
% Acres Treated

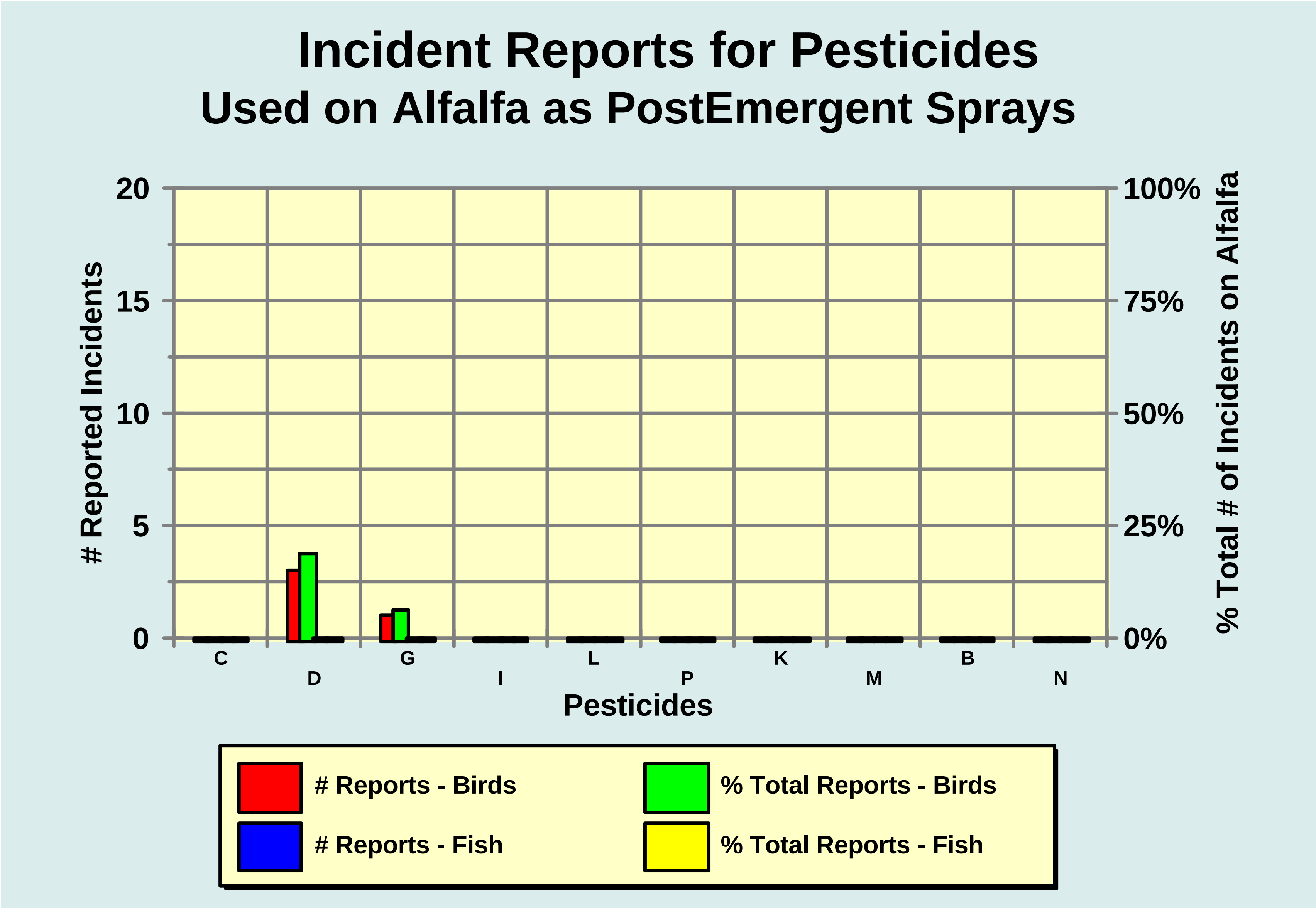

Incident Reports for Pesticides
Used on Alfalfa as PostEmergent Sprays
Reported Incidents
20
15
10
5
0
100%
75%
50%
25%
0%
% Total # of Incidents on Alfalfa
C
D
G
I
L
P
K
M
B
N
Pesticides
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish

Table 5. Data for Figure 3
Pesticides Used on Alfalfa as Post-Emergent Sprays

Birds

Chemical Name	% Avian Acute Bird/Day Risk	% Avian Chronic Risk	% Avian Dietary Risk	% Acres Treated
C	3.9%	22.1%	8.2%	29.7%
D	0.4%	2.3%	0.1%	26.3%
G	93.3%	38.8%	10.7%	16.0%
I	0.0%	0.4%	0.0%	12.2%
L	0.9%	19.5%	78.8%	11.6%
P	0.0%	1.5%	0.1%	2.8%
K	0.8%	2.1%	0.5%	0.6%
M	0.0%	0.5%	0.0%	0.4%
B	0.0%	8.4%	0.0%	0.3%
N	0.1%	4.5%	0.1%	0.0%

Aquatic Organisms

Chemical Name	% Freshwater Fish Acute Risk	% Freshwater Fish Chronic Risk	% Marine/Estuarine Fish Acute Risk	% Freshwater Invertebrate Acute Risk	% Freshwater Invertebrate Chronic Risk	% Marine/Estuarine Crustacean Acute Risk	% Marine/Estuarine Mollusc Acute Risk	% Acres Treated
C	22.2%	19.6%	55.8%	10.3%	26.0%	23.5%	0.2%	29.7%
D	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	26.3%
G	2.1%	48.3%	0.0%	67.7%	70.9%	59.4%	99.2%	16.0%
I	4.0%	0.4%	0.0%	2.7%	1.1%	2.7%	0.0%	12.2%
L	0.0%	0.0%	0.0%	6.5%	0.8%	3.3%	0.2%	11.6%
P	0.1%	0.0%	1.2%	0.1%	0.0%	0.3%	0.0%	2.8%
K	17.4%	2.9%	6.9%	0.3%	0.4%	8.3%	0.0%	0.6%
M	0.0%	0.0%	0.0%	5.7%	0.3%	1.3%	0.0%	0.4%
B	47.5%	28.4%	34.8%	5.9%	0.4%	1.2%	0.0%	0.3%
N	0.0%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%

Incidents

Chemical Name	*# Reports - Birds*	*% Total Reports - Birds*	*# Reports - Fish*	*% Total Reports - Fish*
C	0	0%	0	0%
D	3	50%	0	0%
G	1	3%	0	0%
I	0	0%	0	0%
L	0	0%	0	0%
P	0	0%	0	0%
K	0	0%	0	0%
M	0	0%	0	0%
B	0	0%	0	0%
N	0	0%	0	0%

2. Corn - At-Plant Granular & Post-Emergent Spray Formulations

Granular At-Plant - Figure 4 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as at-plant granular formulations on corn. Table 6 shows the data included in Figure 4. Chemical Q, Chemical C, and Chemical O were used at-plant. We assumed and the labels seemed to support the assumption that there was no overlap between those pesticides used at-plant and those used as post-emergent sprays, i.e., Chemical L, Chemical D, Chemical G, Chemical E, and Chemical I. Figures 4a, b, and c show individual graphs for comparative avian risk, aquatic risk and the incident reports for pesticides used as at-plant granular formulations on corn.

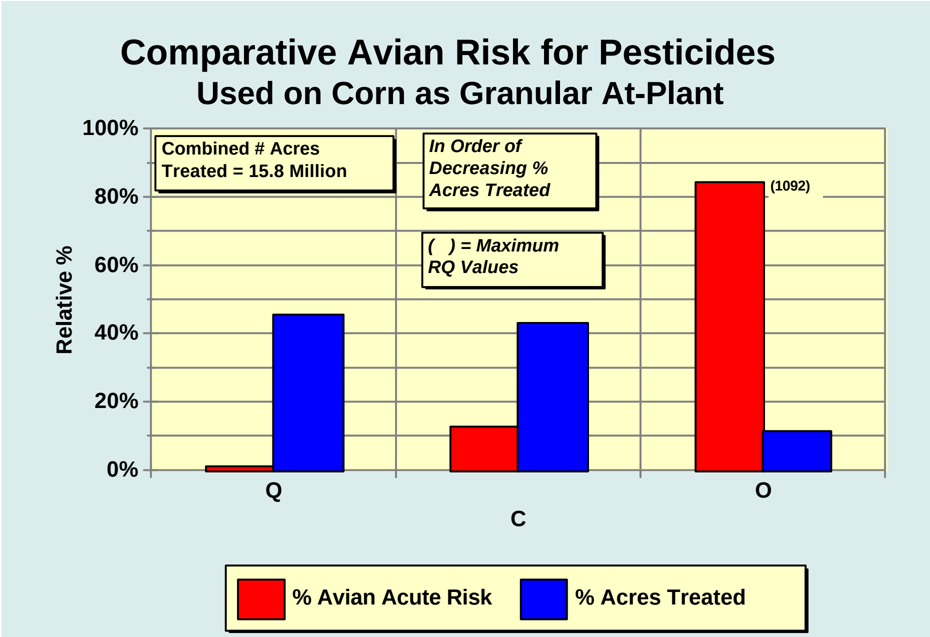
The total combined use for these pesticides is 15.8 million treated acres. Chemical Q and Chemical C lead with greater than 40% each, and followed by Chemical O at approximately 10%.

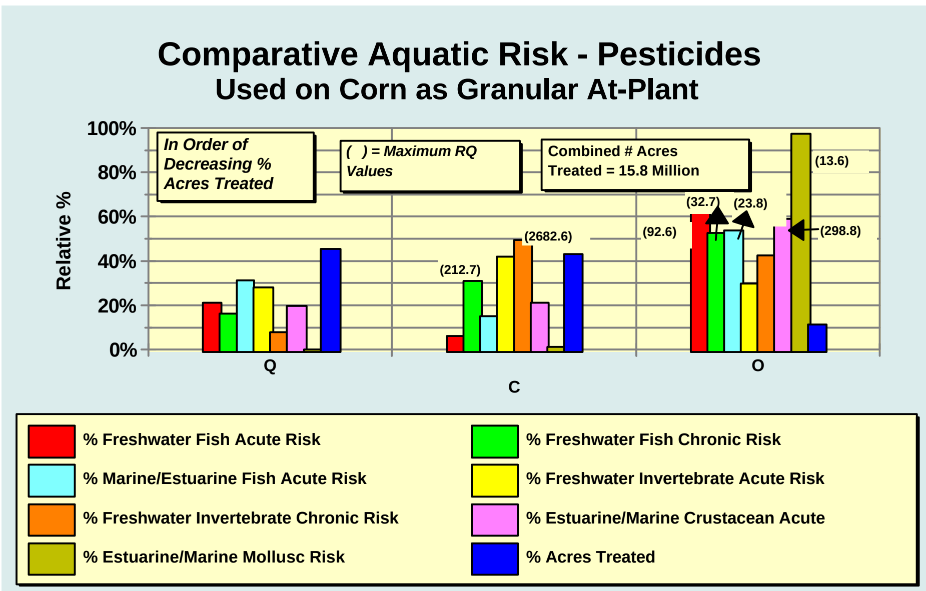
Comparing avian risk, Chemical O leads with the greatest % avian acute risk. This is the only avian risk endpoint compared for granular formulations. Chemical O also leads the comparative aquatic risk with the greatest % risk for five out of the seven endpoints: % freshwater fish acute risk, % freshwater fish chronic risk, % marine/estuarine fish acute risk, % marine/estuarine crustacean acute risk, % marine/estuarine mollusc acute risk. Chemical C leads the comparative aquatic risk with the greatest % risk for two out of the seven endpoints: % freshwater invertebrate acute risk, and the % freshwater invertebrate chronic risk.

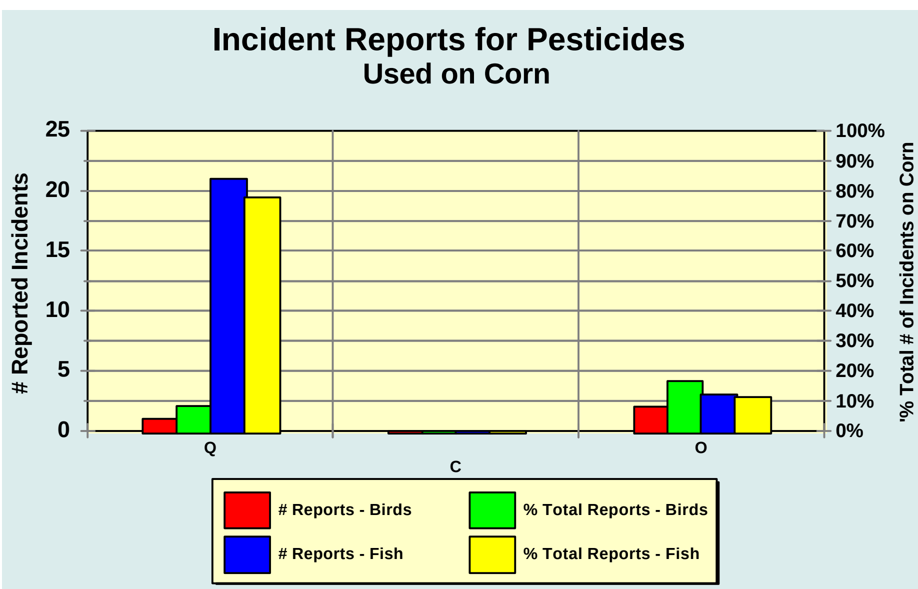
Incidents have been reported for birds and fish for Chemical Q and Chemical O. only. No incidents have been reported for Chemical C. The bird and fish incident reports for Chemical O are not surprising in view of the high acute % risk for birds and fish. The bird and fish incident reports for Chemical Q are probably attributed to the extensive use and may indicate a greater ability to move to water. It is somewhat surprising that there are no reported incidents for Chemical C.

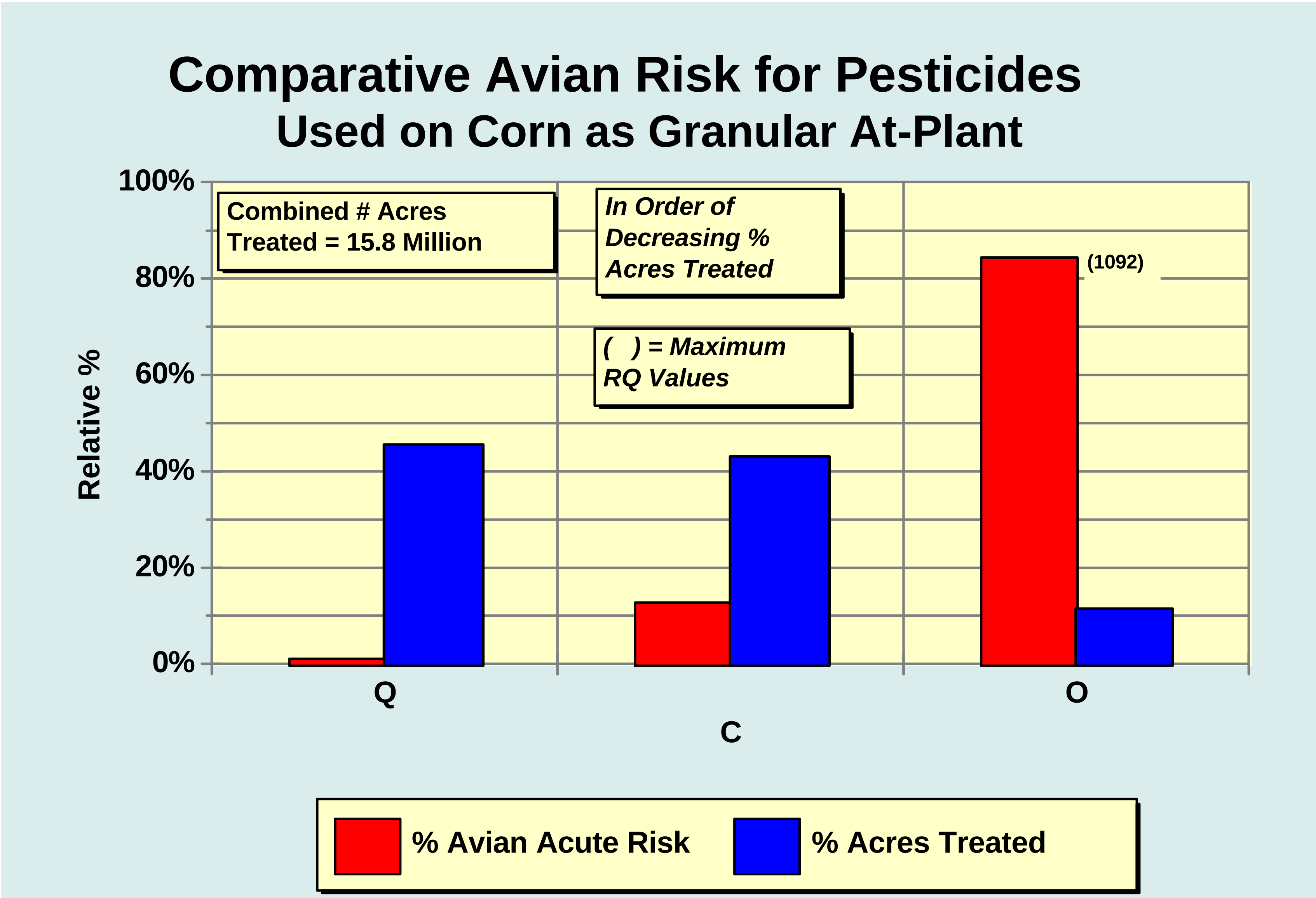
In summary for at-plant granular pesticides on corn, Chemical O stands out as presenting the greatest potential acute risk to birds, as well as to acute and chronic risk to freshwater fish, and acute risk to marine/estuarine crustaceans and molluscs. The acute risk to birds and fish appears to be supported by incident reports. Chemical C presents the greatest acute and chronic risk to aquatic invertebrates. Chemical Q may not present comparatively less acute risk to birds and fish considering the reported incidents.

Figure 4

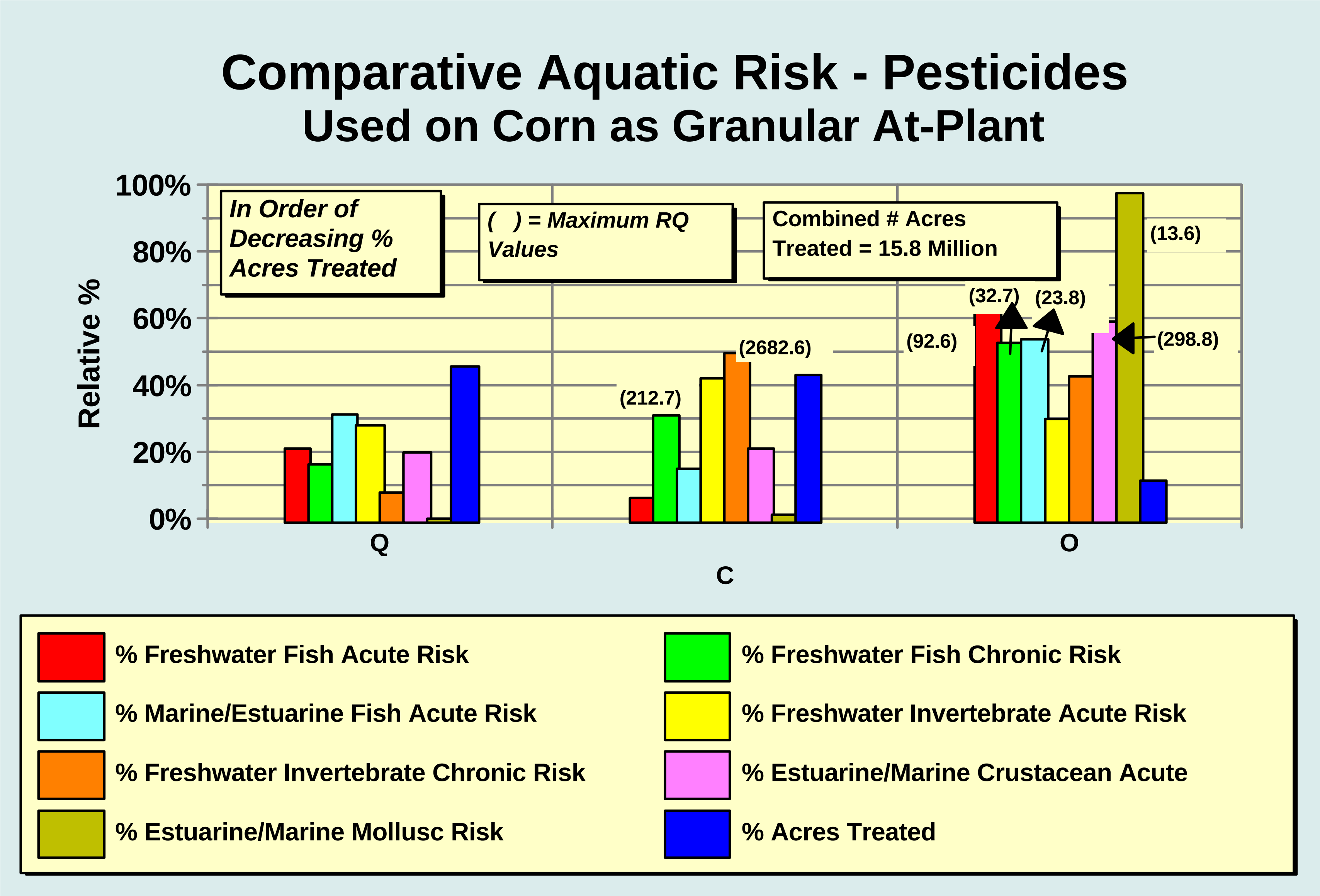

Comparative Avian Risk for Pesticides
Used on Corn as Granular At-Plant
Combined # Acres Treated = 15.8 Million
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
(1092)
Relative %
100%
80%
60%
40%
20%
0%
Q
C
O
% Avian Acute Risk
% Acres Treated

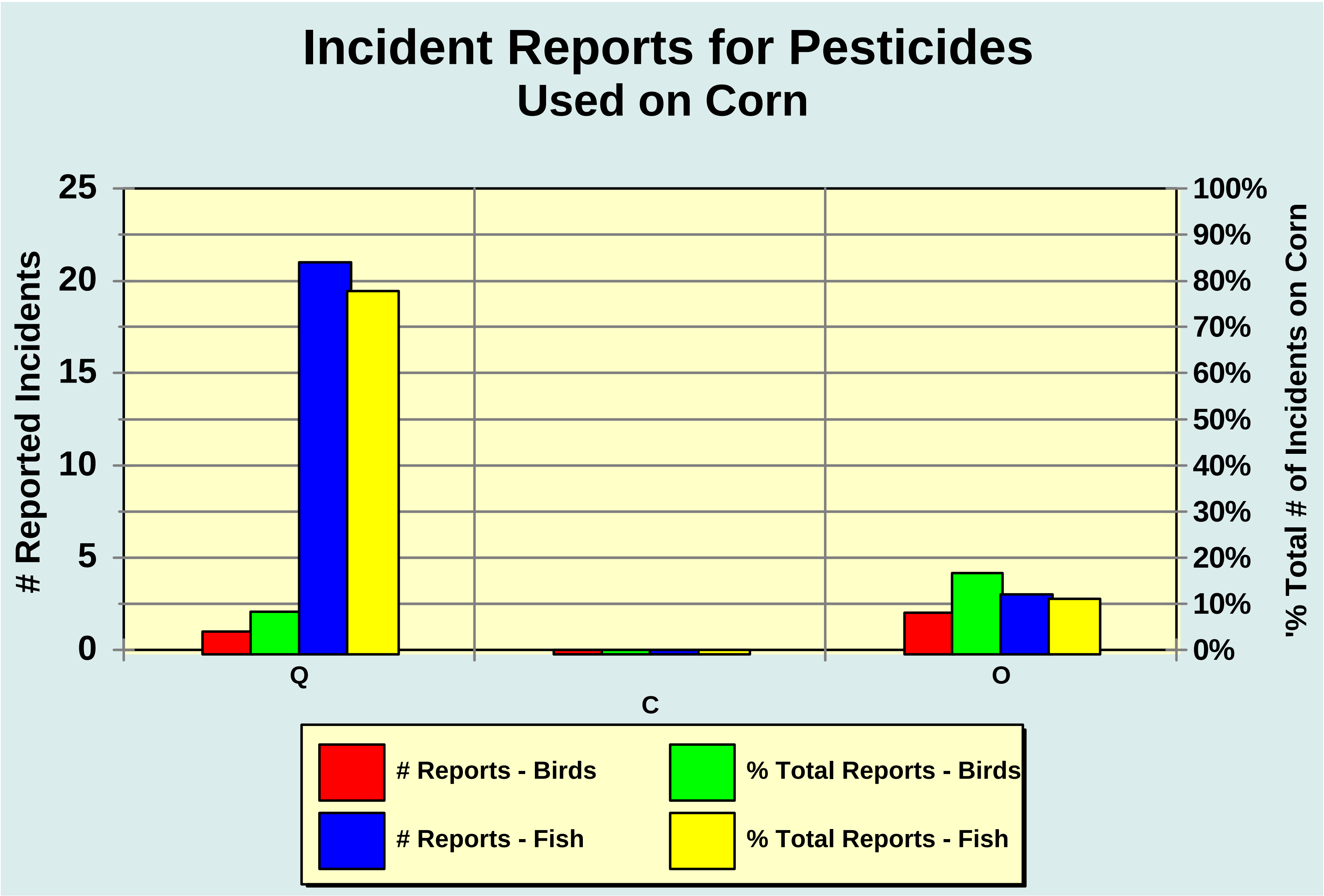

Comparative Aquatic Risk - Pesticides
Used on Corn as Granular At-Plant
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 15.8 Million
(13.6)
(32.7)
(23.8)
(92.6)
(298.8)
(2682.6)
(212.7)
Relative %
100%
80%
60%
40%
20%
0%
Q
C
O
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Risk
% Estuarine/Marine Crustacean Acute
% Estuarine/Marine Mollusc Risk
% Acres Treated


Incident Reports for Pesticides
Used on Corn
Reported Incidents
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Total # of Incidents on Corn
Q
C
O
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish



Comparative Avian Risk for Pesticides
Used on Corn as Granular At-Plant
Combined # Acres Treated = 15.8 Million
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
(1092)
100%
80%
60%
40%
20%
0%
Relative %
Q
C
O
% Avian Acute Risk
% Acres Treated


Comparative Aquatic Risk - Pesticides
Used on Corn as Granular At-Plant
100%
80%
60%
40%
20%
0%
Relative %
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 15.8 Million
(212.7)
(2682.6)
(92.6)
(32.7)
(23.8)
(13.6)
(298.8)
Q
C
O
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Risk
% Estuarine/Marine Crustacean Acute
% Estuarine/Marine Mollusc Risk
% Acres Treated



Incident Reports for Pesticides
Used on Corn
Reported Incidents
25
20
15
10
5
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% Total # of Incidents on Corn
Q
C
O
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish

Table 6. Data for Figure 4
Pesticides Used on Corn as Granular At-Plant Formulations

Birds

Chemical Name	*% Avian Acute Risk*	*% Acres Treated*
Q	1.0%	45.6%
C	12.8%	43.0%
O	84.4%	11.4%

Aquatic Organisms

Chemical Name	*% Freshwater Fish Acute Risk*	*% Freshwater Fish Chronic Risk*	*% Marine/Estuarine Fish Acute Risk*	*% Freshwater Invertebrate Acute Risk*	*% Freshwater Invertebrate Chronic Risk*	*% Marine/Estuarine Crustacean Acute Risk*	*% Marine/Estuarine Mollusc Acute Risk*	*% Acres Treated*
Q	21.1%	16.3%	31.3%	28.0%	7.9%	19.9%	0.0%	45.6%
C	6.3%	31.0%	15.0%	42.1%	49.5%	21.0%	1.2%	43.0%
O	66.3%	52.7%	53.7%	29.9%	42.6%	59.1%	97.5%	11.4%

Incidents

Chemical Name	*# Reports - Birds*	*% Total Reports - Birds*	*# Reports - Fish*	*% Total Reports - Fish*
Q	1	20%	21	46%
C	0	0%	0	0%
O	2	3%	3	75%

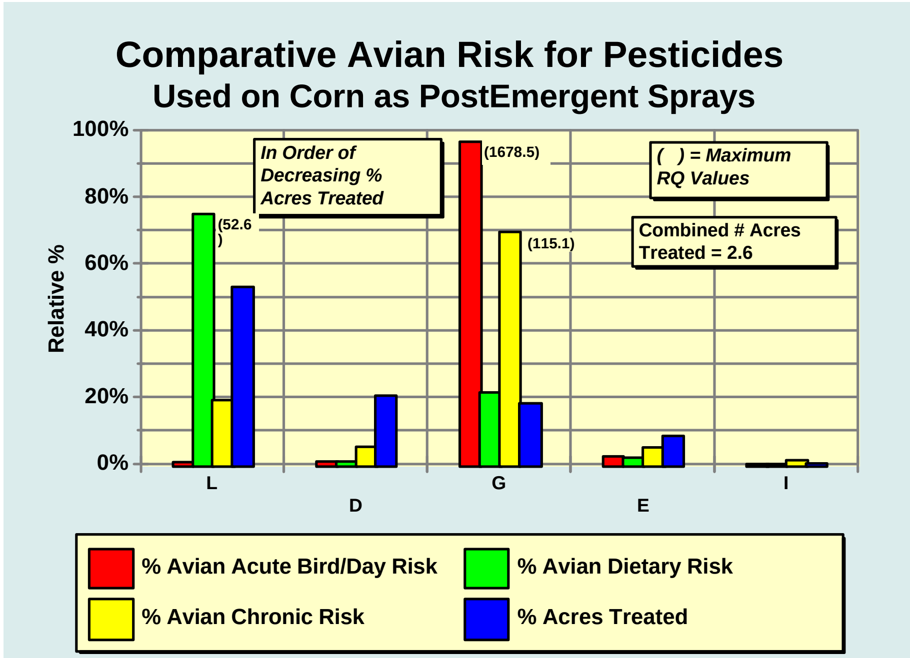
Post-Emergent Sprays - Figure 5 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as post-emergent sprays on corn. Table 7 shows the data included in Figure 5. Chemical L, Chemical D, Chemical G, Chemical E, and Chemical I were used post-emergent sprays. Figures 5a and b show individual graphs for comparative avian risk and aquatic risk for pesticides used as post-emergent sprays on corn. No incidents have been reported for any of the pesticides used as post-emergent sprays on corn.

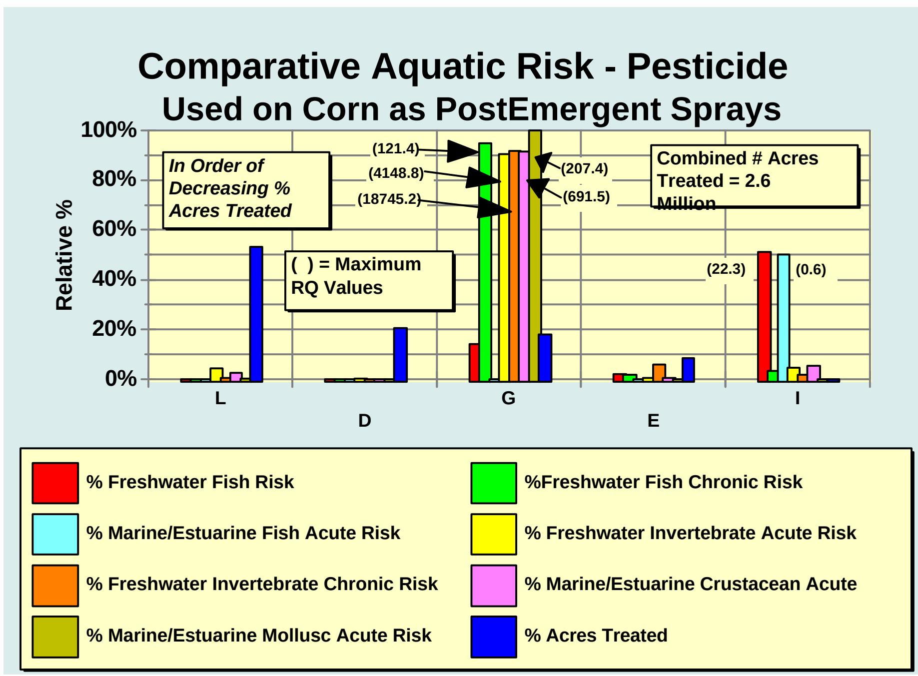
The total combined use for these pesticides is 2.6 million treated acres. Chemical L leads with greater than 50%, and followed by Chemical D at 20% and Chemical G at slightly less than 20%.

Comparing avian risk, Chemical G leads with the greatest % avian acute and chronic risk. Chemical L leads with the greatest % avian dietary risk. Chemical G also leads the comparative aquatic risk with the greatest % risk for five out of the seven endpoints: % freshwater fish chronic risk, % freshwater invertebrate acute risk, % freshwater invertebrate chronic risk, % marine/estuarine crustacean acute risk, % marine/estuarine mollusc acute risk. Chemical I leads the comparative aquatic risk with the greatest % risk for two out of the seven endpoints: % freshwater fish acute risk, % marine/estuarine fish acute risk. It is important to note that the maximum RQ value for the latter is only 0.6, just exceeding the LOC of 0.5.

In summary for post-emergent sprays on corn, Chemical G stands out as presenting the greatest potential acute and chronic risk to birds, as well as to acute and chronic risk to freshwater invertebrates, and acute risk to marine/estuarine crustaceans and molluscs. Chemical L presents the greatest potential avian dietary risk, and Chemical I the same for freshwater fish. Overall, Chemical D and Chemical E appear to be comparatively less risky than the others.

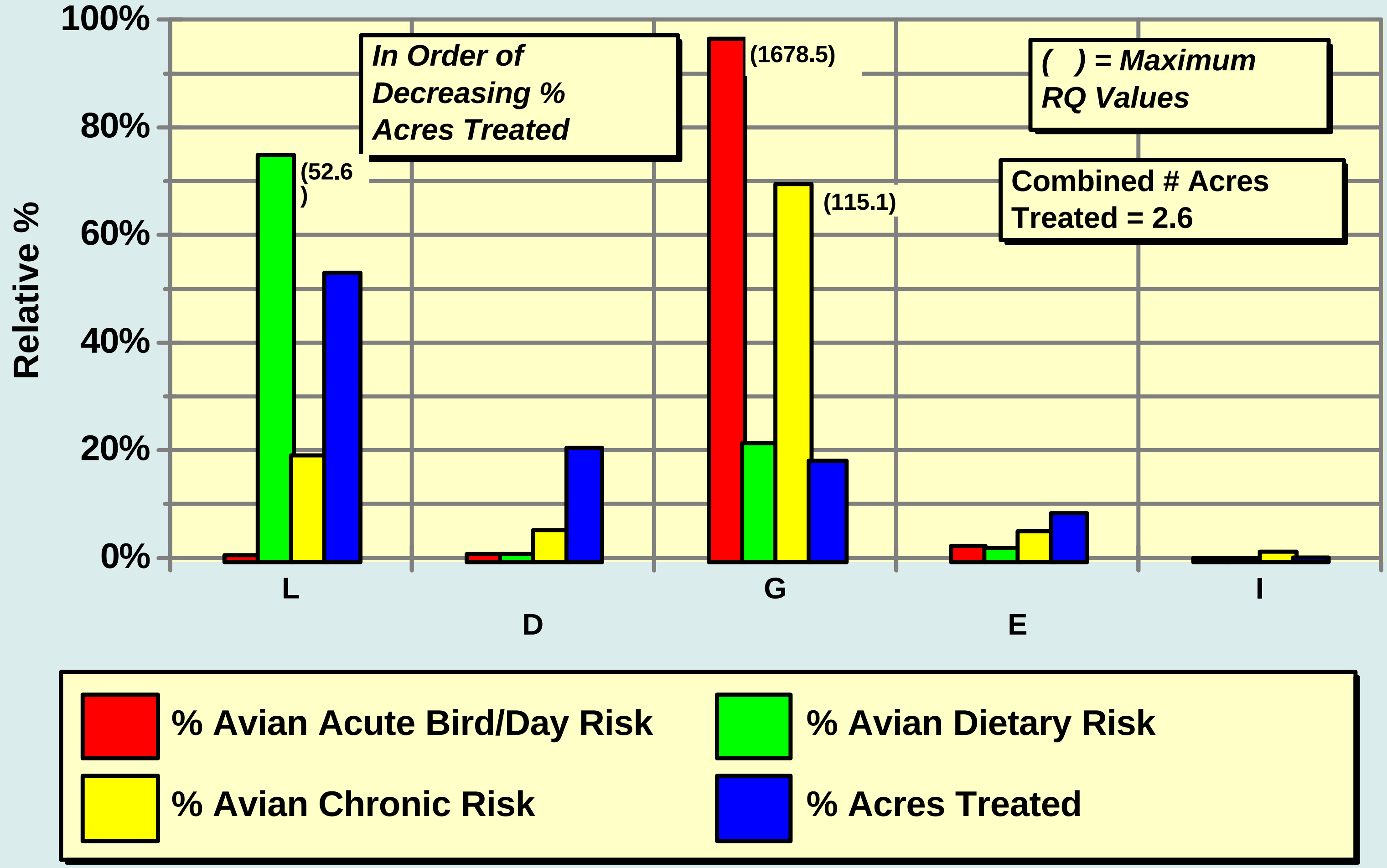
Figure 5





No Incident Reports

Comparative Avian Risk for Pesticides
Used on Corn as PostEmergent Sprays



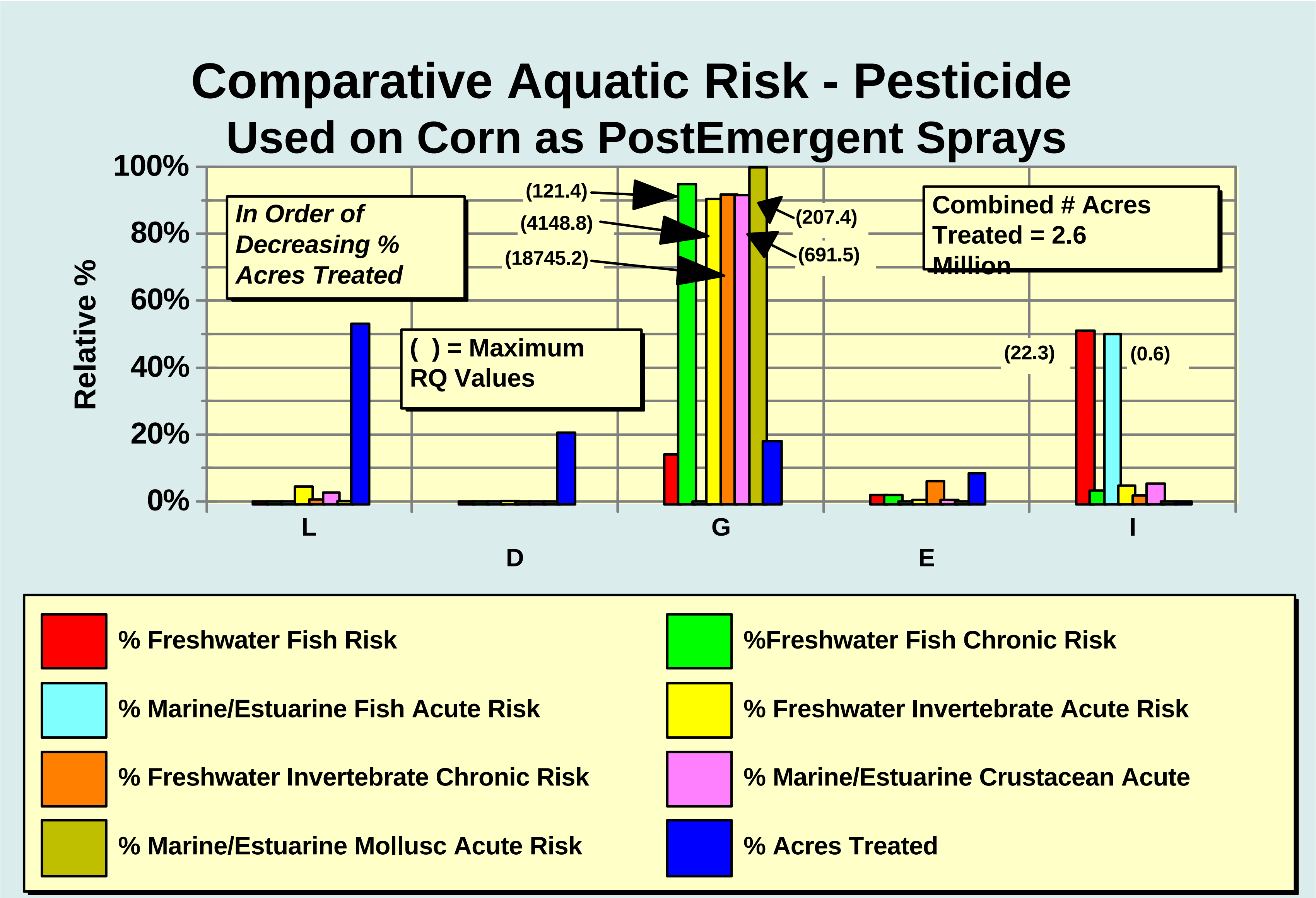

Comparative Aquatic Risk - Pesticide
Used on Corn as PostEmergent Sprays
100%
80%
60%
40%
20%
0%
Relative %
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
(121.4)
(4148.8)
(18745.2)
(207.4)
(691.5)
Combined # Acres Treated = 2.6 Million
(22.3)
(0.6)
L
D
G
E
I
% Freshwater Fish Risk
%Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Risk
% Marine/Estuarine Crustacean Acute
% Marine/Estuarine Mollusc Acute Risk
% Acres Treated

Table 7. Data for Figure 5
Pesticides Used on Corn as Post-Emergent Sprays

Birds

Chemical Name	*% Avian Acute Bird/Day Risk*	*% Avian Dietary Risk*	*% Avian Chronic Risk*	*% Acres Treated*
L	0%	75%	19%	53%
D	1%	1%	5%	20%
G	96%	21%	69%	18%
E	2%	2%	5%	8%
I	0%	0%	1%	0%

Aquatic Organisms

Chemical Name	*% Freshwater Fish Acute Risk*	*% Freshwater Fish Chronic Risk*	*% Marine/Estuarine Fish Acute Risk*	*% Freshwater Invertebrate Acute Risk*	*% Freshwater Invertebrate Chronic Risk*	*% Marine/Estuarine Crustacean Acute Risk*	*% Marine/Estuarine Mollusc Acute Risk*	*% Acres Treated*
L	0%	0%	0%	4%	1%	3%	0%	53%
D	0%	0%	0%	0%	0%	0%	0%	20%
G	14%	95%	0%	90%	92%	92%	100%	18%
E	2%	2%	0%	0%	6%	0%	0%	8%
I	51%	3%	50%	5%	2%	5%	0%	0%

No Incident Reports

3. Cotton - At-Plant Granular & Post-Emergent Spray Formulations

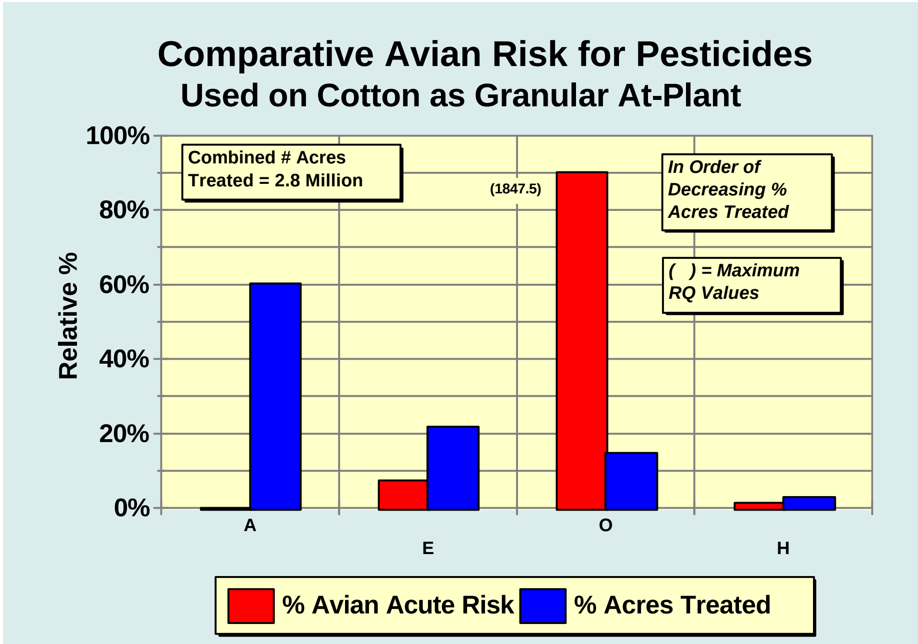
Granular At-Plant - Figure 6 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as at-plant granular formulations on cotton. Table 8 shows the data included in Figure 6. Chemical A, Chemical E, Chemical O, and Chemical H were used at-plant. We assumed and the labels seemed to support the assumption that there was no overlap with the use of Chemical O and Chemical H at-plant and those Chemicals used as post-emergent sprays. However, the remaining Chemicals used on cotton had labels for both at-plant and post-emergent sprays. There was no information separating use by formulation and timing of application. Total use figures were used for both at-plant and post-emergent sprays. Figures 6a and b show individual graphs for comparative avian risk and aquatic risk for pesticides used as at-plant granular formulations on cotton. There were no incident reports for pesticides used at-plant on cotton.

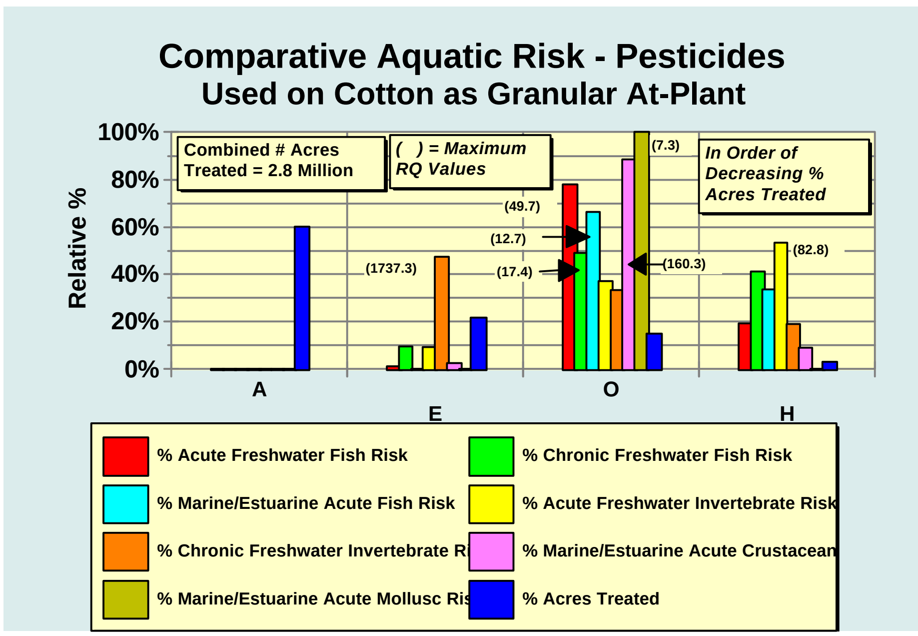
The total combined use for these pesticides is 2.8 million treated acres. Chemical A leads with 60%. Chemical E follows with 22%, and Chemical O is third with 15%.

Comparing avian risk, Chemical O leads with the greatest % avian acute risk. This is the only avian risk endpoint compared for granular formulations. Chemical O also leads the comparative aquatic risk with the greatest % risk for five out of the seven endpoints: % freshwater fish acute risk, % freshwater fish chronic risk, % marine/estuarine fish acute risk, % marine/estuarine crustacean acute risk, % marine/estuarine mollusc acute risk. Chemical H leads the comparative aquatic risk with the greatest % risk for the % freshwater invertebrate acute risk, while Chemical E leads with the greatest % risk for freshwater invertebrate chronic risk.

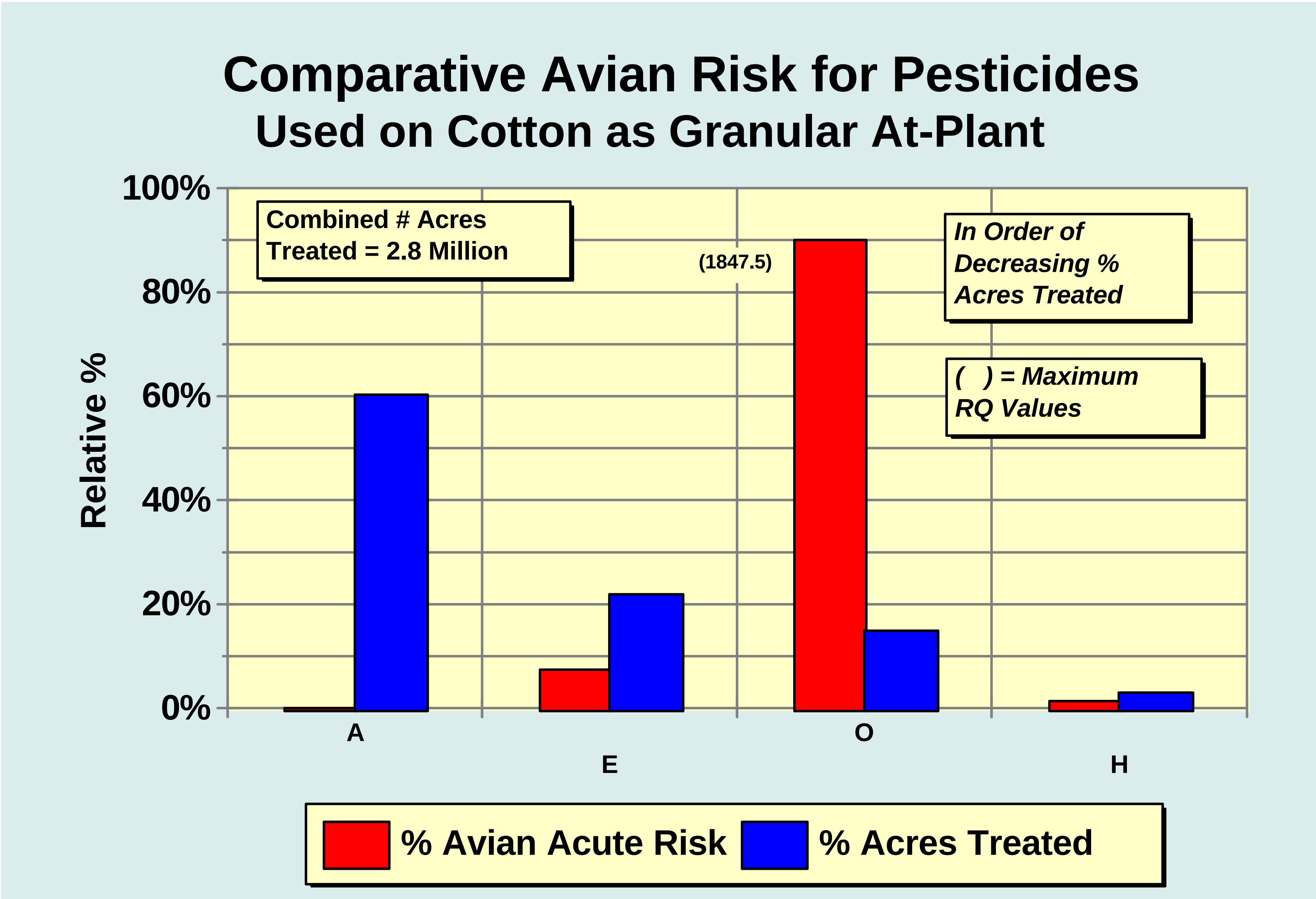
In summary for at-plant granular pesticides on cotton, Chemical O stands out as presenting the greatest potential acute risk to birds, as well as to acute and chronic risk to freshwater fish, and acute risk to marine/estuarine crustaceans and molluscs. Chemical H and Chemical E present the greatest risk freshwater to invertebrates, acute and chronic risk respectively. Overall, Chemical A appears to present comparatively less acute risk to birds and fish.

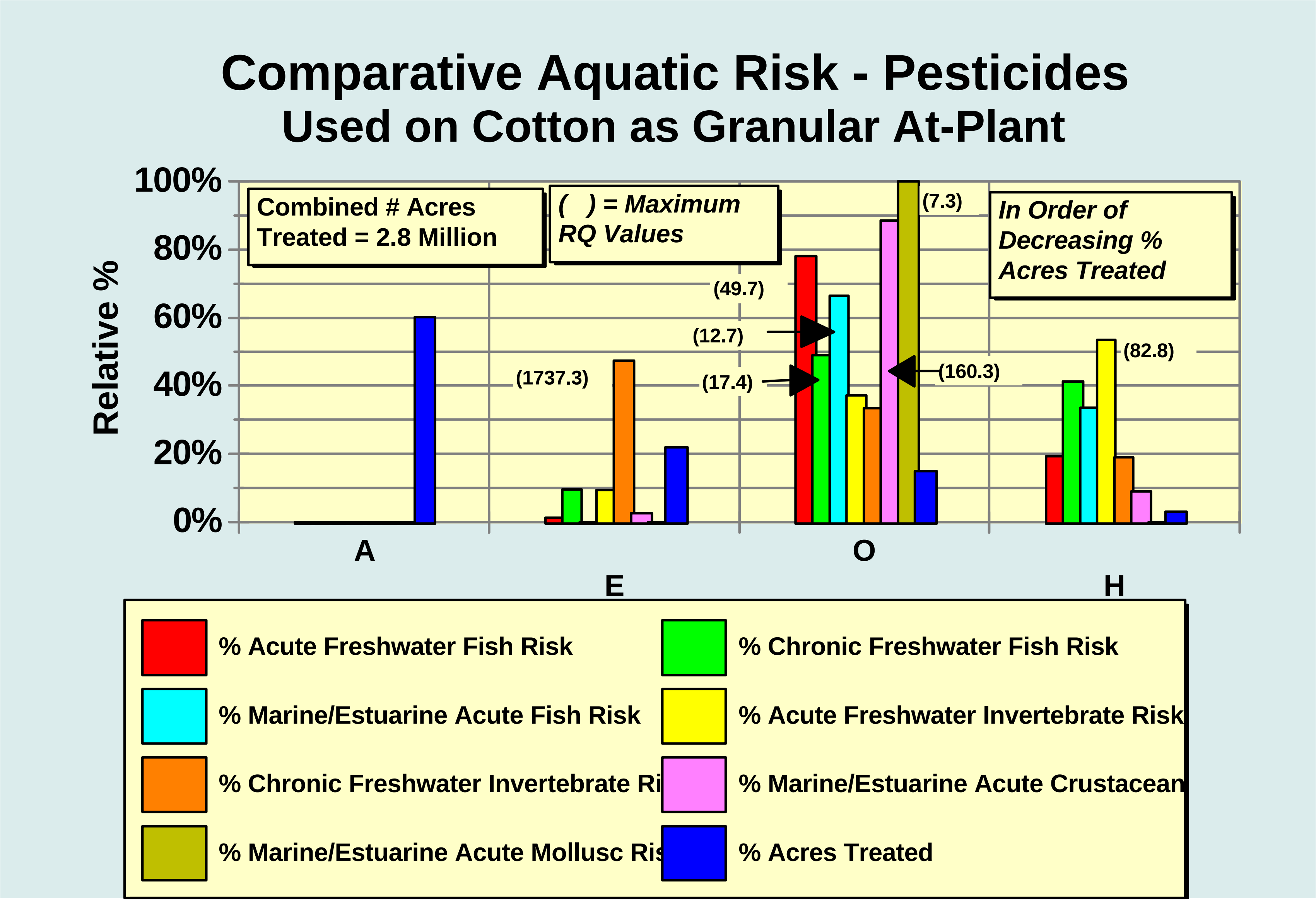
Figure 6





No Incident Reports


Comparative Avian Risk for Pesticides
Used on Cotton as Granular At-Plant
100%
80%
60%
40%
20%
0%
Relative %
Combined # Acres Treated = 2.8 Million
(1847.5)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
A
E
O
H
% Avian Acute Risk
% Acres Treated



Comparative Aquatic Risk - Pesticides
Used on Cotton as Granular At-Plant
Relative %
100%
80%
60%
40%
20%
0%
Combined # Acres Treated = 2.8 Million
( ) = Maximum RQ Values
In Order of Decreasing % Acres Treated
(7.3)
(49.7)
(12.7)
(17.4)
(160.3)
(1737.3)
(82.8)
A
E
O
H
% Acute Freshwater Fish Risk
% Chronic Freshwater Fish Risk
% Marine/Estuarine Acute Fish Risk
% Acute Freshwater Invertebrate Risk
% Chronic Freshwater Invertebrate Ri
% Marine/Estuarine Acute Crustacean
% Marine/Estuarine Acute Mollusc Ris
% Acres Treated

Table 8. Data for Figure 6
Pesticides Used on Cotton as Granular At-Plant Formulations

Birds

Chemical Name	% Avian Acute Risk	% Acres Treated
A	0%	60%
E	7%	22%
O	90%	15%
H	1%	3%

Aquatic Organisms

Chemical Name	% Freshwater Fish Acute Risk	%Freshwater Fish Chronic Risk	% Marine/Estuarine Fish Acute Risk	% Freshwater Invertebrate Acute Risk	% Freshwater Invertebrate Chronic Risk	% Marine/Estuarine Crustacean Acute Risk	% Marine/Estuarine Mollusc Acute Risk	% Acres Treated
A	0%	0%	0%	0%	0%	0%	0%	60%
E	1%	10%	0%	9%	47%	3%	0%	22%
O	78%	49%	66%	37%	34%	88%	100%	15%
H	19%	41%	34%	54%	19%	9%	0%	3%

No Incident Reports

Post-Emergent Sprays - Figure 7 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as post-emergent sprays on cotton. Table 9 shows the data included in Figure 7. Chemical L, Chemical B, Chemical A, Chemical D, Chemical C, Chemical I, Chemical E, Chemical J, Chemical G, Chemical N, Chemical M, and Chemical K were used post-emergent sprays. Figures 7a, b, and c show individual graphs for comparative avian risk, aquatic risk and the incident reports for pesticides used as post-emergent sprays on cotton.

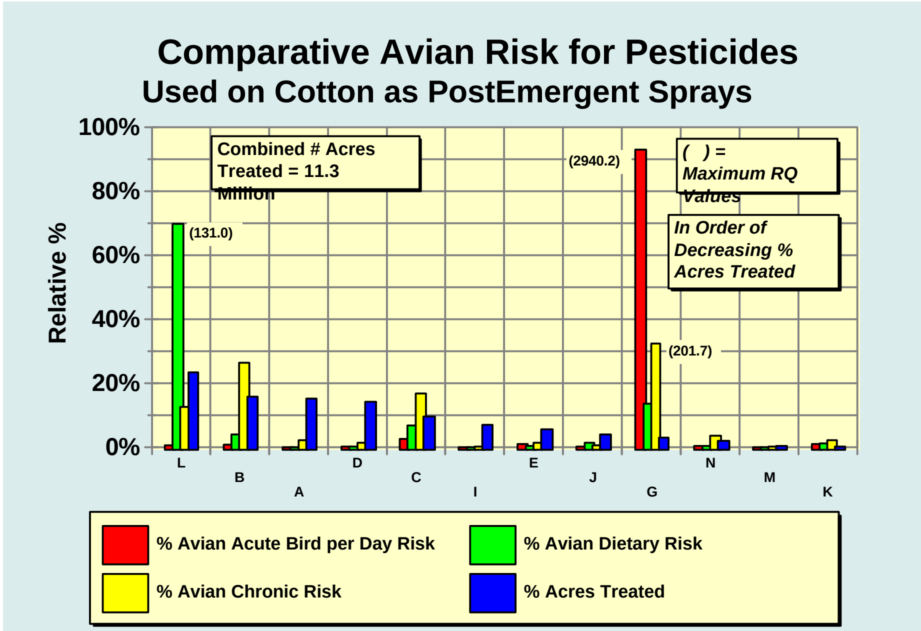
The total combined use for these pesticides is 11.3 million treated acres. Chemical L leads with greater than 20%. Chemical B, Chemical A, Chemical D, and Chemical C, followed with greater than 10%.

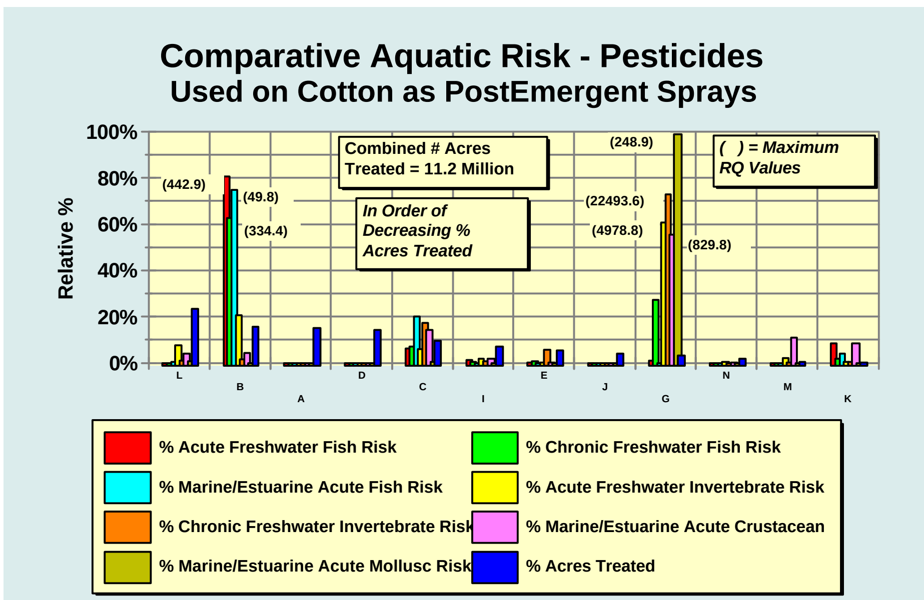
Comparing avian risk, Chemical G leads with the greatest % avian acute and chronic risk. Chemical L leads with the greatest % avian dietary risk. Chemical G also leads the comparative aquatic risk with the greatest % risk for four out of the seven endpoints: % freshwater invertebrate acute risk, % freshwater invertebrate chronic risk, % marine/estuarine crustacean acute risk, % marine/estuarine mollusc acute risk. Chemical B leads the comparative aquatic risk with the greatest % risk for two out of the seven endpoints: % freshwater fish acute risk, % freshwater fish chronic risk, and % marine/estuarine fish acute risk.

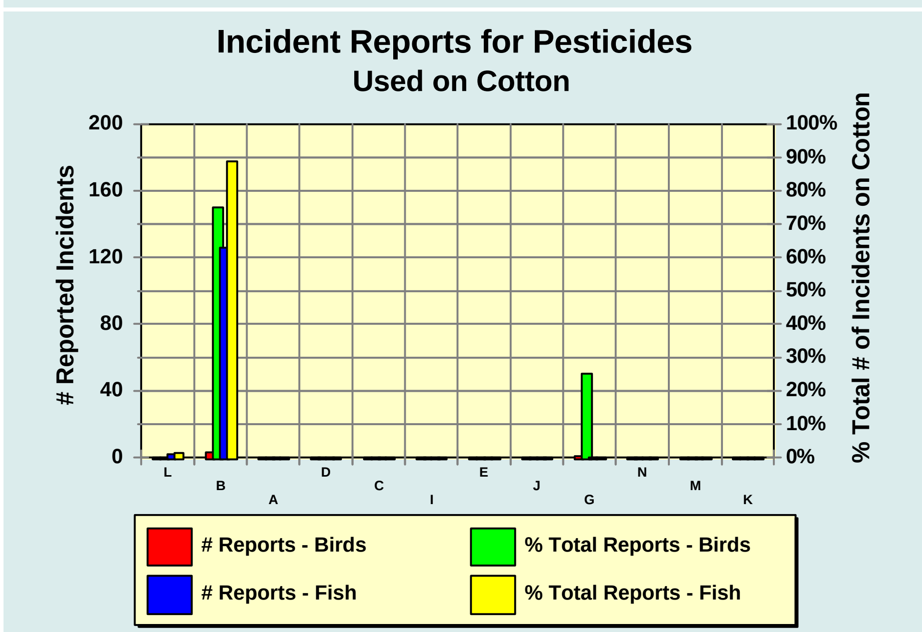
Incidents have been reported for birds and fish. Bird incident reports are reported for Chemical B (3) and Chemical G (1). Fish incidents are reported for Chemical B (126) and Chemical L (2). The bird report for Chemical G and the fish reports for Chemical B are not surprising considering the high acute % risk for birds and fish, respectively. The greater number of bird incidents reported for Chemical B is probably due to its greater use.

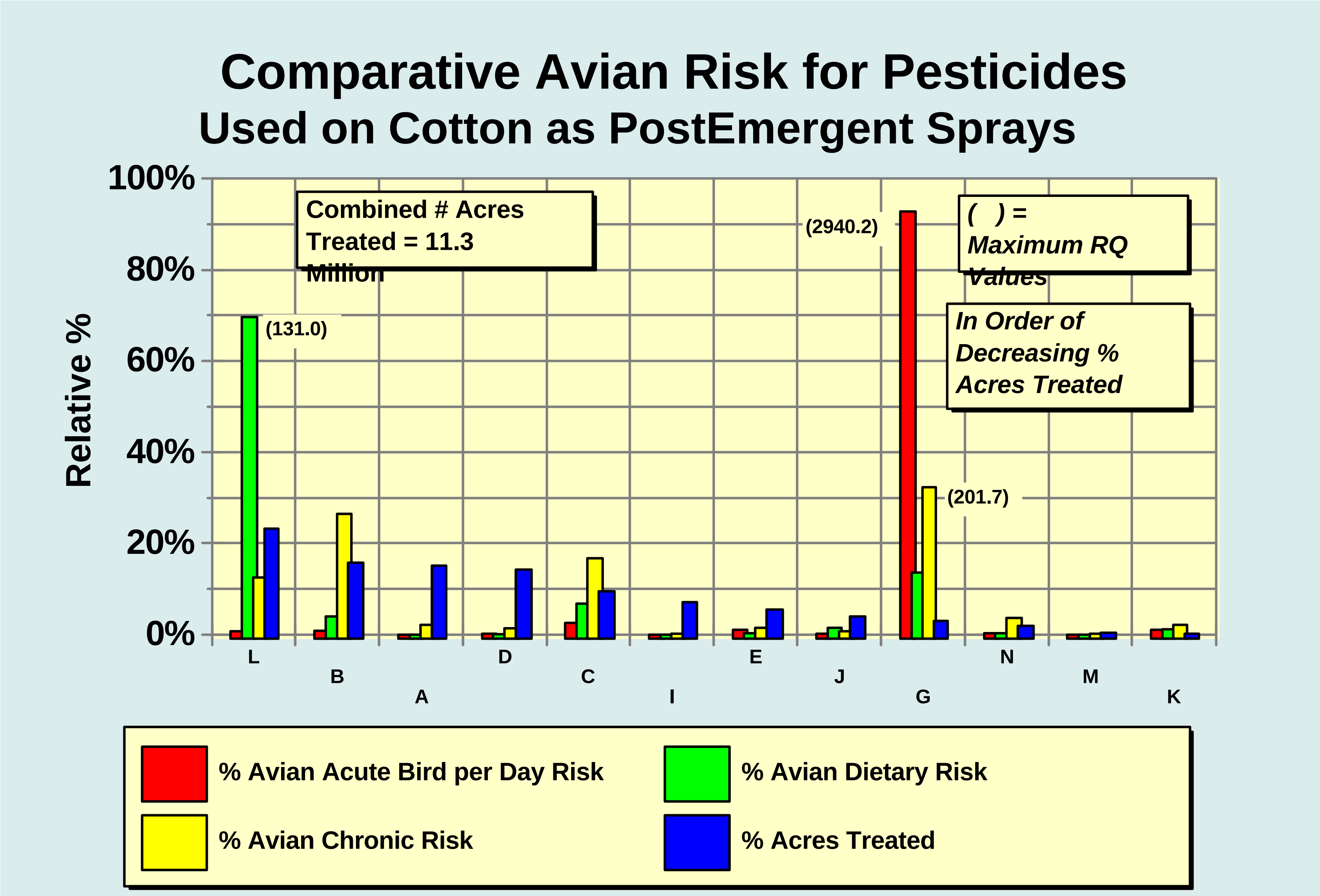
In summary for post-emergent sprays on cotton, Chemical G stands out as presenting the greatest potential acute and chronic risk to birds, as well as to acute and chronic risk to freshwater invertebrates, and acute risk to marine/estuarine crustaceans and molluscs. Chemical L presents the greatest potential avian dietary risk. Chemical B presents the greatest acute risk to freshwater and marine/estuarine fish, as well as chronic risk to freshwater fish. Overall, Chemical A, Chemical D, Chemical I, Chemical J and Chemical N appear to be comparatively less risky than the others.

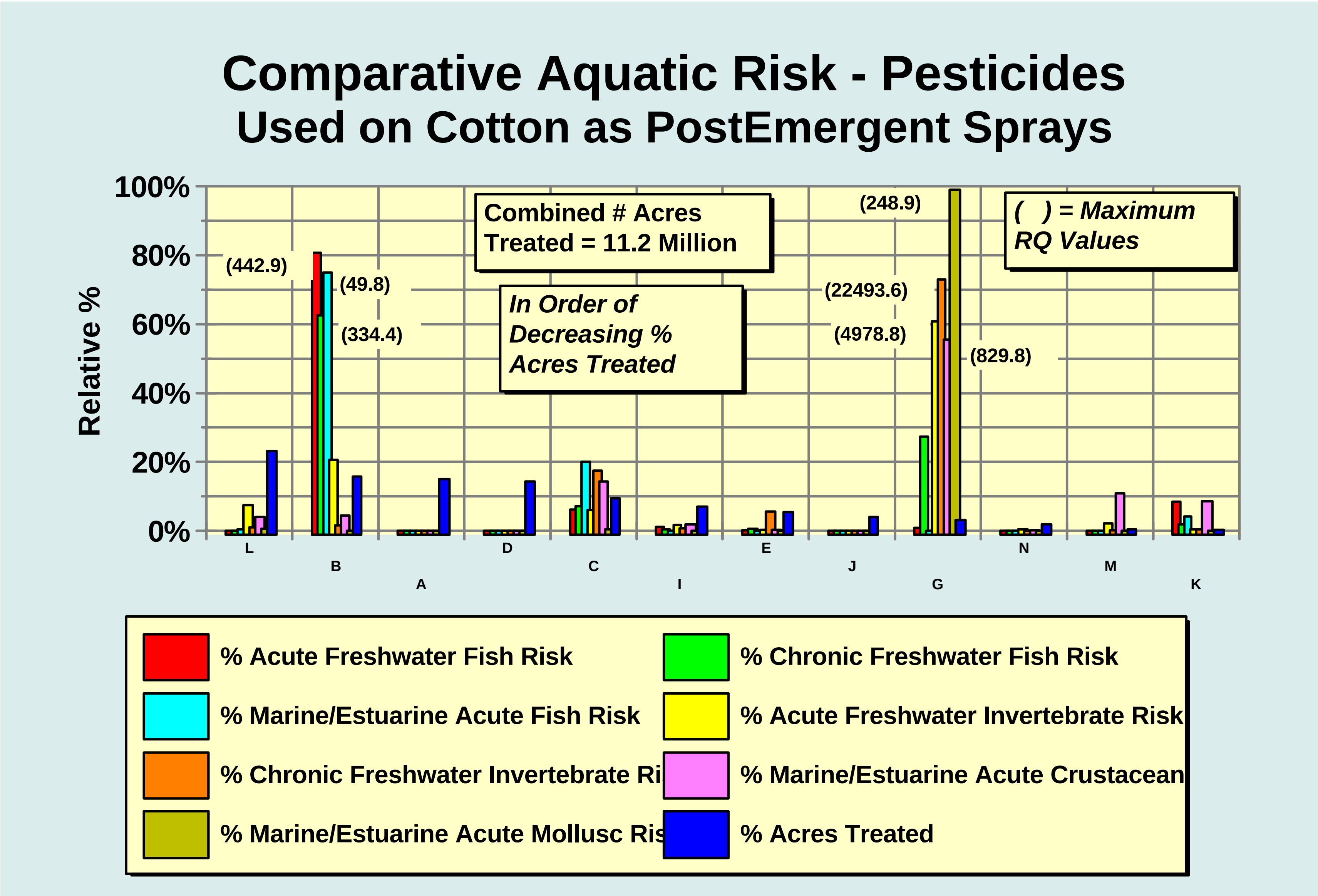
Figure 7


Comparative Avian Risk for Pesticides
Used on Cotton as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
Combined # Acres Treated = 11.3 Million
( ) = Maximum RQ Values
In Order of Decreasing % Acres Treated
(131.0)
(2940.2)
(201.7)
L
B
A
D
C
I
E
J
G
N
M
K
% Avian Acute Bird per Day Risk
% Avian Dietary Risk
% Avian Chronic Risk
% Acres Treated

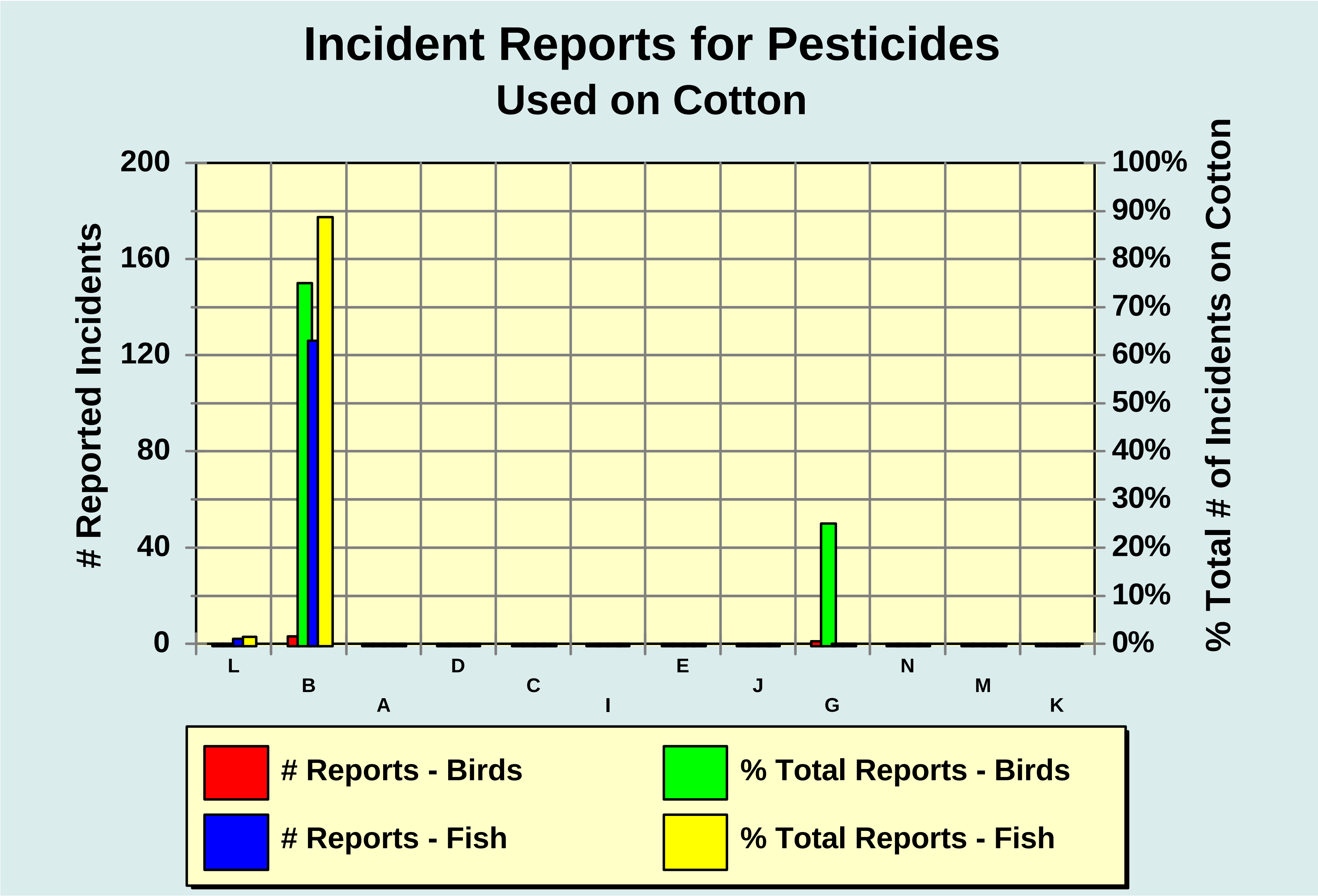

Comparative Aquatic Risk - Pesticides
Used on Cotton as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
Combined # Acres Treated = 11.2 Million
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
(442.9)
(49.8)
(334.4)
(248.9)
(22493.6)
(4978.8)
(829.8)
L
B
A
D
C
I
E
J
G
N
M
K
% Acute Freshwater Fish Risk
% Chronic Freshwater Fish Risk
% Marine/Estuarine Acute Fish Risk
% Acute Freshwater Invertebrate Risk
% Chronic Freshwater Invertebrate Risk
% Marine/Estuarine Acute Crustacean
% Marine/Estuarine Acute Mollusc Risk
% Acres Treated


Incident Reports for Pesticides
Used on Cotton
Reported Incidents
200
160
120
80
40
0
% Total # of Incidents on Cotton
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
L
B
A
D
C
I
E
J
G
N
M
K
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish


Comparative Avian Risk for Pesticides
Used on Cotton as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
Combined # Acres Treated = 11.3 Million
( ) = Maximum RQ Values
In Order of Decreasing % Acres Treated
(131.0)
(2940.2)
(201.7)
L
B
A
D
C
I
E
J
G
N
M
K
% Avian Acute Bird per Day Risk
% Avian Dietary Risk
% Avian Chronic Risk
% Acres Treated



Comparative Aquatic Risk - Pesticides
Used on Cotton as PostEmergent Sprays
Relative %
100%
80%
60%
40%
20%
0%
Combined # Acres Treated = 11.2 Million
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
(442.9)
(49.8)
(334.4)
(248.9)
(22493.6)
(4978.8)
(829.8)
L
B
A
D
C
I
E
J
G
N
M
K
% Acute Freshwater Fish Risk
% Chronic Freshwater Fish Risk
% Marine/Estuarine Acute Fish Risk
% Acute Freshwater Invertebrate Risk
% Chronic Freshwater Invertebrate Ri
% Marine/Estuarine Acute Crustacean
% Marine/Estuarine Acute Mollusc Ris
% Acres Treated



Incident Reports for Pesticides
Used on Cotton
Reported Incidents
% Total # of Incidents on Cotton
200
160
120
80
40
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
L
B
A
D
C
I
E
J
G
N
M
K
Reports - Birds
% Total Reports - Birds
# Reports - Fish
% Total Reports - Fish

Table 9. Data for Figure 7
Pesticides Used on Cotton as Post-Emergent Sprays

Birds

Chemical Name	% Avian Acute Bird/Day Risk	% Avian Dietary Risk	% Avian Chronic Risk	% Acres Treated
L	1%	70%	13%	23%
B	1%	4%	26%	16%
A	0%	0%	2%	15%
D	0%	0%	1%	14%
C	3%	7%	17%	10%
I	0%	0%	0%	7%
E	1%	0%	2%	5%
J	0%	1%	1%	4%
G	93%	14%	32%	3%
N	0%	0%	4%	2%
M	0%	0%	0%	0%
K	1%	1%	2%	0%

Aquatic Organisms

Chemical Name	% Freshwater Fish Acute Risk	% Freshwater Fish Chronic Risk	% Marine/Estuarine Fish Acute Risk	% Freshwater Invertebrate Acute Risk	% Freshwater Invertebrate Chronic Risk	% Marine/Estuarine Crustacean Acute Risk	% Marine/Estuarine Mollusc Acute Risk	% Acres Treated
L	0%	0%	0%	8%	1%	4%	1%	23%
B	81%	63%	75%	21%	2%	4%	0%	16%
A	0%	0%	0%	0%	0%	0%	0%	15%
D	0%	0%	0%	0%	0%	0%	0%	14%
C	6%	7%	20%	6%	17%	14%	0%	10%
I	1%	1%	0%	2%	1%	2%	0%	7%
E	0%	1%	0%	0%	6%	0%	0%	5%
J	0%	0%	0%	0%	0%	0%	0%	4%
G	1%	27%	0%	61%	73%	56%	99%	3%
N	0%	0%	0%	0%	0%	0%	0%	2%
M	0%	0%	0%	2%	0%	11%	0%	0%
K	8%	2%	4%	0%	0%	9%	0%	0%

Incidents

Chemical Name	*# Reports - Birds*	*% Total Reports - Birds*	*# Reports - Fish*	*% Total Reports - Fish*
L	0	0%	2	50%
B	3	60%	126	34%
A	0	0%	0	0%
D	0	0%	0	0%
C	0	0%	0	0%
I	0	0%	0	0%
E	0	0%	0	0%
J	0	0%	0	0%
G	1	3%	0	0%
N	0	0%	0	0%
M	0	0%	0	0%
K	0	0%	0	0%

4. Peanuts - At-Plant Granular & Post-Emergent Spray Formulations

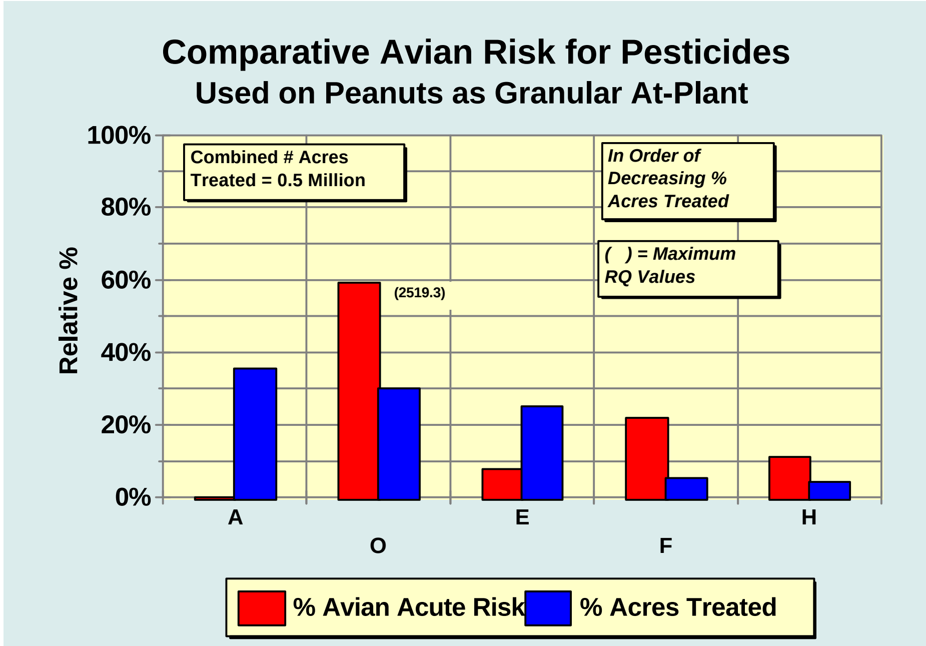
Granular At-Plant - Figure 8 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as at-plant granular formulations on peanuts. Table 10 shows the data included in Figure 8. Chemical A, Chemical O, Chemical E, Chemical F, and Chemical H were used at-plant. Chemical A and Chemical F had labels for post-emergent sprays as well as for at-plant granular formulations. Chemical I labels support only post-emergent sprays. There was no information separating use by formulation and timing of application. Total use figures were used for both at-plant and post-emergent sprays. Figures 8a and b show individual graphs for comparative avian and aquatic risk for pesticides used as at-plant granular formulations on peanuts. There were no incident reports for pesticides used at-plant on peanuts.

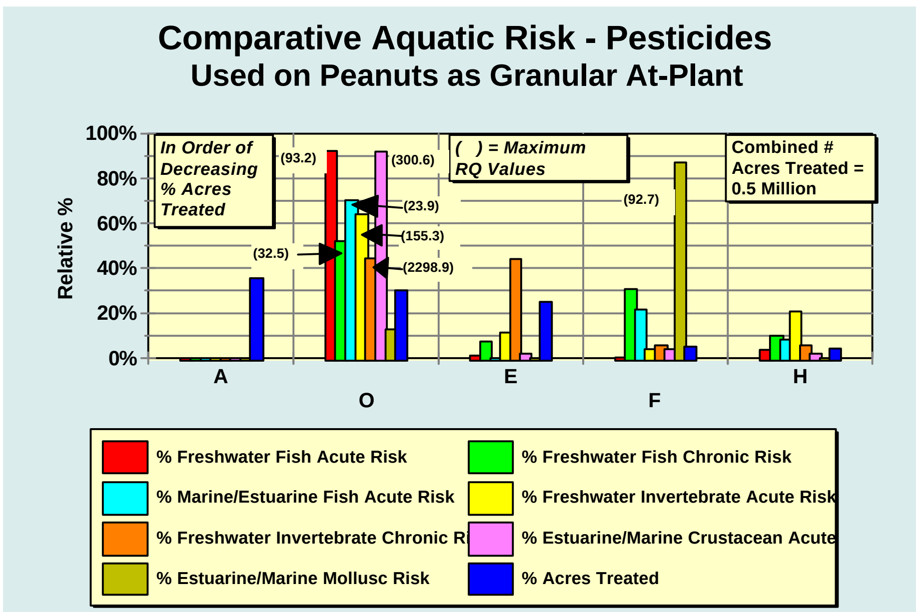
The total combined use for these pesticides is 0.5 million treated acres. Chemical A leads with 35%, with Chemical O and Chemical E closely following with 30% and 25%, respectively.

Comparing avian risk, Chemical O leads with the greatest % avian acute risk. This is the only avian risk endpoint compared for granular formulations. Chemical O also leads the comparative aquatic risk with the greatest % risk for six out of the seven endpoints: % freshwater fish acute risk, % freshwater fish chronic risk, % marine/estuarine fish acute risk, % freshwater fish acute risk, % freshwater fish chronic risk, and % marine/estuarine crustacean acute risk. Chemical F leads with the greatest % marine/estuarine mollusc acute risk.

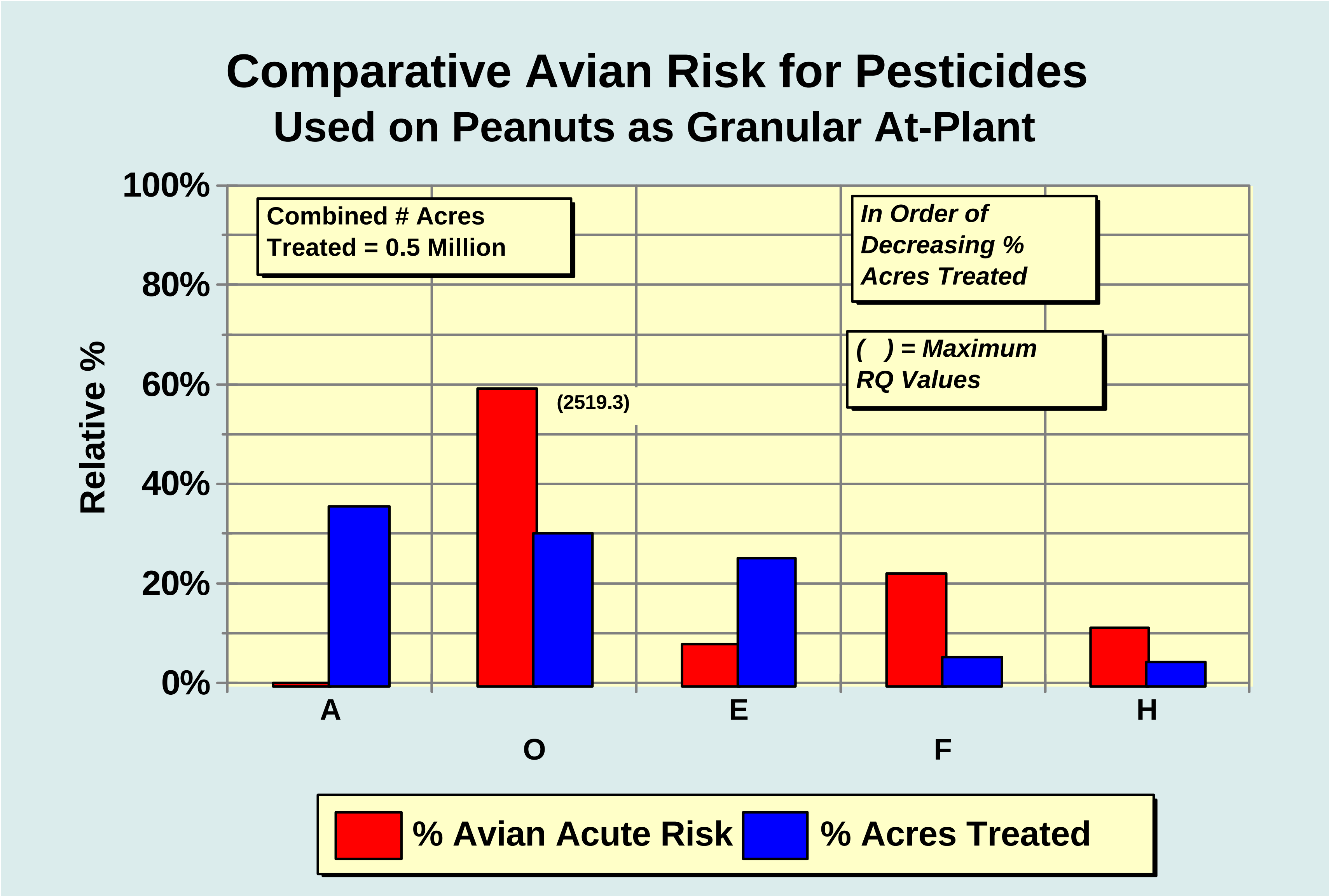
In summary for at-plant granular pesticides on peanuts, Chemical O stands out as presenting the greatest potential acute risk to birds, as well as to acute and chronic risk to freshwater fish, freshwater invertebrates and marine/estuarine invertebrates. Chemical F presents the greatest acute risk to marine/estuarine mollusc. Overall, Chemical A appears to present comparatively less acute risk to birds and fish.

Figure 8





No Incident Reports


Comparative Avian Risk for Pesticides
Used on Peanuts as Granular At-Plant
100%
80%
60%
40%
20%
0%
Relative %
Combined # Acres
Treated = 0.5 Million
In Order of
Decreasing %
Acres Treated
( ) = Maximum
RQ Values
(2519.3)
A
O
E
F
H
% Avian Acute Risk
% Acres Treated

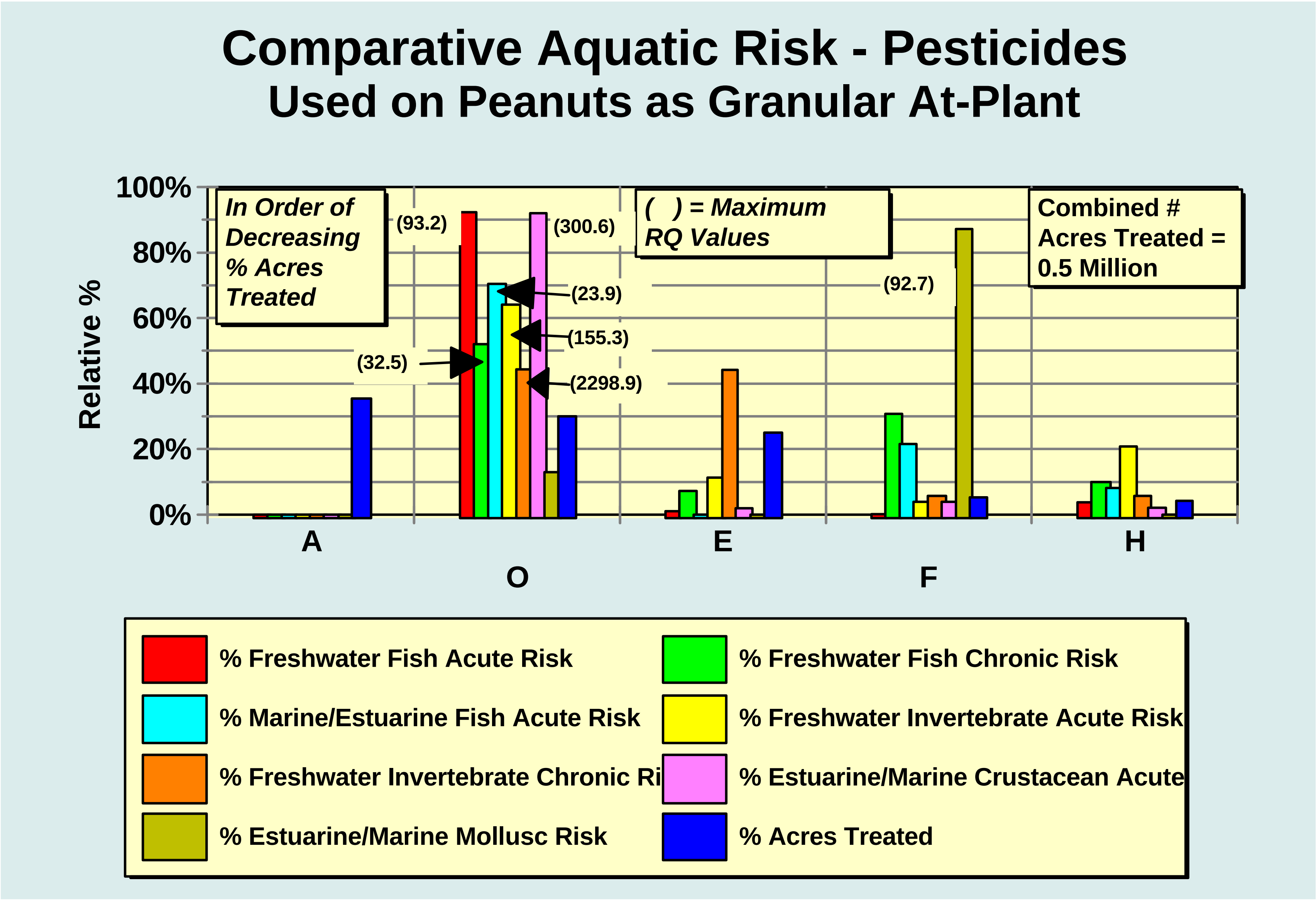

Comparative Aquatic Risk - Pesticides
Used on Peanuts as Granular At-Plant
100%
80%
60%
40%
20%
0%
Relative %
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 0.5 Million
(93.2)
(300.6)
(23.9)
(155.3)
(32.5)
(2298.9)
(92.7)
A
O
E
F
H
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Ri
% Estuarine/Marine Crustacean Acute
% Estuarine/Marine Mollusc Risk
% Acres Treated

Table 10. Data for Figure 8
Pesticides Used on Peanuts as Granular At-Plant Formulations

Birds

Chemical Name	*% Avian Acute Risk*	*% Acres Treated*
A	0%	35%
O	59%	30%
E	8%	25%
F	22%	5%
H	11%	4%

Aquatic Organisms

Chemical Name	*% Freshwater Fish Acute Risk*	*% Freshwater Fish Chronic Risk*	*% Marine/Estuarine Fish Acute Risk*	*% Freshwater Invertebrate Acute Risk*	*% Freshwater Invertebrate Chronic Risk*	*% Marine/Estuarine Crustacean Acute Risk*	*% Marine/Estuarine Mollusc Acute Risk*	*% Acres Treated*
A	0%	0%	0%	0%	0%	0%	0%	35%
O	92%	52%	70%	64%	44%	92%	13%	30%
E	1%	7%	0%	11%	44%	2%	0%	25%
F	0%	31%	22%	4%	6%	4%	87%	5%
H	4%	10%	8%	21%	6%	2%	0%	4%

No Incident Reports

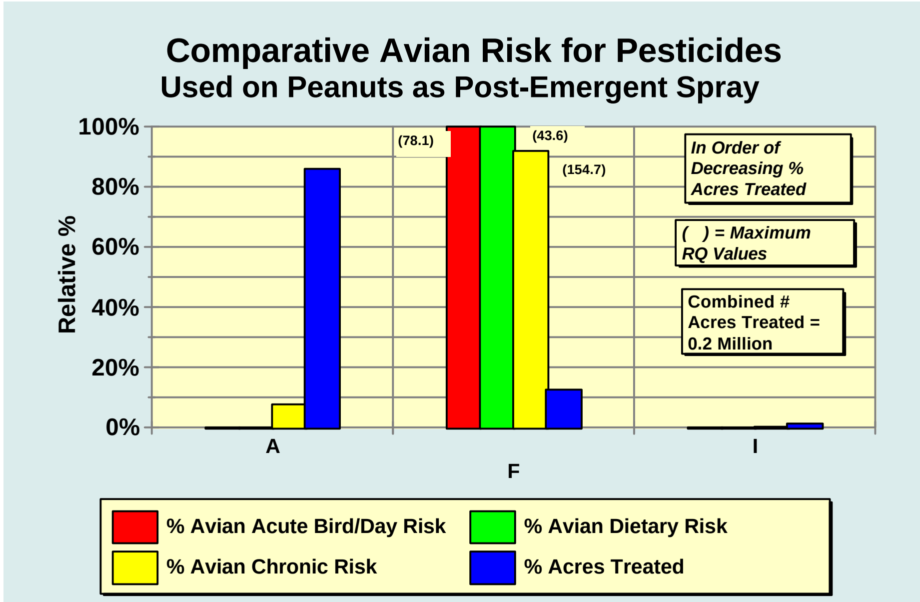
Post-Emergent Sprays - Figure 9 provides overview graphs of the comparative avian risk, aquatic risk and the incident reports for pesticides used as post-emergent sprays on peanuts. Table 11 shows the data included in Figure 9. Chemical A, Chemical F and Chemical I were used post-emergent sprays. Figures 9a and b show individual graphs for comparative avian risk and aquatic risk for pesticides used as post-emergent sprays on peanuts. No incidents were reported for these pesticides used as post-emergent sprays on peanuts.

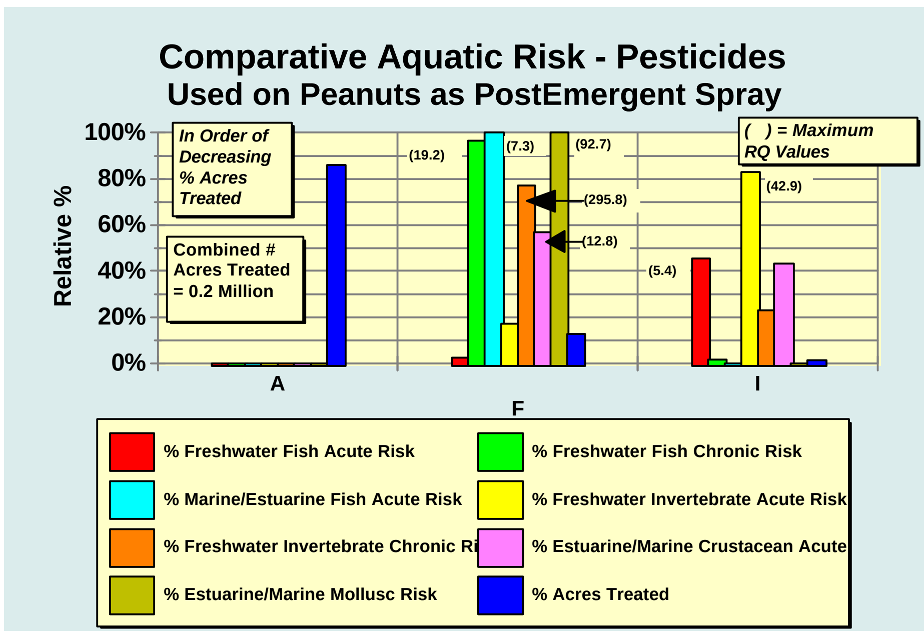
The total combined use for these pesticides is 0.2 million treated acres. Chemical A leads with over 80%. Chemical F follows with 13%.

Comparing avian risk, Chemical F leads with the greatest % avian acute, % avian dietary risk, and % avian chronic risk. Chemical F also leads the comparative aquatic risk with the greatest % risk for five out of the seven endpoints: % freshwater fish chronic risk, % marine/estuarine fish acute risk, % freshwater invertebrate chronic risk, % marine/estuarine crustacean acute risk, and % marine/estuarine mollusc acute risk. Chemical I leads the comparative aquatic risk with the greatest % risk for two out of the seven endpoints: % freshwater fish acute risk, and % freshwater invertebrate acute risk,.

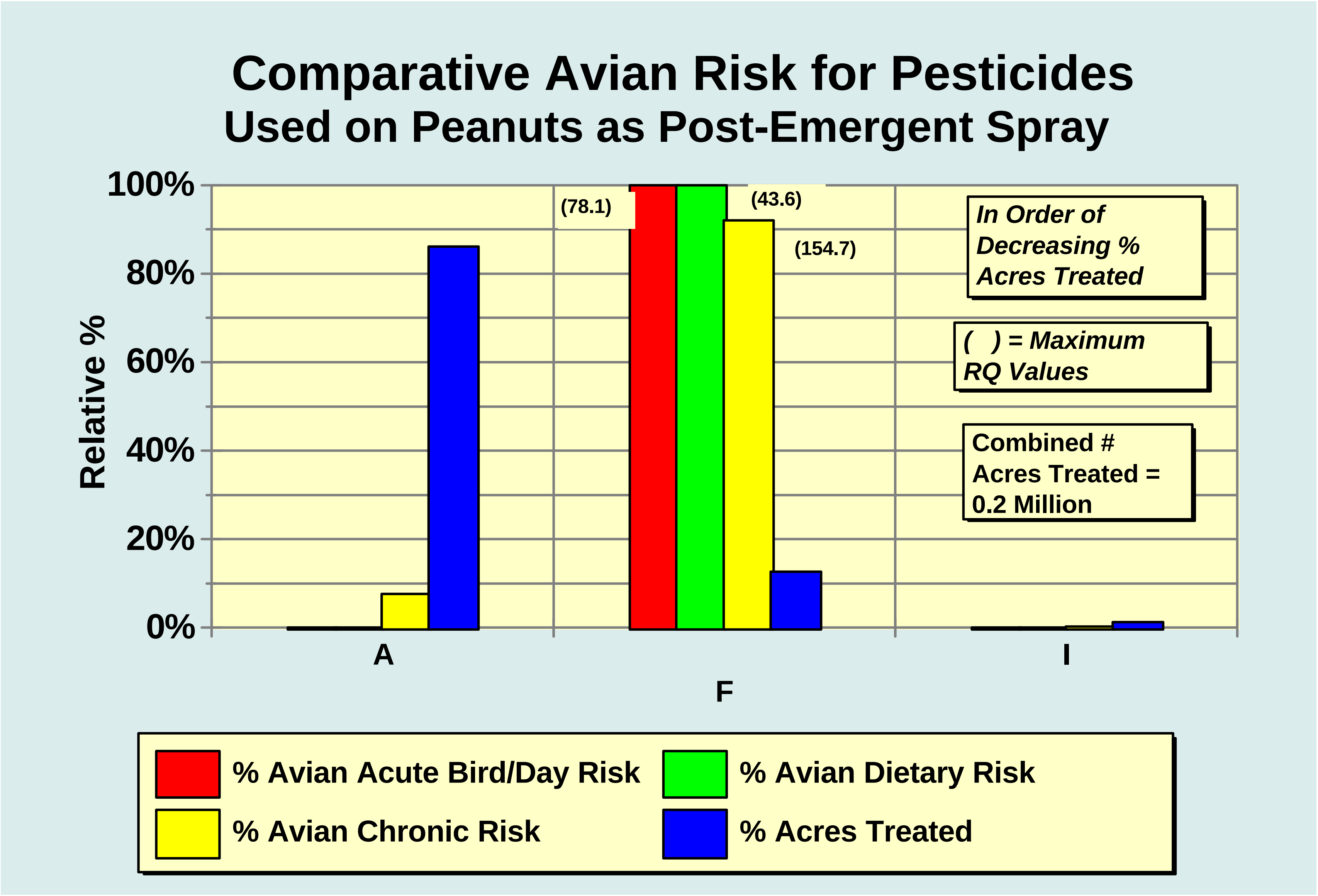
In summary for post-emergent sprays on peanuts, Chemical F stands out as presenting the greatest potential acute, dietary and chronic risk to birds, as well as potential acute risk to marine/estuarine fish, chronic risk to freshwater fish and invertebrates, and acute risk to marine/estuarine crustaceans and molluscs. Chemical I presents the greatest potential acute risk to freshwater fish and invertebrates. Overall, Chemical A appears to be comparatively less risky than the others.

Figure 9





No Incidents Reported


Comparative Avian Risk for Pesticides
Used on Peanuts as Post-Emergent Spray
100%
80%
60%
40%
20%
0%
Relative %
(78.1)
(43.6)
(154.7)
In Order of Decreasing % Acres Treated
( ) = Maximum RQ Values
Combined # Acres Treated = 0.2 Million
A
F
I
% Avian Acute Bird/Day Risk
% Avian Dietary Risk
% Avian Chronic Risk
% Acres Treated

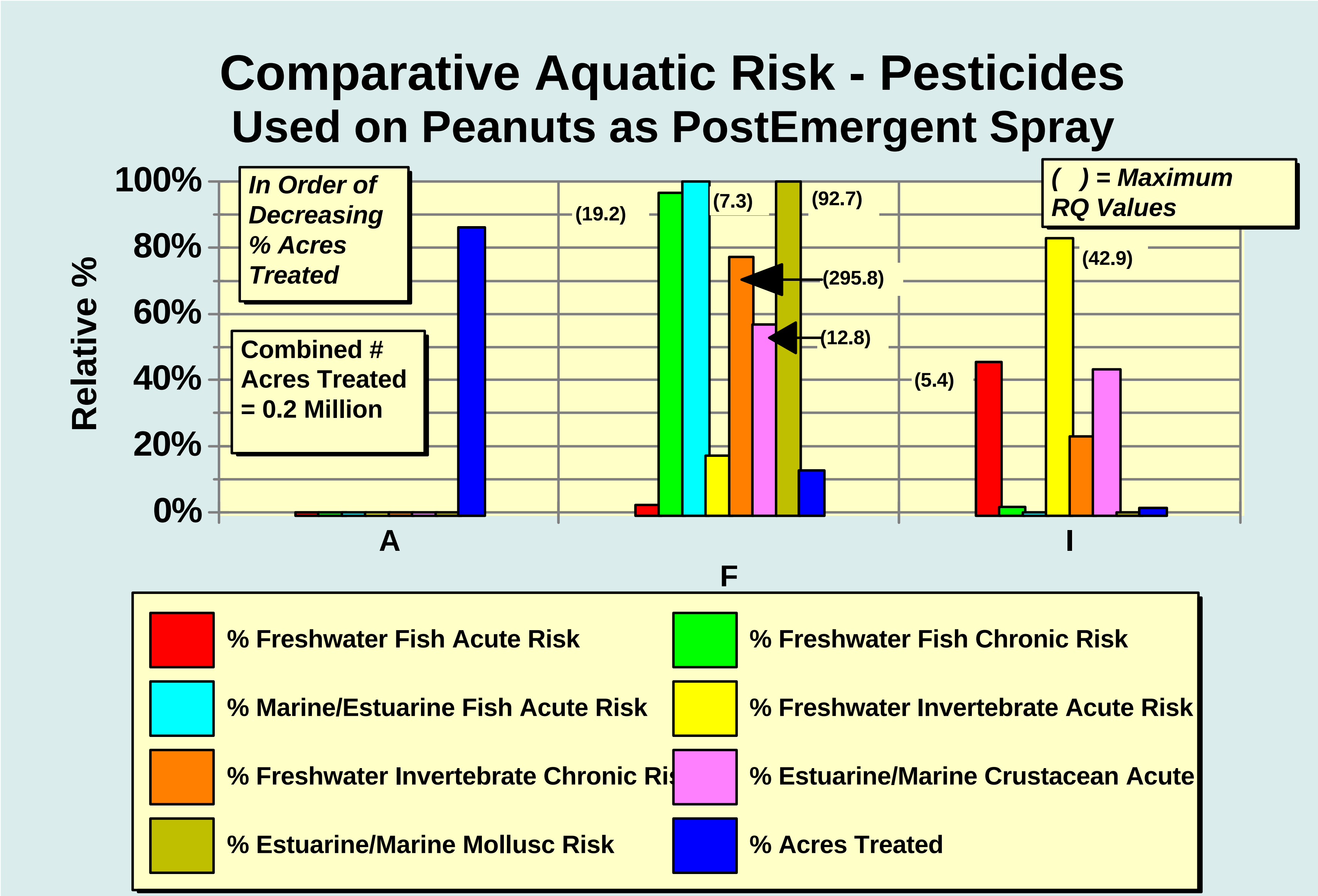

Comparative Aquatic Risk - Pesticides
Used on Peanuts as PostEmergent Spray
In Order of Decreasing % Acres Treated
Combined # Acres Treated = 0.2 Million
( ) = Maximum RQ Values
Relative %
100%
80%
60%
40%
20%
0%
(19.2)
(7.3)
(92.7)
(295.8)
(12.8)
(5.4)
(42.9)
A
F
I
% Freshwater Fish Acute Risk
% Freshwater Fish Chronic Risk
% Marine/Estuarine Fish Acute Risk
% Freshwater Invertebrate Acute Risk
% Freshwater Invertebrate Chronic Ri
% Estuarine/Marine Crustacean Acute
% Estuarine/Marine Mollusc Risk
% Acres Treated

Table 11. Data for Figure 9
Pesticides Used on Peanuts as Post-Emergent Sprays

Birds

Chemical Name	*% Avian Acute Bird/Day Risk*	*% Avian Dietary Risk*	*% Avian Chronic Risk*	*% Acres Treated*
A	0%	0.0%	8%	86%
F	100%	100.0%	92%	13%
I	0%	0.0%	0%	1%

Aquatic Organisms

Chemical Name	*% Freshwater Fish Acute Risk*	*% Freshwater Fish Chronic Risk*	*% Marine/Estuarine Fish Acute Risk*	*% Freshwater Invertebrate Acute Risk*	*% Freshwater Invertebrate Chronic Risk*	*% Marine/Estuarine Crustacean Acute Risk*	*% Marine/Estuarine Mollusc Acute Risk*	*% Acres Treated*
A	0%	0%	0%	0%	0%	0%	0%	86%
F	2%	97%	100%	17%	77%	57%	100%	13%
I	45%	2%	0%	83%	23%	43%	0%	1%

No Incident Reports

5. Overall Summary

Figures 4, 6 and 8 show that Chemical O stands out as consistently presenting the greatest overall potential risk for granular at-plant pesticides applied to these four crops.

Figures 3, 5, 7 and 9 present a more complex picture of potential risk for pesticides applied as post-emergent sprays to these four crops. Chemical G appears to present the greatest risk to birds and aquatic invertebrates on alfalfa, corn and cotton. Chemical B presents the greatest risk to fish on alfalfa and cotton; while Chemical I presents the greatest risk to fish on corn. Peanuts is a separate case and is described above.

VII. Decision Support Analysis to Aid Decision-Making

A. Decision Support Software[16]

Comparative risk assessment can become a daunting process when the risk assessor(s) are faced with ecological risks for a number of alternative pesticides covering multiple endpoints. When attempting to decide which pesticides present the greatest overall risk or which are comparatively less risky than others, the matrix-like result of such comparisons can lead the assessor(s) to rely on individual or group intuition more than they prefer. Further, when additional information characterizing the risk, whether quantitative or not, is added for consideration in the decision making process, paralysis (indecision) can set in. To address this situation, the Agency chose to explore the use of commercially available software called *DecideRight (Version 1.2)*[17] to aid in decision-making for this case study. This software was primarily designed for use in businesses. It is a user friendly tool to help choose among alternatives when many factors must be considered. The underlying methodology is SMART, the Simple Multi-attribute Rating Technique. It was developed about 27-years ago and has become a standard in decision modeling. When faced with a number of choices and a number of criteria, SMART prescribes that (1) each choice be rated on each criterion, (2) each criterion be assigned a measure of importance to the decision-maker, (3) a summary score for each choice be calculated as a weighted average of the ratings, where the weights represent the relative importance of the criteria. Thus, the higher the summary score, the better the choice. The result of this process has proved to be superior to the alternative of reliance on intuition.

SMART is not rooted in probability. The assigned ratings are assumed to be based on full knowledge of how an option works. There are no uncertainties. However, some uncertainty can be dealt with in the ratings by sensitivity testing of the results. Similarly, this analysis is not rooted in probability. However, when the tools for probabilistic ecological risk assessments become available and are implemented in OPP/EFED, a decision tool that is capable of handling probabilities should be considered for comparative analysis. ERGO[18] by Arlington Software Corporation currently is capable of handling probability in decision analysis.

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[16] Much of the software description here was based on a software review by Len Tashman and Sara Munro [24].

[17] *DecideRight* was developed by Avantos Performance Systems of Emertville, California. The company has since closed; however, the software is still available from Parsons Technology, P.O. Box 100, Hiawatha, IA 52233 [http://www.parsonstech.com] Mention of this commercial product does not constitute a recommendation or endorsement by EPA.

[18] Arlington Software Corporation, 740 Saint-Maurice, Suite 410, Montreal, Quebec, Canada, H3C 1L5 [http://www.arlingsoft.com] Mention of this commercial product does not constitute a recommendation or endorsement by EPA.

In addition, there are no interactions between attributes in SMART. Thus, SMART ignores any interplay between two criteria. This interaction effect is handled better by more complex models such as ERGO.

DecideRight is easy to use and provides the results in intuitive and colorful decision tables. In addition to a baseline scenario, the software allows the development various additional scenarios through its scenario facility. This permits consideration of additional risk characterization information and also preferences of different members in a team environment. EPA selected *DecideRight* for this exploratory case study.

B. Baseline Scenario - Alfalfa

The Agency chose to enter the data in Table 5, for all pesticides used on alfalfa as post-emergent sprays, into *DecideRight*. The twelve criteria i.e., the risk endpoints, were considered to be equally important for this scenario, and set at a level of medium importance. The criteria included # of bird incident reports, # of fish incident reports, % avian bird/day risk, % avian dietary risk, % avian chronic risk, % freshwater fish acute risk, % marine/estuarine fish acute risk, % freshwater fish chronic risk, % freshwater invertebrate acute risk, % freshwater invertebrate chronic risk, % marine/estuarine crustacean acute risk, % marine/estuarine mollusc acute risk.

Each pesticide was rated for each criteria using the % risk values in Table 5. The option was chosen to rate lower % risk values better. Thus, lower % risk ratings result in higher summary ratings. The question posed was “Which of the Insecticides Used on Alfalfa are Less Risky?” The corollary is “Which of the Insecticides are More Risky?” The results are presented in a decision table format in Figure 10.

Figure 10. Baseline: Decision Table for Which of the Insecticides Used on Alfalfa are Less Risky

	# of bird incident reports	% avian acute bird/day risk	% avian chronic risk	% avian dietary risk	% freshwater fish acute risk	% freshwater fish chronic risk	% freshwater invertebrate acute risk	% freshwater invertebrate chronic risk	% Marine/Estuarine Fish Acute Risk	% Marine/Estuarine Mollusc Acute Risk	% Marine/Estuarine Crustacean Acute Risk	# of fish incident reports	Summary
Chemical P	N/A	0.00	1.50	0.10	0.10	0.00	0.10	0.00	1.20	0.00	0.30	N/A	9.94
Chemical N	N/A	0.10	4.50	0.10	0.00	0.00	0.30	0.00	0.00	0.00	0.00	N/A	9.89
Chemical M	N/A	0.00	0.50	0.00	0.00	0.00	5.70	0.30	0.00	0.00	1.30	N/A	9.89
Chemical I	N/A	0.00	0.40	0.00	4.00	0.40	2.70	1.10	0.00	0.00	2.70	N/A	9.81
Chemical K	N/A	0.80	2.10	0.50	17.40	2.90	0.30	0.40	6.51	0.00	8.30	N/A	9.25
Chemical D	Poor	0.40	2.30	0.10	0.00	0.00	0.10	0.00	0.00	0.00	0.00	N/A	9.04
Chemical L	N/A	0.90	19.50	78.80	0.00	0.00	6.50	0.80	0.00	0.20	3.30	N/A	8.33
Chemical B	N/A	0.00	8.40	0.00	47.50	28.40	5.90	0.40	34.80	0.00	1.20	N/A	7.47
Chemical C	N/A	3.90	22.10	8.20	22.20	19.60	10.30	26.00	55.80	0.20	23.50	N/A	6.51
Chemical G	Poor	93.30	38.80	10.70	2.10	48.30	67.70	70.90	0.00	99.20	59.40	N/A	2.57

Alternative choices considered are listed down the left side of the table. The criteria used to evaluate the various options are listed along the top. Initially entered in no particular order, both the choices and the criteria were then repositioned according to importance of criteria, held constant in this case at medium, and effectiveness of individual choices in meeting them.

As criteria are evaluated and weights assigned according to which factors are considered to be most significant, the factors are sorted from left to right in order of importance (i.e., the factor considered by the decision maker to be most significant in meeting overall needs ends up in the leftmost position). In this baseline scenario, all are equally important.

Similarly, as choices are evaluated according to effectiveness in meeting criteria, the best choices migrate to the top of the list. When the process is complete, the best choice should emerge at the top, the worst at the bottom.

As selection alternatives and the criteria to be used in evaluating them are entered into the table, weights are assigned to each of the evaluation factors so that they are ranked in order of their importance in fulfilling the overall task. For the baseline decision "Which Insecticides Used on Alfalfa are Less Risky ?," the twelve criteria used to evaluate the choices were all weighted as Medium. Where one or more bird incidents were reported, that criterion was rated as “poor” for that chemical. When no bird incidents were reported, that criterion was rated as N/A for that chemical and it did not contribute to the summary rating. No fish incidents were reported and thus this criterion did not contribute to the summary for any chemical.

The colors under each criteria and under the summary show four rating categories which indicate difference between options:

Medium Green = Top Option(s)
Dark Green = Second Option(s)
Yellow = Third Option(s)
Red = Worst Option(s)

The summary column displays the results of the hidden calculations based on the assigned ratings and weights for the criteria. For a more detailed explanation of the underlying mathematical algorithms, Tashman and Munro [24] recommend a chapter entitled Decisions with Multiple Objectives in the decision analysis textbook by Goodwin and Wright [25]. The higher the summary score, the better the option, and vice versa. The scale for the summary is from 10 to 1, and is expressed as four rating categories as above.

Among the 10 choices (chemicals) considered, 7 were considered to be "top options." (A top option is defined as follows: If the choice immediately following the preferred choice is rated in the same rating category as the recommended selection, then all choices in that category are considered top options. If the second ranking choice is in a different category, the top options are considered to be the recommended choice plus all choices in the same category as the second-place option. Thus, the "top options" list will always have at least two choices in it and may include all of the choices considered in the entire table.) *DecideRight* also provides pair-wise comparisons between the choices where the critical rating factor is identified. This was not included in this document.

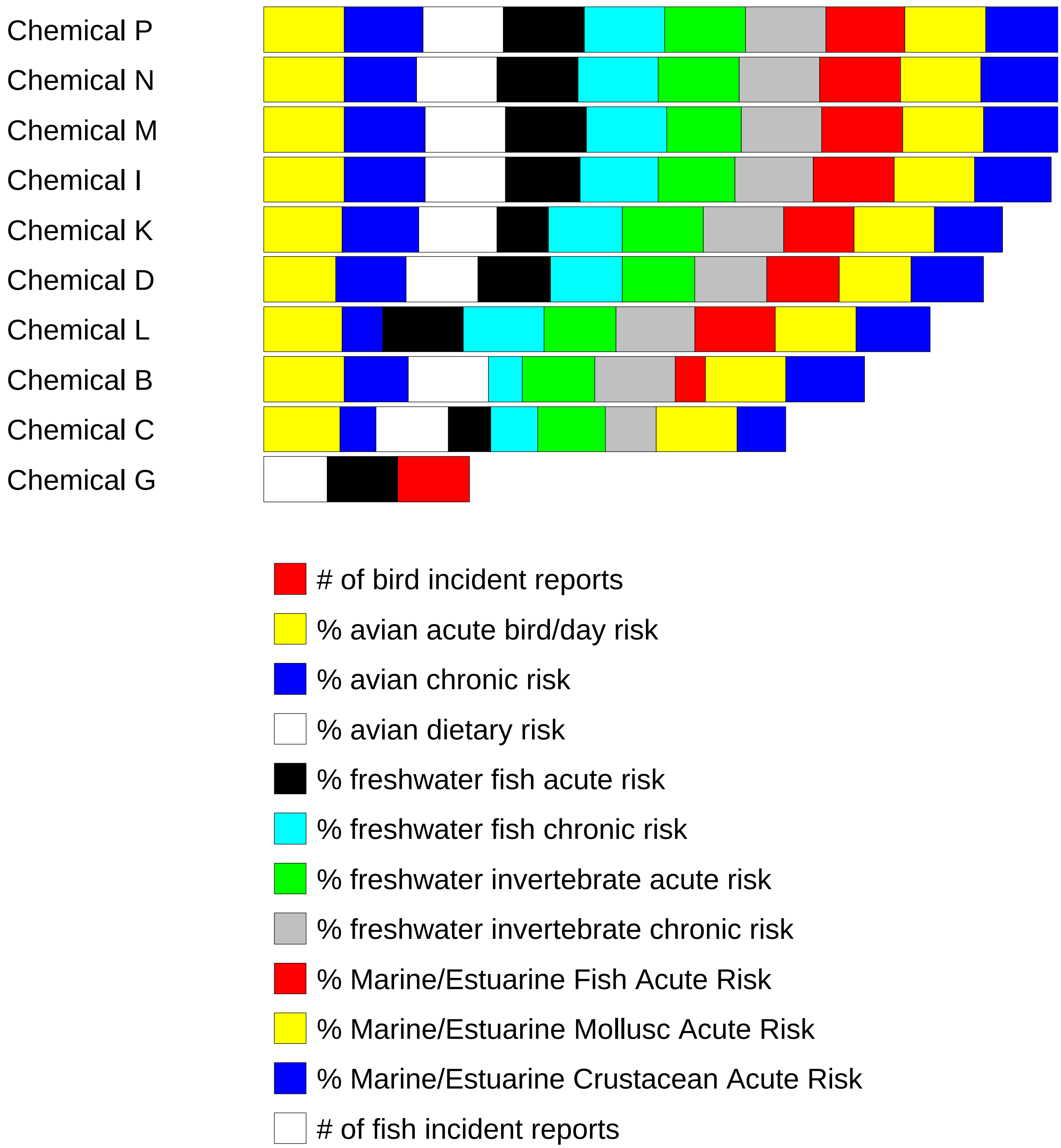
For the decision of "Which Insecticides Used on Alfalfa are Less Risky ?," the top options were:

Chemical P
Chemical N
Chemical M
Chemical I
Chemical K
Chemical D
Chemical L

After a careful evaluation of each option, Chemical P appears to be the best choice. The worst choice was Chemical G, followed by Chemicals C and B.

Finally, the relative strengths of the various choices, i.e., chemicals, in each of the factors is illustrated in Figure 11. The wider the band, the better the rating, i.e., less risk, for that criteria and for that pesticide. Missing bands indicate the worst rating for that criteria and that pesticide.

Figure 11. The Relative Strengths of the 10 Choices Considering the 11 Risk Endpoints



C. Ecological Risk Characterization Information

Following the initial screening analysis for the case study, which is based on readily available data, we considered additional information that could further characterize the potential risk of the chemicals to non-target organisms on alfalfa. This information may be quantitative in nature such as refined estimates of aquatic exposure based on PRZM/EXAMS modelling, updated ecotoxicity data, additional reports of bird and fish incidents not recorded in the EIIS, or measured residues in the environment. It may also come in the form of technical or literature reports addressing the use site, application methods, and/or vulnerable populations of non-target organisms.

Terrestrial and aquatic field studies are important information to include in a comprehensive risk assessment for a pesticide. For this case study on alfalfa, however, field studies had been required to support the registration for six of the ten pesticides, but not for the other four. While most studies confirm the risk concerns raised by the preliminary analysis, four of the pesticides lack any field testing. Since all ten cannot be compared using this criterion, an evaluation of available field study data has not been included in this comparative analysis.

Following is a chemical by chemical breakdown of typical information that can be used to further characterize, and/or refine the potential risk of these 10 pesticides to non-target organisms when used on alfalfa.

Chemical B

Two additional incidents were found:(1) In 1997 in California, 25 birds were killed when Chemical B was sprayed on alfalfa. Residue analysis confirms Chemical B as being the cause of the bird kill; (2) In 1991, again in California, 100+ fish were killed after an application of Chemical B to an alfalfa field. No residue analysis was available, however, the farmer confirmed the application of Chemical B the day prior to the discovery of the fish kill by personnel from the California Department of Fish and Game.

PRZM/EXAMS model results are available and show estimated residues approximately 3X greater than the GENEEC estimates.

Chemical C

PRZM/EXAMS model results are available and show estimated residues from 2 to 3 X lower than the GENEEC estimates.

Chemical D

PRZM/EXAMS model results are available and show estimated residues approximately 2 X lower than the GENEEC peak estimates. However, by 21-days and

60-days the factor increased to approximately 8X and 17X lower, respectively.

Chemical G

A 100-foot buffer from sensitive aquatic habitat is required for the use of this chemical on alfalfa. PRZM/EXAMS model results are available. The spray drift component of the EEC was modified. The results from the model show estimated residues approximately 2 X lower than the GENEEC peak estimates. The 21-day estimated were approximately equal, and the 60-day estimates were slightly greater than the GENEEC estimates.

Chemical I

PRZM/EXAMS model results are available and show estimated residues slightly less than the GENEEC peak estimates. However, by 21-days and 60-days the residue estimates were approximately 7X and 12X lower, respectively.

Chemical K

New avian reproduction study results report a NOAEC of 1 ppm. This is considerably lower than the predicted value of 23 ppm. In addition, PRZM/EXAMS model results are available and show estimated residues approximately 3Xless than the GENEEC peak estimates. However, by 21-days and 60-days the residue estimates were approximately 4X lower.

Chemical L

PRZM/EXAMS model results are available and show estimated residues approximately 7 X less than the GENEEC peak estimates. However, by 21-days and 60-days the residue estimates were approximately 16X and 20X lower, respectively.

Chemical M

PRZM/EXAMS model results are available and show estimated residues approximately 3 X less than the GENEEC peak and 21-day estimates. However, by 60-days the residue estimates were just slightly less than the GENEEC results.

Chemical N

PRZM/EXAMS model results are available and show estimated residues approximately 11 X less than the GENEEC peak, 21-day, and 60-day estimates.

Chemical P

PRZM/EXAMS model results are available and show estimated residues approximately 6 X less than the GENEEC peak and 21-day estimates. By 60-days the residue estimates were approximately 4 X less than the GENEEC results.

D. Scenario #1 - Baseline Plus Ecological Risk Characterization Information

The software has a scenario function where the weights and ratings of the criteria in the baseline can be changed to answer "What if...?" questions. Thus, we asked "What if the ratings of the criteria change based on the additional information in Section C above? Then, "Which are the insecticides used on alfalfa are less risky?" For this scenario, we modified the criteria ratings for % risk and # of incident reports using the information in Table 12. The results for Scenario #1 are presented in Figure 12. below.

Figure 12. Scenario #1: Decision Table for Which Insecticides Used on Alfalfa are Less Risky

	# of bird incident reports	# of fish incident reports	% avian acute bird/day risk	% avian chronic risk	% avian dietary risk	% freshwater fish acute risk	% freshwater fish chronic risk	% freshwater invertebrate acute risk	% freshwater invertebrate chronic risk	% Marine/Estuarine Crustacean Acute Risk	% Marine/Estuarine Fish Acute Risk	% Marine/Estuarine Mollusc Acut	Summary
Chemical P	N/A	N/A	0.00	1.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.97
Chemical M	N/A	N/A	0.00	0.00	0.00	0.00	0.00	3.00	0.00	1.00	0.00	0.00	9.93
Chemical N	N/A	N/A	0.10	3.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.90
Chemical I	N/A	N/A	0.00	0.00	0.00	1.00	0.00	2.00	1.00	3.00	0.00	0.00	9.89
Chemical K	N/A	N/A	0.80	22.00	0.50	4.00	0.00	0.00	0.00	6.00	0.00	0.00	9.15
Chemical D	Poor	N/A	0.40	2.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.03
Chemical L	N/A	N/A	0.90	12.00	78.80	0.00	0.00	2.00	0.00	1.00	0.00	0.00	8.56
Chemical C	N/A	N/A	3.90	20.00	8.20	7.00	4.00	9.00	12.00	24.00	22.00	0.00	8.08
Chemical B	Poor	Poor	0.00	7.00	0.00	85.00	55.00	28.00	2.00	7.00	78.00	0.00	5.21
Chemical G	Poor	N/A	93.30	32.00	10.70	1.00	40.00	56.00	86.00	58.00	0.00	100.00	2.84

Table 12. Data for Scenario #1

Pesticides Used on Alfalfa as Post-Emergent Sprays

(Includes Risk Characterization Information; Compare with Table 5)

Birds

Chemical Name	% Avian Acute Bird/Day Risk	% Avian Chronic Risk	% Avian Dietary Risk	% Acres Treated
C	3.9%	20%	8.2%	29.7%
D	0.4%	2%	0.1%	26.3%
G	93.3%	32%	10.7%	16.0%
I	0.0%	0%	0.0%	12.2%
L	0.9%	12%	78.8%	11.6%
P	0.0%	1%	0.1%	2.8%
K	0.8%	22%	0.5%	0.6%
M	0.0%	0%	0.0%	0.4%
B	0.0%	7%	0.0%	0.3%
N	0.1%	3%	0.1%	0.0%

Aquatic Organisms

Chemical Name	% Freshwater Fish Acute Risk	% Freshwater Fish Chronic Risk	% Marine/Estuarine Fish Acute Risk	% Freshwater Invertebrate Acute Risk	% Freshwater Invertebrate Chronic Risk	% Marine/Estuarine Crustacean Acute Risk	% Marine/Estuarine Mollusc Acute Risk	% Acres Treated
C	7%	4%	22%	9%	12%	24%	0.0%	29.7%
D	0%	0%	0%	0%	0%	0%	0.0%	26.3%
G	1%	40%	0%	56%	86%	58%	100.0%	16.0%
I	1%	0%	0%	2%	1%	3%	0.0%	12.2%
L	0%	0%	0%	2%	0%	1%	0.0%	11.6%
P	0%	0%	0%	0%	0%	0%	0.0%	2.8%
K	4%	0%	0%	0%	0%	6%	0.0%	0.6%
M	0%	0%	0%	3%	0%	1%	0.0%	0.4%
B	85%	55%	78%	28%	2%	7%	0.0%	0.3%
N	0%	0%	0%	0%	0%	0%	0.0%	0.0%

Incidents

Chemical Name	*# Reports - Birds*	*% Total Reports - Birds*	*# Reports - Fish*	*% Total Reports - Fish*
C	0	0%	0	0%
D	3	50%	0	0%
G	1	3%	0	0%
I	0	0%	0	0%
L	0	0%	0	0%
P	0	0%	0	0%
K	0	0%	0	0%
M	0	0%	0	0%
B	1	17%	1	0%
N	0	0%	0	0%

The addition of the risk characterization information provided results which are very similar to the baseline. After a careful evaluation of each option in Scenario #1, once again Chemical P appears to be the best choice. This time there were eight top choices, with the addition of Chemical C. In the baseline, Chemical C followed the worst choice, Chemical G. For Scenario #1, the worst choice again was Chemical G, but his time it is followed by Chemical B.

E. Additional Scenarios - Changes in Criteria Importance

As noted previusly, one of the simplifications of the methodology used in the decision analysis software is that there are no uncertainties. Certainly comparative ecological risk analysis involves much uncertainty. Since the software permits the user to deal with some uncertainty is by running multi-scenarios, we chose to run seven additional scenarios for the case study. These runs show how sensitive the differences between pesticides are to change in the importance of the criteria. The results can add confidence to overall conclusions. The additional scenarios are listed below. The summary columns are presented in Figure 13 below. The different scenarios reflect changes in the importance given to various endpoints and groups of endpoints. In two scenarios, certain criteria are considered to be unimportant and do not contribute to the comparison. They reflect differences in importance that can typically arise during ecological risk assessments, and during discussion with risk managers.

Scenario #2 - Additional Risk Characterization Data Added; Bird Endpoints are Rated High; All Other Endpoints are Rated Medium

Scenario #3 - Additional Risk Characterization Data Added; Aquatic Emdpoints are Rated High; All Other Endpoints are Rated Medium

Scenario #4 - Additional Risk Characterization Data Added; Bird & Fish Incidents are Rated as N/A; All Other Endpoints are Rated Medium

Scenario #5 - Additional Risk Characterization Data Added; Marine/Estuarine Endpoints are Rated as N/A; All Other Endpoints are Rated Medium

Scenario #6 - Additional Risk Characterization Data Added; Fish Endpoints are Rated High; All Other Endpoints are Rated Medium

Scenario #7 - Additional Risk Characterization Data Added; Aquatic Invertebrate Endpoints are Rated High; All Other Endpoints are Rated Medium

Scenario #8 - Additional Risk Characterization Data Added; Bird Endpoints are Rated High; Aquatic Endpoints are Rated Low

Scenario #9 - Additional Risk Characterization Data Added; Aquatic Endpoints are Rated High; Bird Endpoints are Rated Low

The results in Figure 13 show that Chemicals P, N, M, I, K, and D were consistently rated as top options regardless of the changes in importance values for the twelve criteria. Chemical P was the top option for all scenarios except #8 where bird endpoints were given a high importance and aquatic endpoints a low importance. In this scenario, Chemical M was the top choice, closely followed by Chemical P. Chemical C was a top option except in the baseline option. Chemical L was a top option in all scenarios exept scenario #8. Alternately, Chemical G is consistently rated at the bottom as the worst option in all scenarios. Chemical B was the second worst option except for the baseline scenario where Chemical B and C were rated equal as the second worst option. In scenario #8, Chemicals B and L were equal as the second worst option. Chemical D made the largest change within the top options in scenario #4 where incidents were rated as unimportant.

Figure 13.
Scenario Summary

Baseline Scenario		*Scenario #1*		*Scenario #2*		*Scenario #3*		*Scenario #4*		*Scenario #5*		*Scenario #6*		*Scenario #7*		*Scenario #8*		*Scenario #9*	
Chemical P	9.94	Chemical P	9.97	Chemical P	9.95	Chemical P	9.98	Chemical P	9.97	Chemical P	9.95	Chemical P	9.97	Chemical P	9.98	Chemical M	9.96	Chemical P	9.9
Chemical N	9.89	Chemical N	9.93	Chemical M	9.95	Chemical N	9.94	Chemical D	9.93	Chemical M	9.92	Chemical N	9.96	Chemical N	9.93	Chemical P	9.94	Chemical N	9.9
Chemical M	9.89	Chemical M	9.90	Chemical I	9.91	Chemical M	9.92	Chemical M	9.93	Chemical I	9.92	Chemical M	9.93	Chemical M	9.90	Chemical I	9.93	Chemical M	9.9
Chemical I	9.81	Chemical I	9.89	Chemical N	9.85	Chemical I	9.87	Chemical N	9.90	Chemical N	9.86	Chemical I	9.91	Chemical I	9.85	Chemical N	9.82	Chemical I	9.8
Chemical K	9.25	Chemical K	9.15	Chemical K	8.80	Chemical K	9.41	Chemical I	9.89	Chemical K	8.92	Chemical K	9.31	Chemical K	9.32	Chemical K	8.59	Chemical K	9.5
Chemical D	9.04	Chemical D	9.03	Chemical D	8.58	Chemical D	9.41	Chemical K	9.15	Chemical D	8.66	Chemical D	9.24	Chemical D	9.29	Chemical D	8.31	Chemical D	9.5
Chemical L	8.33	Chemical L	8.56	Chemical C	7.93	Chemical L	9.13	Chemical L	8.56	Chemical C	8.24	Chemical L	8.89	Chemical L	8.93	Chemical C	7.84	Chemical L	9.3
Chemical B	7.47	Chemical C	8.08	Chemical L	7.83	Chemical C	8.19	Chemical C	8.08	Chemical L	7.97	Chemical C	8.19	Chemical C	8.12	Chemical L	7.37	Chemical C	8.2
Chemical C	6.51	Chemical B	5.21	Chemical B	5.65	Chemical B	4.86	Chemical B	6.14	Chemical B	4.86	Chemical B	3.98	Chemical B	6.02	Chemical B	5.91	Chemical B	4.7
Chemical G	2.57	Chemical G	2.48	Chemical G	2.66	Chemical G	2.99	Chemical G	3.13	Chemical G	2.65	Chemical G	3.85	Chemical G	2.08	Chemical G	2.55	Chemical G	3.0

Baseline Scenario - All Criteria Medium Importance

Additional Scenario #1 - Additional Risk Characterization Information Added; All Criteria Medium Importance

Additional Scenario #2 - Additional Risk Characterization Information Added; Bird Endpoints High Importance; All Other Medium

Additional Scenario #3 - Additional Risk Characterization Information Added; Aquatic Endpoints High Importance; All Other Medium

Additional Scenario #4 - Additional Risk Characterization Information Added; Bird & Fish Incidents rated as N/A; All Other Medium

Additional Scenario #5 - Additional Risk Characterization Information Added; Marine/Estuarine Endpoints Rated as N/A; All Other Medium

Additional Scenario #6 - Additional Risk Characterization Information Added; Fish Endpoints High Importance; All Other Medium

Additional Scenario #7 - Additional Risk Characterization Information Added; Aquatic Invertebrate Endpoints High Importance; All Other Medium

Additional Scenario #8 - Additional Risk Characterization Information Added; Bird Endpoints High; Aquatic Endpoints Low

Additional Scenario #9 - Additional Risk Characterization Information Added; Aquatic Endpoints High; Bird Endpoints Low

In summary, the insecticides used on alfalfa as postemergent sprays which are potentially the least risky based on the comparison using *DecideRight* software, including multi-scenarios, are these six:

Chemical P

Chemical N

Chemical M

Chemical I

Chemical K

Chemical D

Chemical P is the top option except where bird endpoints are rated high and aquatic endpoints rated low. In this case, Chemical M is the top option. Alternately, Chemical G is the worst option across all scenarios, and Chemical B is consistently rated as the second worst option.

This summary is similar to the summary based on the previous graphical analysis above:

"In summary for postemergent sprays on alalfa, Chemical G stands out as presenting the greatest potential acute and chronic risk to birds, and aquatic invertebrates, and chronic risk to fish. The acute risk to birds appears to be supported by and incident report. Chemical B presents the greatest acute risk to freshwater fish, Chemical C presents the greatest acute risk to marine/estuarine fish, and Chemical L presents the greatest dietary risk to birds. The bird incident reports raises a question concerning the comparatively low risk of Chemical D to birds. Overall, Chemical N, Chemical M, and Chemical P appear to be comparatively less risky than the others."

When the use of the pesticides on alfalfa is considered (See Figure 3), we find that Chemical C and Chemical D lead based on current estimates of % acres treated with greater than 20% each followed by Chemical G, Chemical I, and Chemical L at greater than 10% each. Considering the results from the two previous analyses, the overall risk to non-target organisms from insecticides used on alfalfa could be reduced by reducing the use of Chemical G.

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F. Limitations of this Analysis

This proposed methodology for comparing potential ecological risk from the use of pesticides, is intended to identify those pesticides with large differences in risk. Twelve endpoints were considered; however, other endpoints such as effects on wild mammals, non-target plants, non-target insects, reptiles and amphibians were not included. These could be included in a more comprehensive analysis.

The available ecotoxicity and environmental fate data were limited, so that in some cases missing values had to be estimated so that the comparison could proceed. The tools used to estimate missing values is not perfect as shown by the later submission of an avian chronic NOAEC value of 1 ppm for Chemical K, which differed significantly from the estimated value of 23 pm.

The exposure estimates were based on maximum label rates and one-half those rates. Ideally, typical rates would be better information to use for comarison. It is interesting to note that while refined aquatic EEC estimates based on PRZM/EXAMS were in most cases 2X to 20 X lower than the GENEEC EECs, the overall top options and worst options did not change significantly (compare the summary for the Baseline Scenario and Scenario #1 in Figure 13).

This analysis employs a number of new calculations for expressing potential risk, such as the % contribution to the RQ sum, the frequency of RQ exceedance, the % contribution to the Time to RQ=1 sum, and % risk. These have not been used beyond this analysis for these 17 pesticides. Thus, we do not know how useful they will prove to be in expressing risk for other groups and combinations of pesticides.

We have already identified a number of limitations of the decision support software, *DecideRight* and others are identified by Tashman and Munro [24]. Comparions with other decision support products have not yet been made.

IX. REFERENCES

1. Memorandum from Linda J. Fisher, Assistant Administrator, Office of Pesticides and Toxic Substances, to Douglas Campt, Director, Office of Pesticide Programs, March 26.1992. Establishment of Ecological and Environmental Fate Data Requirements Task Force

2. Memorandum from Linda J. Fisher, Assistant Administrator, Office of Pesticides and Toxic Substances, to Douglas Campt, Director, Office of Pesticide Programs, October 29, 1992. Decisions on the Ecological, Fate, and Effects Task Force.

3. U.S. EPA. 1992 (March). Comparative Analysis of Acute Avian Risk from Granular Pesticides. U.S. EPA, Office of Pesticide Programs.

4. U.S. EPA. 1994 (September). Avian Granular Risk Reduction Initiative - Progress Report. U.S. EPA, Office of Pesticide Programs.

5. OPP Ecotoxicity Data Base, 1998. Environmental Fate & Effects Division, Office of Pesticide Programs [7507C], Washington, D.C. 20460

6. Driver, C.J., M.W. Ligotke, P. Van Voris, B. D. Greenspan and D. B. Brown. 1991. Routes of uptake and their relative contribution to the toxicologic response of northern Bobwhite (*Colinus virginianus*) to an organophosphate pesticide. Environ. Toxicol. Chem. 10: 21-33.

7. Erbach, D. and J. Tollefson. 1983. Granular insecticide application for corn rootworm control. Trans. ASAE-1983. Amer. Soc. Agric. Eng. 0001-2351/83/2603-0696.

8. DeWitt, J.B. 1966. Methodology for determining toxicity of pesticides to wild vertebrates. J. Applied Ecol. 3 (suppl.):275-278.

9. U.S. EPA. 1977a. Memorandum, dated 9 September 1977, to Environmental Safety Section, OPP, U.S. EPA: Classification of granulated formulations, from R. Felthousen.

10. U.S. EPA. 1986. Hazard Evaluation Division Standard Evaluation Procedure Ecological Risk Assessment. Office of Pesticide Programs, Washington, D.C. EPA 540/9-86-167.

11. U.S. EPA. 1989. Technical Support Document for the Special Review of Carbofuran. January 1989.

12. Hoerger, F. and E. E. Kenaga. 1972. Pesticide Residues on Plants: Correlation of Representative Data as a Basis for Estimation of Their Magnitude in the Environment. IN:F. Coulston and F. Corte, eds., Environmental Quality and Safety: Chemistry, Toxicology, and Technology. Vol I. Georg Thieme Publishers, Stuttgart, West Germany, pp. 9-28.

13. Fletcher, J.S., J.E. Nellesson and T.G. Pfleeger. 1994. Literature Review and Evaluation of the EPA Food-Chain (Kenaga) Nomogram, an Instrument for Estimating Pesticide Residues on Plants. Environ. Tox. and Chem. 13(9): 1383-1391.

14. Willis, G. H. and L. L. McDowell. 1987. Pesticide persistence on foliage. Rev. Environ. Contam. & Tox. 100: 23-73.

15. Rattner, B. A., L. Sileo, and C. G. Scanes. 1982. Oviposition and the Plasma Concentrations of LH, Progesterone and Corticosterone in Bobwhite Quail *(Colinus virginianus)* fed Parathion. J. Reprod. Fert. 66: 147-155.

16. Bennett, J. K. and R. S. Bennett. 1990. Effects of Dietary Chemical L on Northern Bobwhite Egg Production and Eggshell Quality. Environ. Toxicol. Chem. 19: 907-912.

17. Bennett, R. S. and L. M. Ganio. 1991. Overview of Methods for Evaluating Effects of Pesticides on Reproduction in Birds. U. S. EPA. Environmental Research Laboratory, Corvallis, OR. EPA 600/3-91/048.

18. Hill, E. F. 1994. Acute and Subacute Toxicology in Evaluation of Pesticide Hazard to Avian Wildlife. IN: R. J. Kendall and T. E. Lacher, Jr., eds., Wildlife Toxicology and Population Modeling: Integrated Studies of Agroecosystems. Special Publication of Society of Environmental Toxicology and Chemistry. Lewis Publishers, Boca Raton, FL. pp. 207-226 (Chapter 22).

19. Nagy, K. A. 1987, Field metabolic rate and food requirement scaling in mammals and birds. Ecol. Monogr. 57:111-128.

20. U. S. EPA. 1993. Wildlife Exposure Factors Handbook. Volume I of II. EPA/600/R-93/187a. Office of Research and Development, Washington,

D.C. 20460. p. 3-4.

21. R. D. Parker, H. P. Nelson, R. D. Jones*, 1995. GENEEC: A Screening Model for Pesticide Environmental Exposure Assessment. The International Symposium on Water Quality Modeling, American Society for Agricultural Engineering. Orlando, Florida, 1995.

22. U.S. EPA. 1994 (July). Ecological Incident Information System. U.S. EPA, Office of Pesticide Programs.

23. Brassard, C. A., L. P. Kendrick, S. M. Lees, and A. F. Maciorowski. In press. An overview of ecological incident monitoring and reporting. Society of Environmental Chemistry and Toxicology.

24. Tashman, L. and S. Munro. 1997 (January 15, 1997). Software Review - DecideRight. In The Forum, the newsletter of the International Associaction of Business Forecasting. [http://www.loyola.edu/iabf/form.htm]

25. Goodwin, P. and G. Wright. 1991. Decision Analysis for Management Judgement. John Wiley & Sons, publisher.

26. Carsel, R.F., C.N. Smith, L.A. Mulkey, J.D. Dean and P. Jowise. 1984. Users manual for pesticide root zone model (PRZM): Release 1, Rep.EPA-600/3-84-109, 219 pp. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.

27. Mullins, J.A., R.F.Carsel, J.E. Scarbrough and A.M. Ivery. 1993. PRZM2 users manual version 1.0, Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens GA.

28. Burns, L.A. 1991. Exposure analysis modeling system: users guide for EXAMS II version 2.94, Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA.