Higher-tier risk characterization of agricultural uses of synthetic pyrethroids: species sensitivity distributions, species response distributions, risk quotients, joint probability curves, and risk statements

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PYRETHROID WORKING GROUP

Introduction

The higher-tier risk assessment of synthetic pyrethroids conducted by the Pyrethroid Working Group (PWG) is presented in poster 949, and elements of the assessment are described in many other posters and presentations at this IUPAC Congress. This poster discusses the risk characterization, using the assessment of deltamethrin as an example. Quantitative risk characterization, incorporating Risk Quotients for standard and lower tier EEC's and Joint Probability Curves for more refined assessments, shows that the potential aquatic risk of deltamethrin use is much lower than indicated by the screening-level assessment for a wide range of crops. Consideration of other factors that affect the behavior of pyrethroids in the environment suggests that even the refined exposure assessments over-predict real-world concentrations. The results of the probabilistic risk assessment are expressed in the form of risk statements that accurately describe the underlying assumptions and uncertainties.

Risk Quotients

$$\text{Risk Quotient (RQ)} = \frac{\text{Estimated Exposure Concentration (EEC)}}{\text{Toxic Effect Endpoint}}$$

RQs at all tiers of the assessment were calculated using the upper end of the exposure concentration range (based on conservative exposure modeling) and the lower end of the toxicity range for each taxonomic group (plants, mollusks, arthropods, and fish). The EEC was selected as the 90th percentile (1-in-10 years or 1-in-10 site-years) of the annual maximum 24-h or 21-d time-weighted average in the water column or the 21-d time-weighted average in the sediment pore water. Toxic effect endpoints for each taxon were selected to represent the lowest acute (LC50) or chronic (NOEC) concentration, or (when data were available for 6 or more species) the 5th percentile of the Species Sensitivity Distribution (i.e., the HC5). RQs were compared with Levels of Concern (LOCs) established by the US EPA, which are 0.05 for acute risk to threatened and endangered (listed) species, 0.5 for acute risk to non-listed species, and 1 for chronic risk. When the RQ exceeds the LOC, a refined assessment or further evaluation of risk is needed. As an example, the table below shows the RQs at each tier of the assessment for deltamethrin use on cotton. RQs for soybeans are shown in Poster 949. Both examples illustrate the reduction in RQs at higher tiers of the assessment.

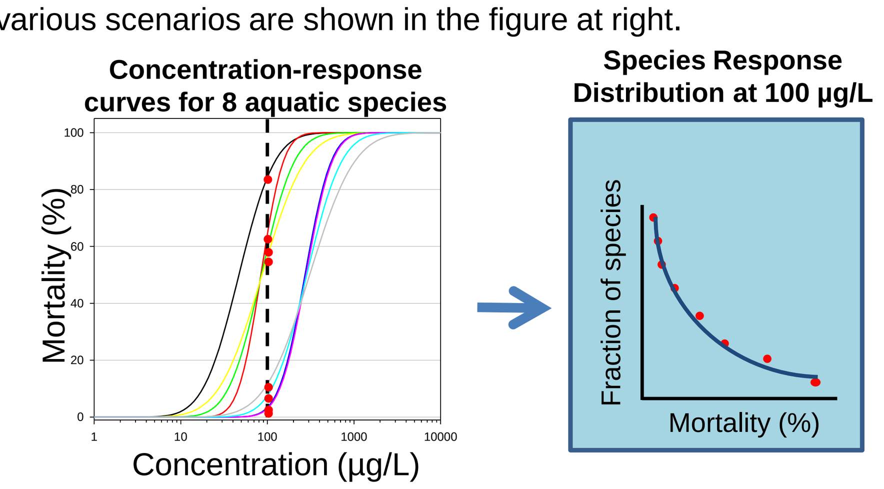
Risk Quotients for deltamethrin: cotton

	Plants	Mollusks	Fish			Arthropods (Insects and Crustaceans)			
Cotton			Acute	Chronic Freshwater	Chronic Saltwater	Acute water	Chronic Freshwater	Chronic Saltwater	Pore Water
Tier II	<0.01	<0.01	0.96	1.1	0.79	319	6.3	35	16
Tier II+	<0.01	<0.01	0.08	0.22	0.16	13	1.6	9.2	2.6
Tier II+AR	<0.01	<0.01	0.10	0.21	0.15	10	1.7	9.4	2.9
LR1	<0.01	<0.01	0.01	<0.01	<0.01	3.4	0.19	1.1	0.29
LR2	<0.01	<0.01	0.01	<0.01	<0.01	3.1	0.25	1.4	<0.01
LR2+PTA	<0.01	<0.01	<0.01	<0.01	<0.01	0.12	0.01	0.05	<0.01

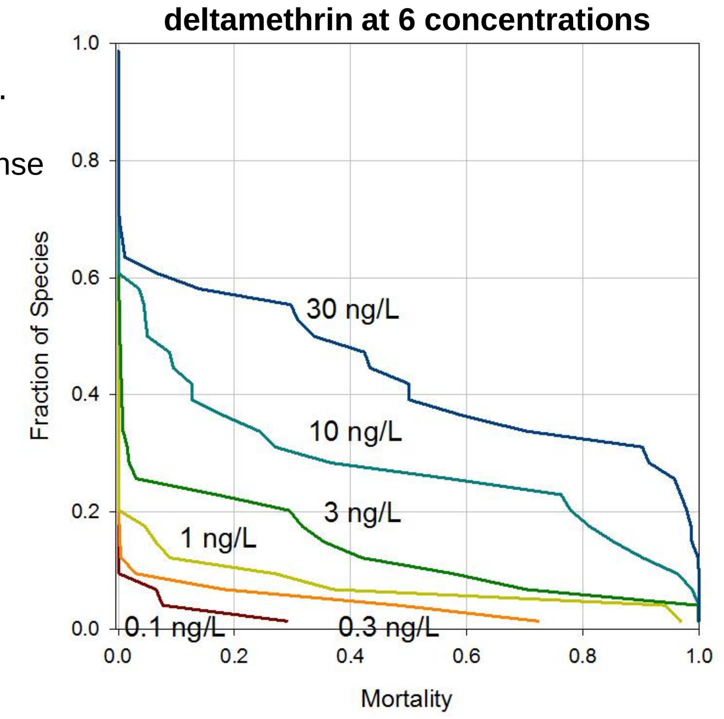
KEY
RQ < LOC for listed species
RQ < LOC for non-listed species
RQ < 2x LOC
RQ > 2x LOC

Species Response Distributions

Concentration-response curves for each species allow estimation of the response (e.g. mortality) of each species to a given exposure concentration. The distribution of species responses indicates the magnitude of ecological effect within an ecological community at that concentration. Species Response Distributions for deltamethrin at 6 concentrations that span the EECs for various scenarios are shown in the figure at right.



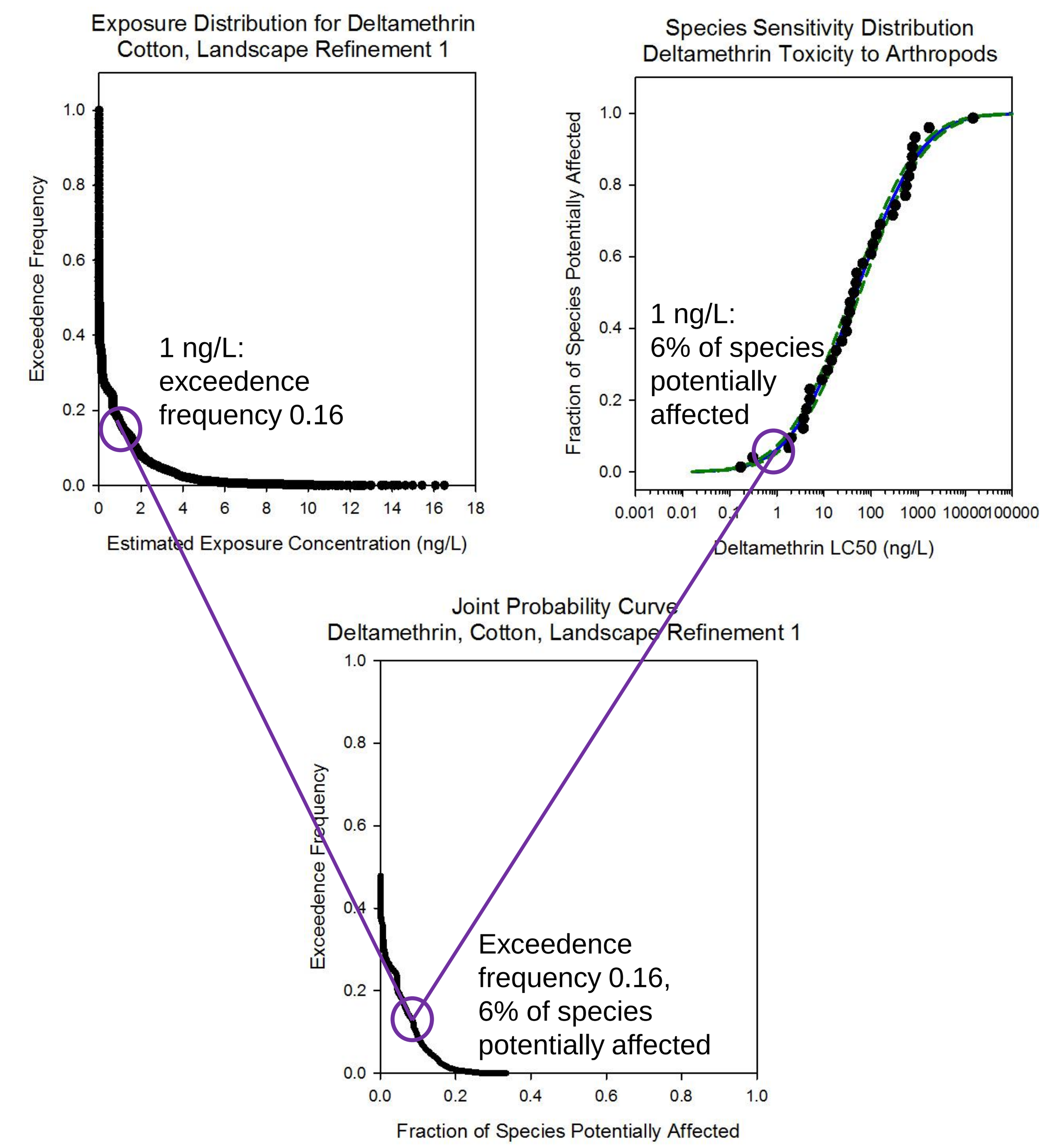
Species Response Distributions for deltamethrin at 6 concentrations



Joint Probability Curves

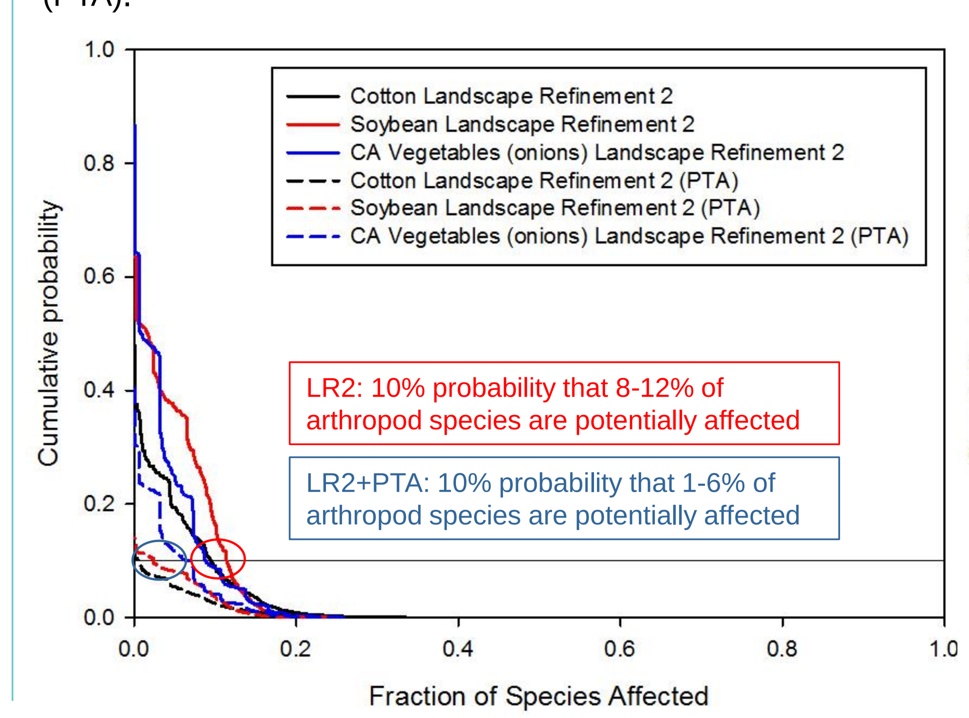
RQs are intentionally conservative, based on the most sensitive toxicity endpoint and the 90th percentile EEC. However, in a probabilistic risk assessment, a probabilistic risk characterization more fully represents the underlying data.

Joint Probability Curves (JPCs) integrate the full distribution of EECs (not only the 90th percentile as used in RQs) with the full distribution of toxicity data (the Species Sensitivity Distribution, SSD) as illustrated at right. Each EEC has a predicted exceedence frequency, and that concentration is associated with potential effects on a particular fraction of species as indicated by the SSD. The JPC is constructed by linking each value in the EEC distribution with a fraction of potentially affected species determined from the SSD. The result is a cumulative frequency distribution of the fraction of species affected, depicting the relationship between the magnitude of potential effect and the likelihood of its occurrence. JPCs from the deltamethrin risk assessment are shown in the figures below.



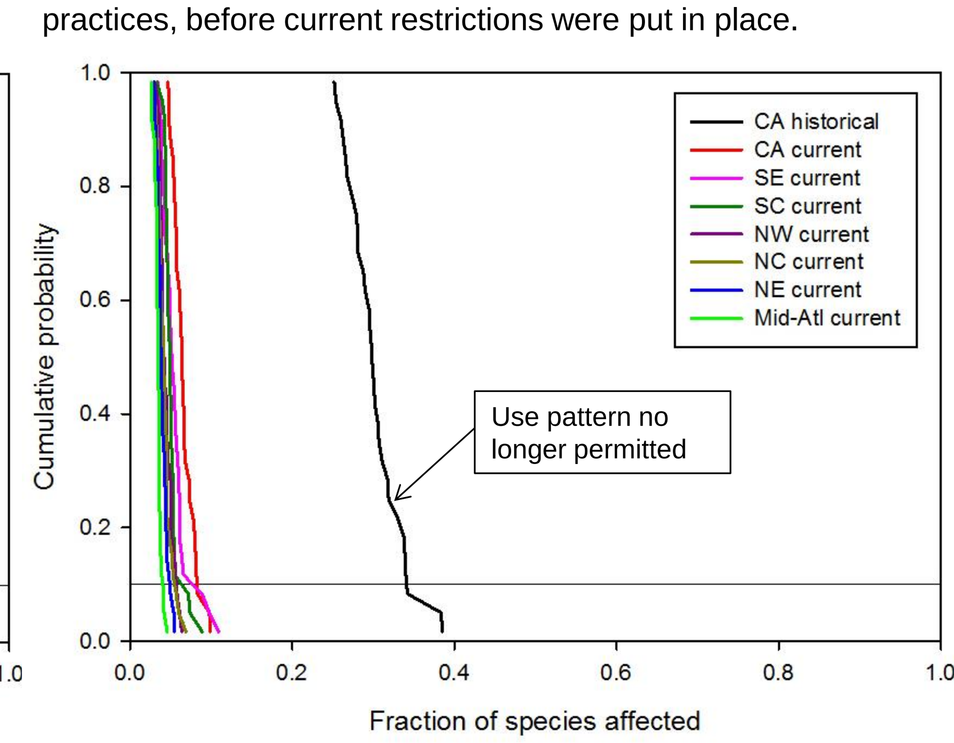
Joint Probability Curves for deltamethrin: agricultural uses

The figure below shows JPCs for 3 crops at the highest tier of the deltamethrin risk assessment (Landscape Refinement 2), with and without incorporation of data on Percent Treated Area (PTA).



Joint Probability Curves for deltamethrin: residential uses

The figure below shows JPCs for residential uses of deltamethrin in California and 6 other regions of the US. The "historical" California scenario represents previous application practices, before current restrictions were put in place.



Risk Statements

A key element of any risk assessment is a clear and precise statement of risk. This is especially challenging in a probabilistic risk assessment, where statements about "likelihood" are meaningful only in the context of the assumptions – implicit and explicit – under which the risk estimates are made. Risk statements can be framed differently to address specific questions, such as, "What fraction of water bodies in a watershed, a region, or nationally are expected to exceed the threshold of ecological effects more than 1 year in 10 as a result of this use pattern?" or "What fraction of arthropod species in static water bodies resembling the EPA standard pond will be affected in fewer than 10% of years, with all residential applications made at the maximum labeled rate?" Such risk statements are accompanied by a full accounting of the assumptions of the exposure modeling, such as the dimensions of the water body, the watershed landscape, soil properties, climate, and application frequencies and practices, as well as a clear definition of the threshold for ecological effects.

Here is an example of a risk statement from the highest tier (Landscape Refinement 2) of the deltamethrin risk assessment:

> In 90% of EPA standard aquatic exposure modeling water bodies receiving drift and runoff from the national or regional distribution of small watersheds that have grown any crop of interest between 2008 and 2012, the fraction of arthropod species affected (i.e., exposed to the LC50 concentration in the water column for at least 24 h) is not expected to exceed the following value in any given year: **5.8% (cotton, nationally), 10% (soybeans, nationally), 11% (vegetables, California).** These values reflect the drift load distribution from the percentage of cropped area within 10- to 50-m and 50- to 200-m proximity zones around each water body, coupled with the runoff/erosion load distribution based on local rainfall and soils in small watersheds growing the crop of interest in 2012.

Statements such as this one are accompanied by a detailed analysis of the assumptions and uncertainties upon which the conclusions depend. A major assumption in all of the exposure modeling in the pyrethroid risk assessments is the use of the standard EPA pond scenario (1-ha pond 2 m deep receiving runoff and drift from a 10-ha watershed) to represent the receiving water body. Another key assumption is that growers have universally adopted the long standing drift and erosion mitigation requirements (no-spray buffers, vegetative filter strips) that have been specified on all pyrethroid labels for the past 20 years. Many other assumptions and uncertainties affect the risk estimates. For example, these quantitative risk estimates assume that the wind speed is always the maximum allowed on the product label and the wind always blows from the treated area toward the water body, even when an individual crop receives multiple applications throughout the growing season. While these assumptions and uncertainties can affect the risk estimates in either direction, in combination they are likely to result in at least an order of magnitude of additional (unquantified) protection.

Risk Description and Ecological Relevance

In addition to the quantitative risk characterization approaches reflected by RQs and JPCs, other information about the ecological relevance of the potential effects is incorporated qualitatively into the description of risk. Species Response Distributions (see section at lower left of this poster) are one component of the risk description. Other factors taken into account in evaluating the ecological relevance of potential effects include:

- The non-homogeneous distribution of the pesticide, resulting in microhabitats and areas of low exposure. These constitute refugia which provide a source for population recovery and recolonization of affected areas.
- Populations of some species differ widely in their sensitivity to pyrethroids. It has been found that populations of some taxa in the field, notably the amphipod *Hyalella azteca*, are much less sensitive than lab cultures. Thriving populations of *H. azteca* have been observed in many streams where severe effects were predicted based on laboratory toxicity tests.
- Results of bioassessments of many California streams have shown no correlation between pyrethroid concentrations and benthic macroinvertebrate communities.
- Mesocosm studies have demonstrated that many sensitive invertebrate populations recover from exposure to pyrethroids at concentrations that greatly exceed the toxicity endpoints used in RQs and JPCs.

Consideration of these qualitative factors suggests that the quantitative risk characterization is protective of aquatic life. As shown in the accompanying poster 949, the tiered aquatic risk assessment concluded that ***deltamethrin exposure from residential and agricultural uses according to current labels is unlikely to cause ecologically significant effects in aquatic systems.***

Acknowledgements

The Pyrethroid Working Group (PWG) is a US task force whose members include eight primary pyrethroid registrants (AMVAC Chemical Corporation, BASF Corporation, Bayer CropScience LP, Cheminova A/S, DuPont Crop Protection, FMC Corporation, Syngenta Crop Protection, LLC, Valent U.S.A. Corporation).