Perspectives on the Derivation of Aquatic Life Criteria for Pesticides

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Pesticides represent a special case for derivation of Aquatic Life Criteria

- Pesticides may be transported to surface waters by spray drift or surface runoff from outdoor application sites. Exposure to aquatic life, when it occurs, is typically brief and intermittent.
  - Chronic exposure may occur when a pesticide is applied repeatedly during a growing season, or when persistent pesticides remain in the water column or sediment.
- Pesticides may also be applied directly to surface waters for control of nuisance plants and other invasive species.
- Pesticide labels include instructions for use that are specifically aimed at reducing exposure and risk to the aquatic environment.

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Pesticides represent a special case for derivation and application of Aquatic Life Criteria

- A suite of aquatic toxicity tests are required for registration of pesticides under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).
  - Freshwater and estuarine/marine invertebrates
  - Warm water, cold water, and estuarine/marine fish
  - Algae and a representative vascular aquatic plant (duckweed)
- OPP's Environmental Fate and Effects Division (EFED) conducts a comprehensive ecological risk assessment on all pesticides before approving registration or continuing registration.

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Issues related to ALC derivation and implementation for pesticides

- Protection goals for aquatic animals and plants
- Selection of toxicity data for ALC
- Statistical methods for Species Sensitivity Distributions
- Acute-to-chronic ratios (ACRs)
- Concentration averaging periods and return frequencies
- Use of mesocosm data to inform or adjust ALC
- Triggers for adjusting ALC to protect key species

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Protection goals and toxicity endpoints for aquatic animals and plants

- Protection goals
  - Animals: population abundance, persistence
  - Plants: community function and structure
- Toxicity endpoints
  - Animals: reduced survival, growth, reproduction
  - Plants: reduced growth (individuals or populations)
- Implications for plant-based ALC
  - Protection goals for plants are compatible with a greater fraction of species affected (e.g., HC20), longer durations, greater frequencies of exceedance than for animals.
    - Plant community function in mesocosms studies is generally not impaired by exposure below the HC20.

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Selection of toxicity endpoints for ALC derivation

- Sensitivity or relevance?
  - Endpoints should be related to protection goals.
- Measured parameters
  - Animals: survival, growth, reproduction
  - Plants: standing crop (e.g. dry weight, chlorophyll, shoot length, frond count); growth rate can be calculated from standing crop measurements repeated over time
  - These endpoints are more sensitive (more conservative) than population- and community-level protection goals.
- Data quality must be considered when selecting toxicity data.

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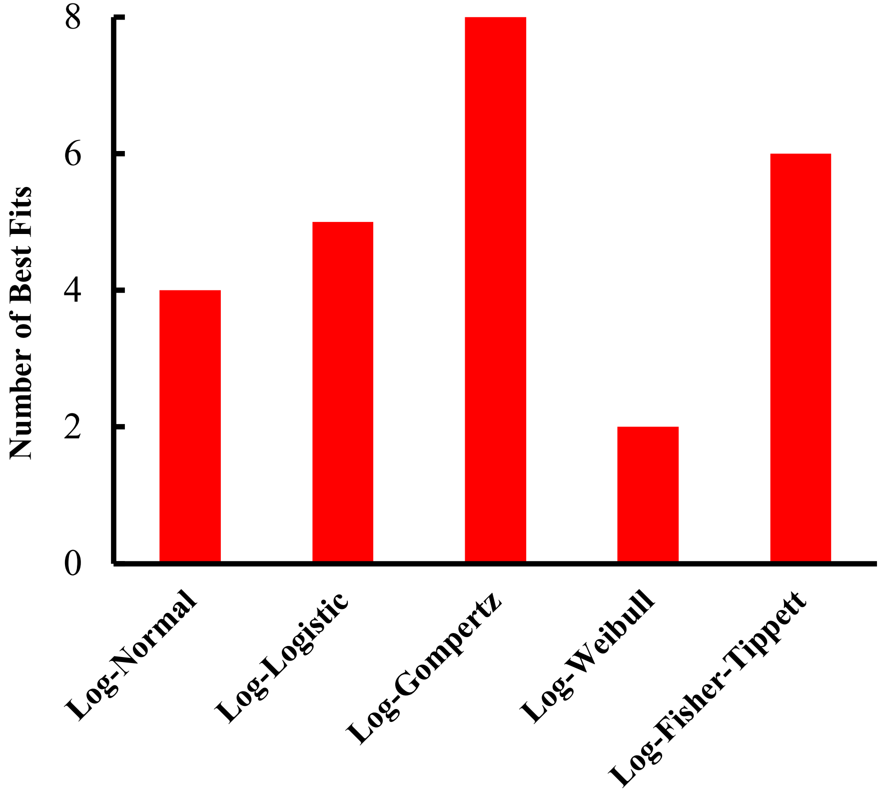
Statistical methods for Species Sensitivity Distributions (SSDs)

- No one distribution suitable for all pesticides
  - Need to test range of distributions
  - Can use a variety of tools to determine goodness-of-fit, e.g., p-p and q-q plots, Akaike's information criterion, Anderson-Darling test statistic, fit in the lower tail, etc
- Need to establish minimum sample size to ensure statistical reliability, taxonomic composition to ensure ecological relevance
- Variety of fitting methods available including maximum likelihood, regression analysis and graphical methods
  - All are acceptable
  - ORD recently developed an SSD tool that relies on maximum likelihood method

Best-fitting distributions from 25 pesticide datasets



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Acute-to-chronic ratios (ACRs)

- ACR calculated by dividing acute LC50/EC50 by a NOEC, MATC or chronic EC20
- Recommend chronic EC20, if available, given many shortcomings of hypothesis tests
  - NOELs and LOELs are always test levels and are not associated with consistent levels of effect
  - Poor experimental design = higher NOELs and LOELs
  - Most information from toxicity test ignored
  - Various studies have shown that geomean of NOEL and LOEL reasonably close to the EC20

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Guidance on selecting an ACR

Pesticide and Taxon-specific ACR

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Pesticide-specific ACR

↓

MOA and Taxon-specific ACR

↓

MOA-specific ACR

↓

Generic ACR for All Pesticides (12.4)

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Generic ACR for All Chemicals (18)

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Concentration averaging periods and return frequencies

- Acute aquatic toxicity endpoints are based on 48-h (daphnids) or 4-d exposure durations.
- Chronic toxicity endpoints are based on 21-d (daphnids) or longer (60-d, 90-d, etc) exposure durations.
- Current averaging periods (1-h acute, 4-d chronic) are overprotective when compared to the toxicity endpoints.
- 1-d or 21-d averaging periods would be more relevant, and still conservative when compared to animal toxicity data; 4-d relevant to plant toxicity data.

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Concentration averaging periods and return frequencies (continued)

- The 3-year return frequency in the 1985 guidelines was based on observed recovery times of fish populations.
- Most aquatic invertebrate species have much shorter recovery times.
  - Populations of crustaceans and many insect species recover from effects of pesticides within days or weeks, as observed in mesocosm studies. Univoltine insect populations may not recover until the following year.
  - Invertebrate population recovery is faster when nearby or upstream unexposed water bodies are present as sources for recolonization.
- Aquatic vascular plant communities typically recover from herbicide effects within the same growing season. Algae recover within days.
- For herbicides and insecticides with low toxicity to fish, even a 1-year return frequency is adequate for population and community recovery.

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Use of mesocosm data to inform or adjust ALC

- Many widely used pesticides have extensive mesocosm datasets.
- Such studies have more ecological realism than laboratory studies.
  - Include species interactions and interactions with abiotic environment.
  - Mitigating factors (e.g., binding to sediment) and recovery often incorporated in mesocosm studies.
  - Less extrapolation to protection goals, e.g., protect community function.
- Recommend using results of mesocosm studies to inform ALCs or evaluate laboratory-based ALCs.
  - Could use Brock et al. (2000) method to determine concentration where effects transition from slight to significant.
  - Can use taxon sensitivity distribution from mesocosm studies to derive HC5.

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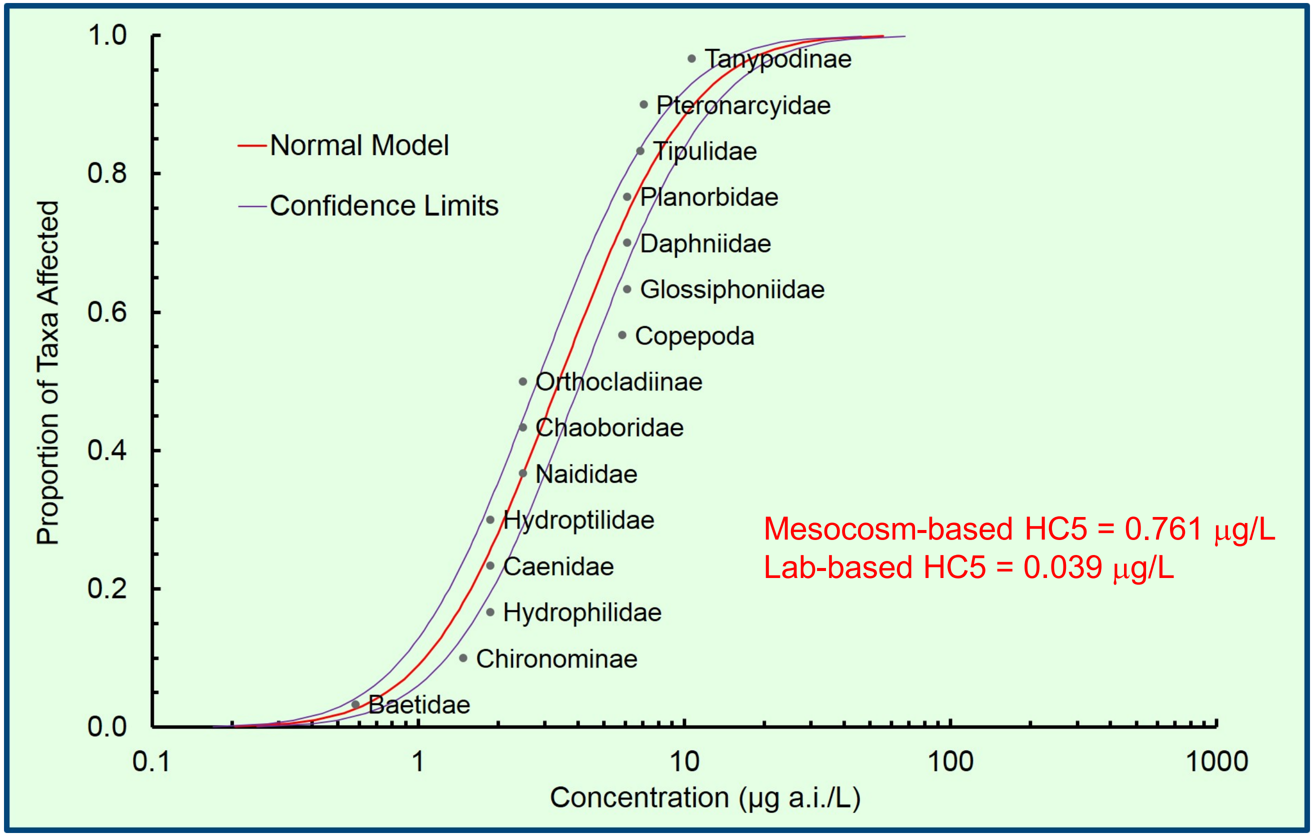
Example taxon sensitivity distribution from mesocosm studies



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Adjusting ALC to protect key species

- Current guidelines allow adjustment of ALC if necessary to protect "commercially or recreationally important species."
  - In such cases, ALC is based on the toxicity value for the more sensitive species rather than the HC5.
- Guidelines in other countries make similar allowances for certain species not protected by the HC5.
  - Canada: *species at risk (as defined by the Committee on the Status of Endangered Wildlife in Canada)*
  - Australia/New Zealand: *high conservation ecosystems (e.g. world heritage sites), important species*
  - EU: *values below the [HC5] need to be discussed…If all are from one trophic level, this could be an indication that a particular sensitive group exists.*

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Adjusting ALC to protect key species (continued)

- None of these adjustments contradicts the principle that the HC5 is adequately protective of aquatic populations and communities in general.
- In California, WQC guidelines note that the HC5 is preferred since "variability in the tails of the distributions tends to compound, rather than clarify, uncertainties (Tenbrook et al. 2009).
- However, recently proposed California WQC for some pesticides are based on the HC1 because the most sensitive species falls below the HC5, regardless of the economic or recreational value of the species.
  - *We strong disagree with this proposal. Any pesticide with >20 tested species is expected to include at least one value below the HC5, but unless the species is of special importance no criteria adjustment is warranted. As acknowledged by California guidelines, the HC1 is extremely uncertain.*

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Summary (1)

- Pesticides are required under FIFRA to be tested for toxicity to a range of sensitive aquatic plants and animals. Data quality is high because testing must follow standard guidelines and Good Laboratory Practice. Most widely used pesticides have been tested with many additional species.
- Toxicity measurement endpoints (survival, growth, reproduction) are protective of assessment endpoints for animals (population abundance, persistence) and plants (community structure and function).

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Summary (2)

- The SSD method is much superior to relying on most sensitive species, but guidance is required.
- Pesticides typically have a unique mode of action and thus care is required with extrapolation methods, e.g., ACRs.
- Concentration averaging periods for animals (1-h acute and 4-d chronic) are overprotective when compared with toxicity test exposures.
- A 3-year return frequency is overprotective for most aquatic invertebrates and plants.

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Summary (3)

- Mesocosm data should be used to derive or evaluate ALCs when available.
- Adjustment of ALC to protect sensitive species is warranted only for species of special concern.

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