Species sensitivity distributions and exposure concentrations; placing recent results into context

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Background

- Recent focus on ammonia in Delta
  - March 2009 white paper
  - March 2009 research framework

- Outstanding questions
  - "Are the US EPA chronic and acute criteria adequately protective for Delta and Suisun Bay species?"
Approach

- Build species sensitivity distributions for unionized ammonia
- Determine environmental concentrations at various locations in Delta
- Estimate risk
- Compare to current standards
Species Sensitivity Distributions

- A statistical distribution describing the variation among a set of species in their response to a chemical
  - Represented as a cumulative frequency distribution function
  - Can be used in “forward” or “inverse” manner
Forward and Inverse Use

- **Inverse**
  - Calculate a “safe” concentration, $HC_5$
  - Establishes the environmental criterion necessary to protect 95% of species

- **Forward – ecological risk assessment**
  - Estimation of the ambient concentration at a location
  - Use SSD to determine the Potentially Affected Fraction
Construction of SSD for Unionized Ammonia

- **Raw data**
  - Studies from US EPA (1999) criteria document and additional recent toxicity studies

- **Calculate Genus Mean Acute Values**
  - Corrects for over-representation of some species such as *Oncorhynchus mykiss*

- **Apply geometric mean of the acute-to-chronic ratio to obtain chronic HC₅**

- **Calculate sensitivities of HC₅ to each GMAV**
Data Manipulation

- Calculate GMAV for fish and invertebrates separately
- Transform GMAV to Log\(_{10}\) scale
- Standardize to distribution \(\mu = 0, \sigma = 1\)
- Plot SSDs
Invertebrate SSD

Invertebrate Ammonia GMAV SSD

Cumulative Frequency

Standardized Concentration

-3 -2 -1 0 1 2 3

Input
Normal

7.9%
5.0%

92.1%
90.0%

0.0%
5.0%
SSD Statistics

- **Acute invertebrate HC$_5$** = 0.259 mg/L unionized ammonia (n = 18)
  - 95% confidence bounds set by Bayesian analysis (Aldenberg et al. 2002)
  - LB AHC$_5$ = 0.092 mg/L; UB AHC$_5$ = 0.458 mg/L

- **GMACR** = 3.17

- **Chronic invertebrate HC$_5$** = 0.082 mg/L unionized ammonia (Eq 17.23 in Warren-Hicks et al. 2002)
  - LB CHC$_5$ = 0.029 mg/L; UB CHC$_5$ = 0.145 mg/L
<table>
<thead>
<tr>
<th>Genus</th>
<th>GM NH$<em>3$ LC$</em>{50}$</th>
<th>Sensitivity Upper</th>
<th>Sensitivity Median</th>
<th>Sensitivity Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eurytemora</td>
<td>0.12</td>
<td>0.379</td>
<td>0.276</td>
<td>0.208</td>
</tr>
<tr>
<td>Pseudodiaptomus</td>
<td>0.12</td>
<td>0.377</td>
<td>0.275</td>
<td>0.207</td>
</tr>
<tr>
<td>Callibaetis</td>
<td>2.95</td>
<td>0.004</td>
<td>0.021</td>
<td>0.032</td>
</tr>
<tr>
<td>Philarctus</td>
<td>10.2</td>
<td>-0.140</td>
<td>-0.078</td>
<td>-0.036</td>
</tr>
</tbody>
</table>
Vertebrate SSD

Vertebrate Ammonia GMAV SSD

- Standardized Concentration
- Cumulative Frequency

Graph showing cumulative frequency distribution with input and normal curves.
SSD Statistics

- **Acute vertebrate HC\(_5\) = 0.273 mg/ L** unionized ammonia (N = 20)
  - LB AHC\(_5\) = 0.157 mg/ L; UB AHC\(_5\) = 0.385 mg/ L (Aldenberg et al. 2002)
- **GMACR = 5.59**
- **Chronic vertebrate HC\(_5\) = 0.049 mg/ L** unionized ammonia (Eq 17.23 in Warren-Hicks et al. 2002)
  - LB CHC\(_5\) = 0.028 mg/ L; UB CHC\(_5\) = 0.069 mg/ L
## Sensitivities of HC$_5$ to GMAC Values

<table>
<thead>
<tr>
<th>Genus</th>
<th>GM NH$<em>3$ LC$</em>{50}$</th>
<th>Sensitivity Upper</th>
<th>Sensitivity Median</th>
<th>Sensitivity Lower</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypomesus</td>
<td>0.15</td>
<td>0.364</td>
<td>0.270</td>
<td>0.204</td>
</tr>
<tr>
<td>Morone</td>
<td>0.28</td>
<td>0.253</td>
<td>0.192</td>
<td>0.150</td>
</tr>
<tr>
<td>Micropterus</td>
<td>1.17</td>
<td>0.007</td>
<td>0.020</td>
<td>0.029</td>
</tr>
<tr>
<td>Gambusia</td>
<td>2.63</td>
<td>-0.133</td>
<td>-0.077</td>
<td>-0.040</td>
</tr>
</tbody>
</table>
Comparisons

- VA HC\textsubscript{5} = 0.273 mg/ L
- VC HC\textsubscript{5} = 0.049 mg/ L
- IA HC\textsubscript{5} = 0.259 mg/ L
- IC HC\textsubscript{5} = 0.037 mg/ L

- Delta smelt LC\textsubscript{50} = 0.147 mg/ L
- Delta smelt NOEC = 0.066 mg/ L
- Eurytemora LC\textsubscript{10} = 0.078 mg/ L; ACR HC\textsubscript{5} = 0.025 mg/ L
- Pseudodiaptomus LC\textsubscript{10} = 0.072 mg/ L; ACR HC\textsubscript{5} = 0.023 mg/ L
Exposure and Risk

- Risk defined as the probability of some randomly selected Exposure Concentration (EC) exceeding a randomly selected Species Sensitivity (SS).
  - Assumes the SSD represents the sensitivities of species in system.
  - Assumes the time scale of measurements of EC “matches” the time scale of measurements used in toxicity studies.
Calculations

- Simplified if both SSD and EC are normally distributed
- Standardize distribution of $\log_{10} EC$ values to distribution of $\log_{10} SS$ values
- Look up probabilities of risk in Table 5.3 of Aldenberg et al. 2002
- Calculated risk from DWR data for period 1975-1995 (uncorrected for salinity)
  - San Joaquin River near Vernalis (C10)
  - Sacramento River above Pt. Sacramento (D4)
San Joaquin River near Vernalis – Raw Data

Un-ionized Ammonia (mg/L)

C10/C10A San Joaquin River near Vernalis
note y-axis scale

A
San Joaquin River near Vernalis – Frequency Distribution

Unionized Ammonia at San Joaquin River near Vernalis

-2.000
5.0%
6.5%

-0.420
90.0%
88.2%

-0.420
5.0%
5.3%

0.5
2.0
2.5
2.0
1.5
1.0
0.5
0.0

-2.5 -2 -1.5 -1 -0.5 0 0.5

Input

Normal
Sacramento River above Pt.
Sacramento - Raw Data
Sacramento River above Pt. Sacramento - Frequency Distribution

Unionized Ammonia at Sacramento River above Pt. Sacramento

- Frequency Distribution

- Input

- Normal
Risk Calculations - Vertebrates

- **San Joaquin River near Vernalis (C10)**
  - Risk = 1.29 - 3.86%

- **Sacramento River near Pt. Sacramento (D4)**
  - Risk = 0.13 - 0.7%
Conclusions

- Are current species’ toxicity data reflective of Delta fauna?
  - Chronic HC₅ values would not be protective of 3 Delta species
- US EPA criteria may be an order of magnitude too high
- Ammonium measurements not collected at correct scale to allow comparisons to toxicity data