Welcome
Dr. Vicki Blazer
11-19-20

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Temporal Changes in Pesticide Concentrations and Biological Responses

Vicki S. Blazer, K. Smalling, S. Gordon, H. Walsh, D. Kolpin and P. Phillips

1U.S. Geological Survey, Leetown Science Center, Kearneysville, WV
Background

• Fish Health Issues
  – Fish kills of adult smallmouth bass (Potomac) and young of year (Susquehanna)
  – Skin lesions of adults and young of year
  – Multiple bacterial and viral pathogens as well as multiple and often heavy parasite infections
  – Intersex (testicular oocytes) and vitellogenin (indicators of exposure to estrogenic endocrine disruptors) in male bass
  – Population declines of an economically important species
Risk Factors

• Pesticides – found correlations of intersex with agricultural landuse and atrazine in the Potomac drainage

• Prevalence of a myxozoan parasite associated with young of year disease correlated with agricultural landuse in the Susquehanna

• More recently CART (classification and regression tree) analyses at sites throughout the Chesapeake watershed
  – Scale (upstream versus immediate catchment) matters
  – Positive correlations with estrogenicity/estrogenic endocrine disruption were:
    – Agricultural (percent cultivated, pesticide application, phytoestrogen cover crops)
    – Developed (population density, road density, impervious surface)

• However, pesticides are likely only part of the story
  – Nutrients
  – Other contaminants
  – Emerging pathogens
  – Climatic factors
Complex Interactions of Risk Factors Associated with Trematode Infections

↑ Nutrients  ↑ Temperature
Increase algal/periphyton  → Increased snail populations

Increased Trematode Infections

Atrazine

Immunomodulation  → Increased trematode cercariae

Bifenthrin

reduces aquatic insect larvae that consume cercariae

Estrogens (estrone)
Immune and Endocrine Systems

• Both can be affected during early development resulting in long term effects
• Both are regulated by soluble mediators (hormones, cytokines) and cell receptors
• Both have feedback mechanisms to regulate the response
  – Decreased response or overexpression can be detrimental
• Immune system
  – Innate – defense mechanisms in the skin mucus and elsewhere
  – Adaptive
Integrated Temporal and Spatial Monitoring

• Focused on a range of agricultural landcover
• Started with 6 sites in 2014, reduced to 4 in 2016 due to funding
• Surface water samples were collected monthly (bimonthly in the spring) from fall 2014 through fall 2019
• Adult bass health was assessed in the spring (prespawn) and fall (recrudescence)
  – Range of biological indicators including morphometric/age/condition factors, microscopic pathology, immune function, gene expression
• Young of year were collected in late spring/early summer (1-3 months old)
  – Focused on microscopic pathology
Sites

- Evaluating data at both the immediate and upstream catchment scale
- Immediate hydrologic unit containing the sampling site while upstream is the immediate plus all upstream catchments
- Some chemicals may persist longer and so upstream might be important
- Some significant differences in landcover at the two scales
## Site Land Cover

<table>
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<tr>
<th>Site</th>
<th>% Forest</th>
<th>% Developed</th>
<th>% Agriculture</th>
<th>Pasture</th>
<th>Crop</th>
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Common Pesticide Detections

• In 2014 – 2017
  – Atrazine – triazine herbicide
  – Simazine – triazine herbicide
  – Metolachlor – chloroacetanilide herbicide
  – Fipronil – insecticide

• Significant variation among sites, seasons and years
2015 Atrazine (ng/L) Site Comparison

Jan  Feb  March  April  May  June  July  Aug  Sept  Oct  Nov  Dec

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<th>Site</th>
<th>Jan</th>
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<th>Mar</th>
<th>Apr</th>
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Annual Differences in Atrazine (ng/L) Antietam and West Branch Mahantango (2016-2017)
Key Exposure Periods

March – May
- Nest/eggs – sediment/water
  - Final maturation, sperm quality

Late May - June
- Water, maternal, sediment
  - YOY – sexual differentiation and organ development

August – Dec
- Water food, sediment
  - Adults - recrudescence
Common Pesticide Detections

- Late 2017 – 2019 changed the schedule used for pesticide analyses to increase number of compounds and also included metabolites of numerous pesticides
  - Atrazine, simazine, metolachlor still most common detects and highest concentrations
  - Prometon (triazine herbicide), metribuzin (triazine herbicide), tebuthiuron (heterocyclic herbicide), 4-hydroxy chlorothalonil (fungicide metabolite), carbendazim (fungicide), imidocloprid (neonicotinoid insecticide), fipronil (insecticide)

- High concentration of atrazine and metolachlor metabolites at Antietam and West Branch Mahantango
Atrazine and Metolachlor Metabolites

• Atrazine
  - Didealkyl atrazine
  - Deisopropyl atrazine
  - Deethyl atrazine
  - Hydroxy atrazine
  - 2-Hydroxy atrazine

• Metolachlor
  - Dechlorometolachlor
  - Hydroxymetolachlor
  - Metolachlor oxanilic acid
  - Metolachlor ethanesulfonic acid
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Importance of Long-Term Integrative Data Sets

• Provides documentation of temporal changes in chemical concentrations to better understand exposure during critical time periods

• Range of biological responses measured also provide important information
  – Intersex (testicular oocytes) are most likely induced or primed during sexual differentiation
  – Plasma vitellogenin – indicative of exposures within weeks to months
  – Gene transcript changes – indicative of exposure within days

• Exposome – measure of all exposures in the individual (population) life time and how that relates to health
  – Can document exposure of adults as the go through recrudescence (development and incorporation of yolk into eggs; spermatogonia to sperm) in the fall
  – Exposure of adults prior to spring prespawn sampling
  – Exposure of eggs and young in the spring/early summer
  – Evaluate that population as it becomes sexually mature (2 years+)
Conclusions – Left with More Questions

• How do we evaluate these complex mixtures of both parent compounds and metabolites?

• Are the chronic exposures to moderate concentrations important?

• Instead of looking at one compound at a time in association with biological effects should we looking at the sum of compounds with similar structure – i.e. triazine herbicides and metabolites?

• Need long term integrative monitoring together with laboratory exposures to understand effects in wild populations
  – Lab exposures can help identify adverse outcome pathways and mechanisms, but can’t duplicate the effects of the complex mixtures and other environmental stressors
Acknowledgements

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