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Assessing the impacts of toxic mixtures over a broad geographic scale: challenges and first steps

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Assessing the impacts of toxic mixtures over a broad geographic scale: challenges and first steps

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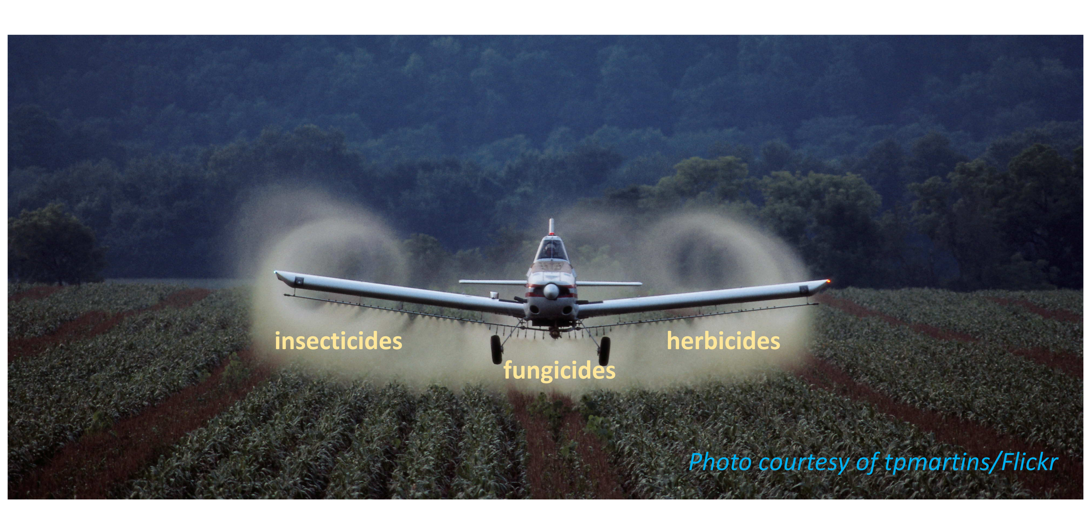
Abstract

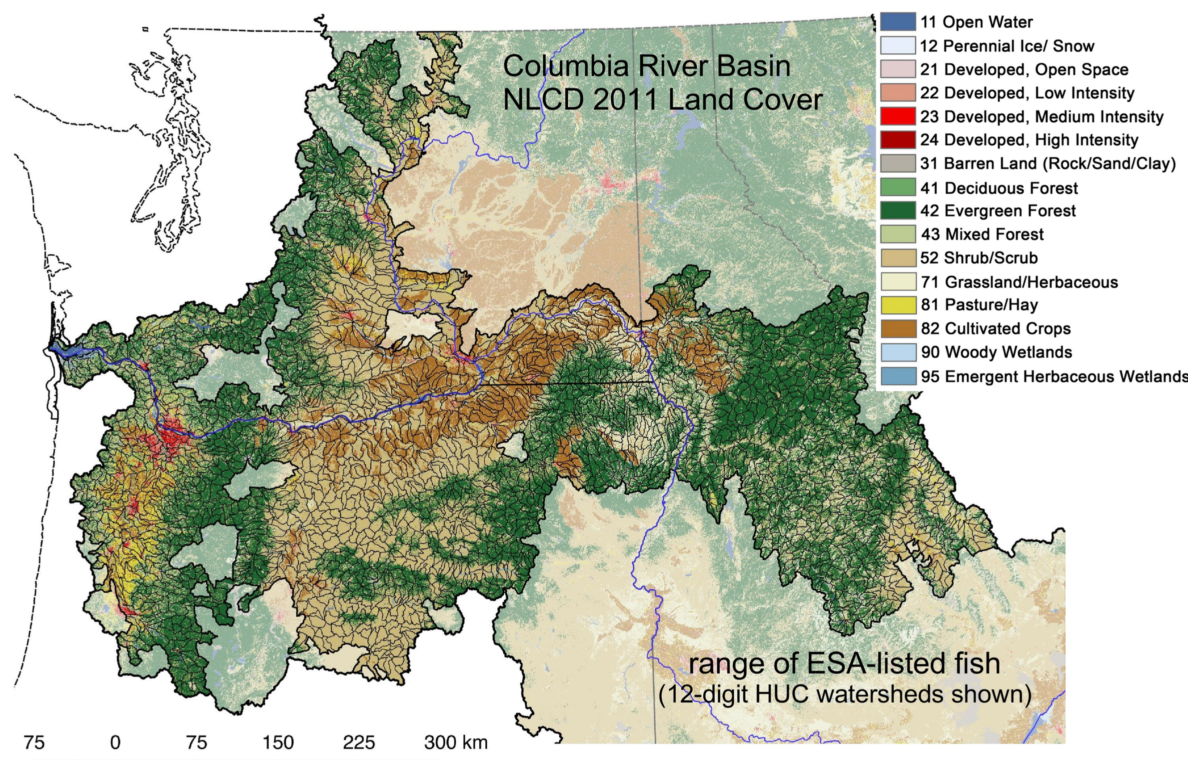
Assessing the risks posed by chemical mixtures is a complex process. Ideally, details are available on exposure (e.g. which chemicals and what concentrations) and effects (e.g. mechanisms of action and toxicity data). Even for a single location and time such as a lab or field site this can be challenging. Unfortunately, risk assessments often need to cover much larger scales such as an entire watershed or a wide-ranging species. This increase in scale substantially increases the risk assessment complexity. Thousands of chemicals in use lead to potential environmental mixture exposures, including pesticide runoff and municipal wastewater discharges. At the landscape scale the nature of chemical mixtures will vary across space and time. At this increased complexity, available monitoring data are inadequate for describing realistic exposure scenarios and effects on aquatic species. Therefore, creative solutions are required to utilize sources of data that are available to identify where and when risk is the greatest. Sources of data are available for beginning to develop a less-detailed, but still useful, landscape scale risk assessment for mixtures. These include data on potential use (e.g. crop locations and pesticide labels) or release (e.g. mapping of NPDES permits) sites. For example, the use of crop designations to represent where pesticide use is allowed can be a surrogate of actual use to establish where the greatest potential for exposure occurs. This landscape scale risk assessment for mixtures can establish priority watersheds for monitoring and further study. Similarly, aquatic species exposure to complex mixtures discharged in wastewater can be related to urban land uses and permit distributions. The goal is to develop a process to prioritize the relative risks and identify important data needs necessary for more detailed mixture analyses in the context of a landscape scale risk assessment.



Challenges

- Over 85,000 synthetic chemicals are approved for use in the United States.
- Human activity leads to the widespread contamination of aquatic habitats.
- Stormwater runoff, effluent discharges, pesticides applications are regulated activities that contaminate aquatic habitats.
- Water quality monitoring shows that contaminants are present over large geographic areas as complex mixtures.
- Exposures to many contaminants are known to be toxic to aquatic species including those listed under the Endangered Species Act (ESA).
- Many ESA-listed aquatic species have broad ranges and are likely to encounter numerous contaminants.
- Detailed information on the locations and amounts of almost all contaminants is not available.
- Assessing the risks posed by contaminant exposures to endangered species is a necessary, but daunting, task.

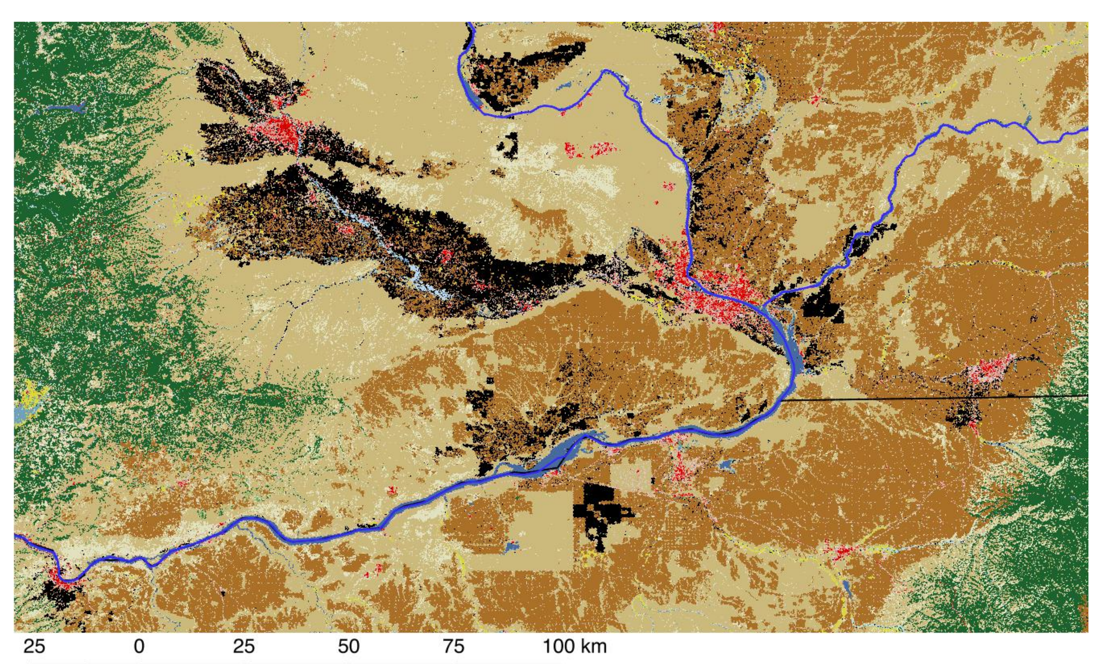
Range of ESA-listed species in the Columbia River Basin (CRB) encompasses many land uses



Use Category	% of CRB ESA range
Rangeland	33.57
Managed Forests	25.56
Pasture	10.39
Right of Way	5.02
Wheat	3.67
Other Crops	3.07
Developed	1.72
Cull Piles	1.67
Open Space Developed	1.62
Vegetables and Ground Fruit	0.90
Orchards and Vineyards	0.87
Corn	0.28
Other Grains	0.26
Christmas Trees	0.17
Other Row Crops	0.06

Left) Map of land types within the CRB highlighting the range of NMFS ESA-listed fish. Watershed boundaries based on 12-digit hydrologic units (HUCs) are denoted within the ESA-range. **Right)** Table showing land use categories and the percent of the Columbia River Basin for each category (data from EPA, 2017). Pesticides are approved for use on all of the listed use categories.

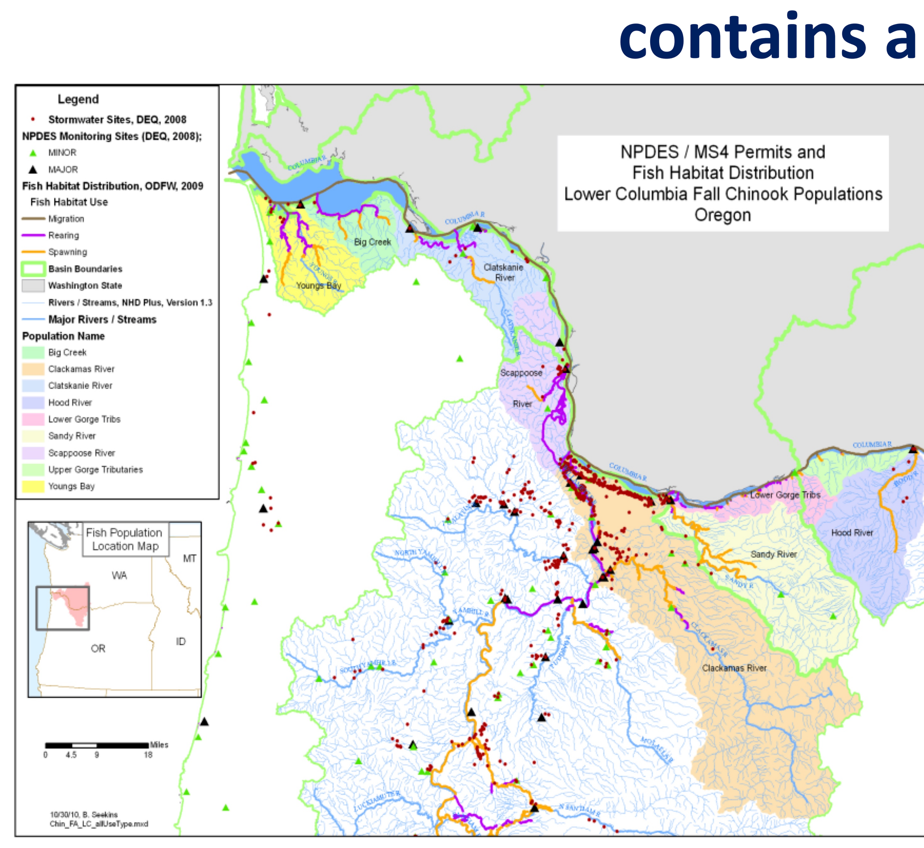
A single land use such as apple orchards in the CRB can produce a complex mixture of pesticides



Above) Enlarged area of the above map near Yakima showing the locations of orchards (**black**) (EPA, 2017). **Right)** Table of reported pesticide uses on apples in Washington State in 2015. Data from USDA's National Agricultural Statistics Survey. Pesticide uses <2% of total and those with data withheld are not listed.

Pesticide	Pounds Applied	% of Total
Insecticides		
Kaolin	558,200	49%
Petroleum distillate	175,200	15%
Chlorpyrifos	136,400	12%
Carbaryl	129,900	11%
Phosmet	38,700	3%
Diazinon	19,200	2%
Fungicides		
Calcium polysulfide	1,607,800	61%
Sulfur	704,400	27%
Mancozeb	61,500	2%
Copper oxide	52,500	2%
Copper hydroxide	48,600	2%
Herbicides		
Glyphosate iso. Salt	55,300	42%
Paraquat	24,200	18%
Glufosinate-ammonium	10,800	8%
Pendimethalin	7,800	6%
Oryzalin	5,400	4%
Oxyfluorfen	4,600	4%
2,4-d, dimeth. Salt	3,400	3%
Glyphosate amm. Salt	2,800	2%
Glyphosate	2,200	2%

CRB wastewater and runoff has numerous sources and contains a complex mixture of contaminants



Types of contaminants detected in CRB wastewater and runoff by USGS from 2008-2010

Detergent metabolites

Flame retardants (e.g. polybrominated diphenyl ethers; PBDEs)

Metals (e.g. methyl mercury, copper, zinc)

Personal care products

Pesticides (e.g. chlorpyrifos, atrazine, carbaryl, fipronil)

Plasticizers

Polycyclic aromatic hydrocarbons (PAHs)

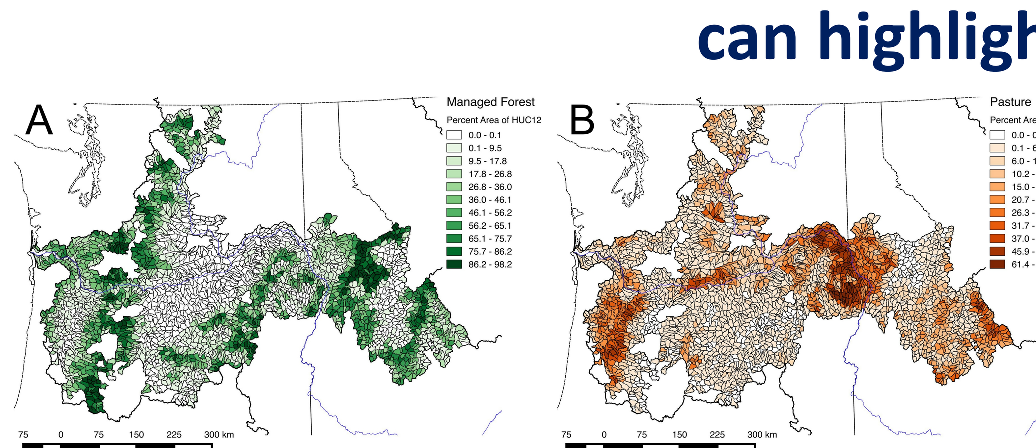
Steroids

Pharmaceuticals (e.g. caffeine, carbamazipene, diphenhydramine)

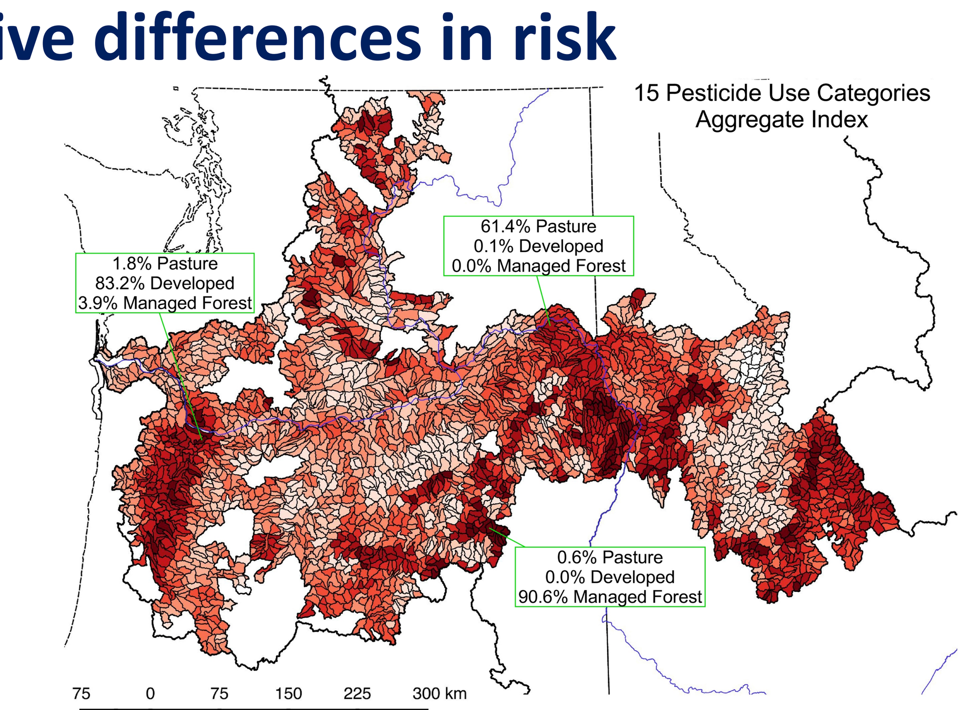
Polychlorinatedbiphenyls (PCBs)

Left) Map showing MS4 and NPDES permit effluent outfalls into the Columbia River and tributaries (from NMFS, 2012). **Right)** List of different classes of contaminants found in wastewater effluent and stormwater runoff in the Columbia River Basin from 2008-2010 (USGS, 2012).

Assessing the distribution of land uses across the CRB can highlight relative differences in risk



Above) Maps showing the percent of the area of each watershed that consists of either (**A**) managed forest or (**B**) pasture. Both represent land uses with potential pesticide applications. **Right)** Map showing an aggregated index combining 15 different land use categories to identify areas of relatively higher risk. Data from three of the identified "high risk" watersheds highlight how different combinations of land use can produce similar levels of expected risk.



First Steps

- Develop a land use index to identify priority watersheds where contaminant exposures are more likely to pose a risk to endangered species.
- Identify important data needed to understand the risk posed by contaminants in these watersheds.
- Focus further data collection such as use surveys and monitoring studies of both contaminants and species in these watersheds.
- Target restoration and mitigation efforts that will reduce contaminant loading to these watersheds.