The use of risk assessment to construct a watershed risk analysis and management framework

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http://www.wwu.edu/toxicology/

Goals of the risk analysis program

Perform a multiple stressor ecological risk assessment for the South River area that contains Hg contamination.

Create a modeling framework to calculate risk and to run scenarios to assist the restoration efforts for the region.
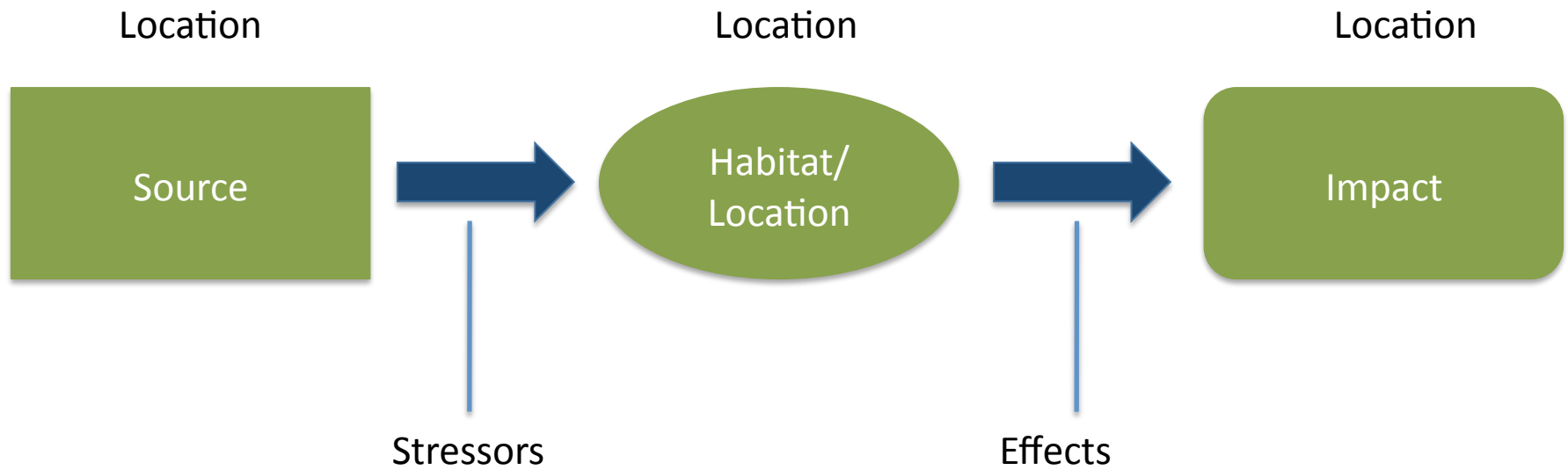
Update

Re-evaluation of the structure of the conceptual model and the cause-effect pathways

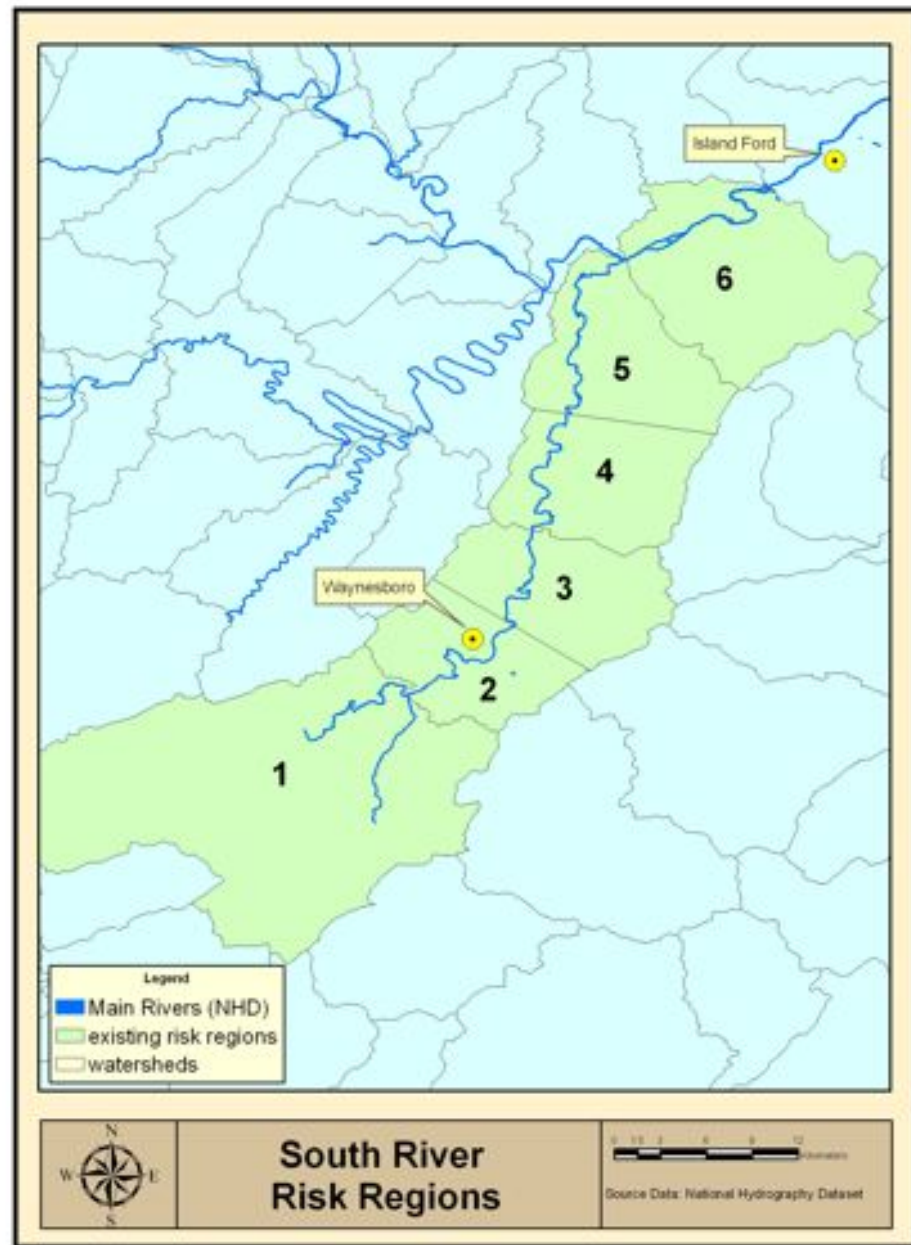Characterization of the risk regions with GIS and sampling data.

Detailed descriptions of the endpoints so that region specific risk can be calculated.

Relative Risk Model-the basics

Location

Location

Location

Source

Habitat/
Location

Impact

Stressors

Effects

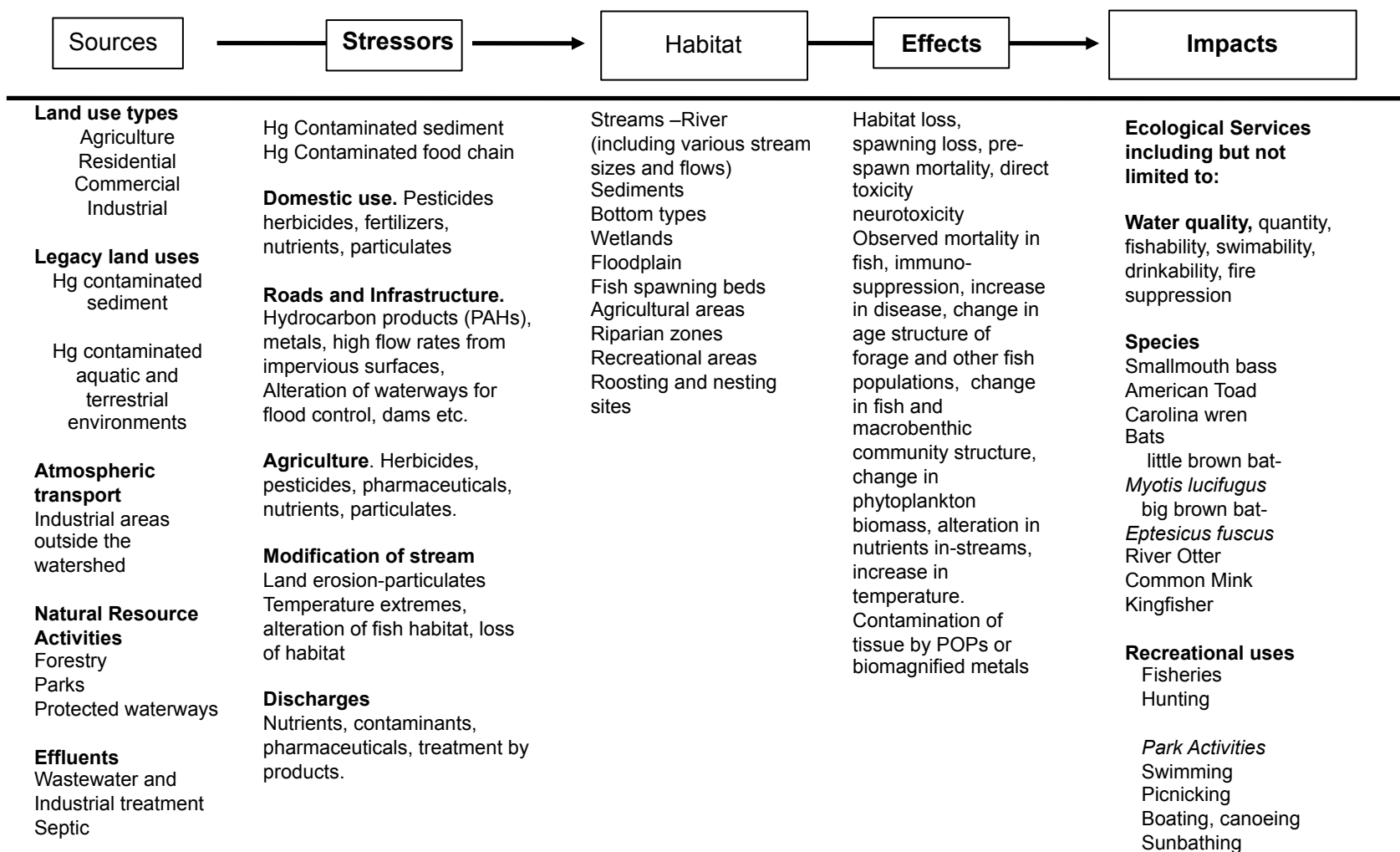# Study area for the risk assessment program

Six risk regions along the South River and the South Fork of the Shenandoah River.

Update

Re-evaluation of the structure of the conceptual model and the cause-effect pathways

Original Conceptual Model April 2010.

| Sources | → | Stressors | → | Habitat | Effects | → | Impacts |

Land use types
  Agriculture
  Residential
  Commercial
  Industrial

Legacy land uses
  Hg contaminated sediment

  Hg contaminated aquatic and terrestrial environments

Atmospheric transport
Industrial areas outside the watershed

Natural Resource Activities
Forestry
Parks
Protected waterways

Effluents
Wastewater and Industrial treatment
Septic

Hg Contaminated sediment
Hg Contaminated food chain

Domestic use. Pesticides herbicides, fertilizers, nutrients, particulates

Roads and Infrastructure. Hydrocarbon products (PAHs), metals, high flow rates from impervious surfaces, Alteration of waterways for flood control, dams etc.

Agriculture. Herbicides, pesticides, pharmaceuticals, nutrients, particulates.

Modification of stream Land erosion-particulates Temperature extremes, alteration of fish habitat, loss of habitat

Discharges Nutrients, contaminants, pharmaceuticals, treatment by products.

Streams –River (including various stream sizes and flows)
Sediments
Bottom types
Wetlands
Floodplain
Fish spawning beds
Agricultural areas
Riparian zones
Recreational areas
Roosting and nesting sites

Habitat loss, spawning loss, pre-spawn mortality, direct toxicity neurotoxicity Observed mortality in fish, immuno-suppression, increase in disease, change in age structure of forage and other fish populations, change in fish and macrobenthic community structure, change in phytoplankton biomass, alteration in nutrients in-streams, increase in temperature. Contamination of tissue by POPs or biomagnified metals

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Ecological Services including but not limited to:

Water quality, quantity, fishability, swimability, drinkability, fire suppression

Species
Smallmouth bass
American Toad
Carolina wren
Bats
  little brown bat-
Myotis lucifugus
  big brown bat-
Eptesicus fuscus
River Otter
Common Mink
Kingfisher

Recreational uses
  Fisheries
  Hunting

  Park Activities
  Swimming
  Picnicking
  Boating, canoeing
  Sunbathing

Original Conceptual Model April 2010.

Habitat

Streams –River (including various stream sizes and flows)
Sediments
Bottom types
Wetlands
Floodplain
Fish spawning beds
Agricultural areas
Riparian zones
Recreational areas
Roosting and nesting sites

Habitat was not very specific to a particular species or other type of endpoint.

Revised Conceptual Model October 2010.

Habitat

Water Quality
Streams –River (including various stream sizes and flows)
Wetlands
Riparian zones
Floodplains
Macroinvertebrates

Warm Water Fish Habitat (smallmouth bass, snapping turtle)
   Spawning/feeding
   Nursery areas

Mammal habitat (otter and mink)

Cold Water Fish Habitat (trout)

Terrestrial Habitat-Birds (Carolina wren, Kingfisher)

Terrestrial Habitat Bats

Terrestrial-Wetlands Habitat Toad

Recreational areas

Habitat is now specific to the endpoint.

October 2010 South River and South Fork of the Shenandoah River Conceptual Model-**Mercury**.

Sources	Stressors	Habitat	Effects	Impacts
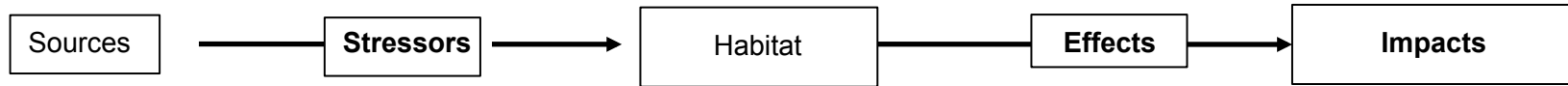
Land use
Industrial

Legacy land uses
Hg Contaminated:
1. sediment
2. water
3. aquatic veg.
4. floodplain soils/veg
5. terre. soils/veg

Hg Contaminated Prey/Food

Atmospheric transport
Industrial areas inside the watershed

Regional/Global outside the watershed
  Natural
  Anthropogenic

Effluents
Wastewater and Industrial treatment

Stormwater Runoff

Chemical complexes of Hg
Elemental Hg
Hg Salts
Methyl Hg
Organo-complexed Hg

Habitat Alteration
1. Stream meanders- erosion/ deposition of Hg Contaminated sediment

2. Stream bank /floodplain modifications - Hg contaminated soils/sed.

3. Landslides (natural, anthropogenic)

Trophic Transfer
Hg Contaminated food /prey

Water Quality
Streams –River (including various stream sizes and flows)
Wetlands
Riparian zones
Floodplains
Macroinvertebrates

Warm Water Fish Habitat (smallmouth bass, snapping turtle)
  Spawning/feeding
  Nursery areas

Mammal habitat (otter and mink)

Cold Water Fish Habitat (trout)

Terrestrial Habitat-Birds (Carolina wren, Kingfisher)

Terrestrial Habitat Bats

Terrestrial-Wetlands Habitat Toad

Recreational areas

Habitat Effects
Vegetative losses

Fish/Mammals/Birds
Direct effects - egg, larval, adult mortality
Indirect effects - behavioral, sensory, neurotoxicity , immuno-suppression, disease, change in age structure, species abundance and diversity, trophic structure and function

Vegetation/Plant
macrobenthic community structure, change in phytoplankton biomass, change in trophic transfer of nutrients/energy

Biomagnificaiton
Tissue contamination
Trophic transfer:
  Aquatic to aquatic
  Aquatic to waterfowl
  Aquatic to birds
  Aquatic to small mammals & wildlife

Physicochemical
Hg Contaminated Ecosystems
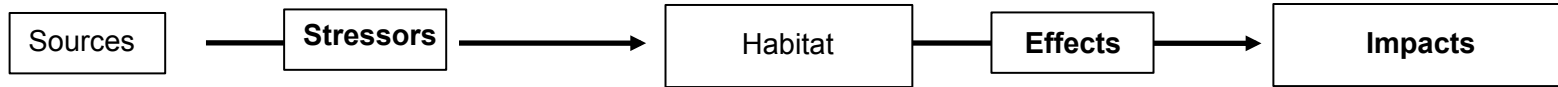 FPOM, DOC, DIC, water , soil/sediment matrices

Ecological Services including but not limited to:

Water quality/quantity
  Drinking
  Irrigation
  Fire suppression

Species
  Smallmouth bass
  American Toad
  Carolina wren
  Bats
    Little brown bat- *Myotis lucifugus*
    Big brown bat *Eptesicus fuscus*
  River Otter
  Common Mink
  Kingfisher

Recreational uses
  Fisheries
  Hunting

  Park Activities
  Swimming
  Picnicking
  Boating, canoeing
  Sunbathing

October 2010 South River and South Fork of the Shenandoah Conceptual Model-**Land Use**

Sources	→	**Stressors**	→	Habitat	→	**Effects**	→	**Impacts**

Land use types
Agriculture
Residential
Commercial
Industrial

Domestic use. Pesticides herbicides, fertilizers, nutrients, particulates

Roads and Infrastructure. Hydrocarbon products (PAHs), metals, high flow rates from impervious surfaces, Alteration of waterways for flood control, dams etc.

Agriculture. Herbicides, pesticides, pharmaceuticals, nutrients, particulates.

Modification of stream
Land erosion-particulates
Temperature extremes, alteration of fish habitat, loss of habitat

Discharges
Nutrients, contaminants, pharmaceuticals, treatment by products.

Water Quality
Streams –River (including various stream sizes and flows)
Wetlands
Riparian zones
Floodplains
Macroinvertebrates

Warm Water Fish Habitat (smallmouth bass, snapping turtle)
　　Spawning/feeding
　　Nursery areas

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Terrestrial Habitat Bats

Terrestrial-Wetlands Habitat Toad

Recreational areas

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Direct effects - egg, larval, adult mortality
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Vegetation/Plant
macrobenthic community structure, change in phytoplankton biomass, change in trophic transfer of nutrients/energy

Biomagnificaiton
Tissue contamination
Trophic transfer:
　　Aquatic to aquatic
　　Aquatic to waterfowl
　　Aquatic to birds
　　Aquatic to small
　　mammals & wildlife

Physicochemical
Hg Contaminated Ecosystems
　　FPOM, DOC, DIC,
　　water , soil/sediment
　　matrices

Ecological Services including but not limited to:

Water quality, quantity, fishability, swimability, drinkability, fire suppression

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River Otter
Common Mink
Kingfisher

Recreational uses
　Fisheries
　Hunting

　Park Activities
　Swimming
　Picnicking
　Boating, canoeing
　Sunbathing

Diagram of potential Source-Stressor connections for conceptual model

Sources

Stressors	Land use Types				Legacy Land Uses		Atmospheric Transport	Natural Resource Activities			Effluents	
	Agricultural	Residential	Commercial	Industrial	Hg in sediment	Hg contaminated aquatic and terrestrial environments	Atmospheric Transport	Forestry	Parks	Protected Waterways	Wastewater and Industrial Treatment	Septic
Mercury				Hg	Hg	Hg	Hg				Hg	
Particulates (5)	P	P	P	P				P	P	P	P	
Contaminants (metals, pesticides, herbicides, etc.) (4)	C	C	C	C				C	C			
Pharmaceuticals	PH										PH	PH
Persistent Organic Pollutants	POP			POP			POP				POP	POP
Habitat Loss	HL	HL	HL	HL				HL	HL	HL		
Nutrients	N	N	N	N			N	N	N	N	N	N
Temperature (3)	Temp	Temp	Temp	Temp				Temp	Temp	Temp	Temp	
Structural changes to South River	SC	SC	SC	SC				SC	SC	SC	SC	
Total	P, HL, SC	Hg ,P, C PH, OP,N	Hg, P, C, PH,POP, HL, N, Temp, SC	Hg, P, C, PH, POP, HL, N, Temp, SC	Hg	Hg	Hg, POP,N	P, C, HL, N, Temp, SC	P, C, HL, N, Temp, SC	P, HL, N, Temp, SC	Hg, P, PH, POP, N, Temp, SC	PH, POP, N

Diagram of potential stressor-habitat connections for conceptual model

		Habitat						
		Water				Terrestrial		
Stressors	Recreation (1)	Quality	warm-water fish	Cold-water fish	Mammals (mink, otter)	Terrestrial Birds (2)	Terrestrial Bats	Toad
Mercury		Hg	Hg	Hg (trout)	Hg	Hg	Hg	Hg
Particulates (5)	P	P	P	P	P			
Contaminants (metals, pesticides, herbicides, etc.)(4)		C	C	C	C			C
Pharmaceuticals		PH	PH	PH	PH			
Persistent Organic Pollutants		POP	POP	POP	POP	POP	POP	POP
Habitat Loss	HL		HL	HL	HL	HL	HL	HL (wetlands)
Nutrients		N	N	N	N			
Temperature (3)				Temp				
Structural changes to South River	SC		SC	SC	SC			
Total	P, HL, SC	Hg ,P, C PH, OP,N	Hg, P, C, PH,POP, HL, N, Temp, SC	Hg, P, C, PH, POP, HL, N, Temp, SC	Hg, P, C, PH,POP HL, N, SC	Hg, POP, HL	Hg, POP, HL	Hg, C, POP, HL

1) Parks and other areas used for recreational activities
2) Kingfisher uses bank area for breeding and captures fish from riverine areas.
3) Temperature due to loss of riparian area or channel disturbance-not climate change
4) Chemicals are also not persistent or bioaccumulative-biomagnified.
5) Materials that will eventually become sediment.

Update

Characterization of the risk regions with GIS and sampling data.

Characterization of the Risk Regions
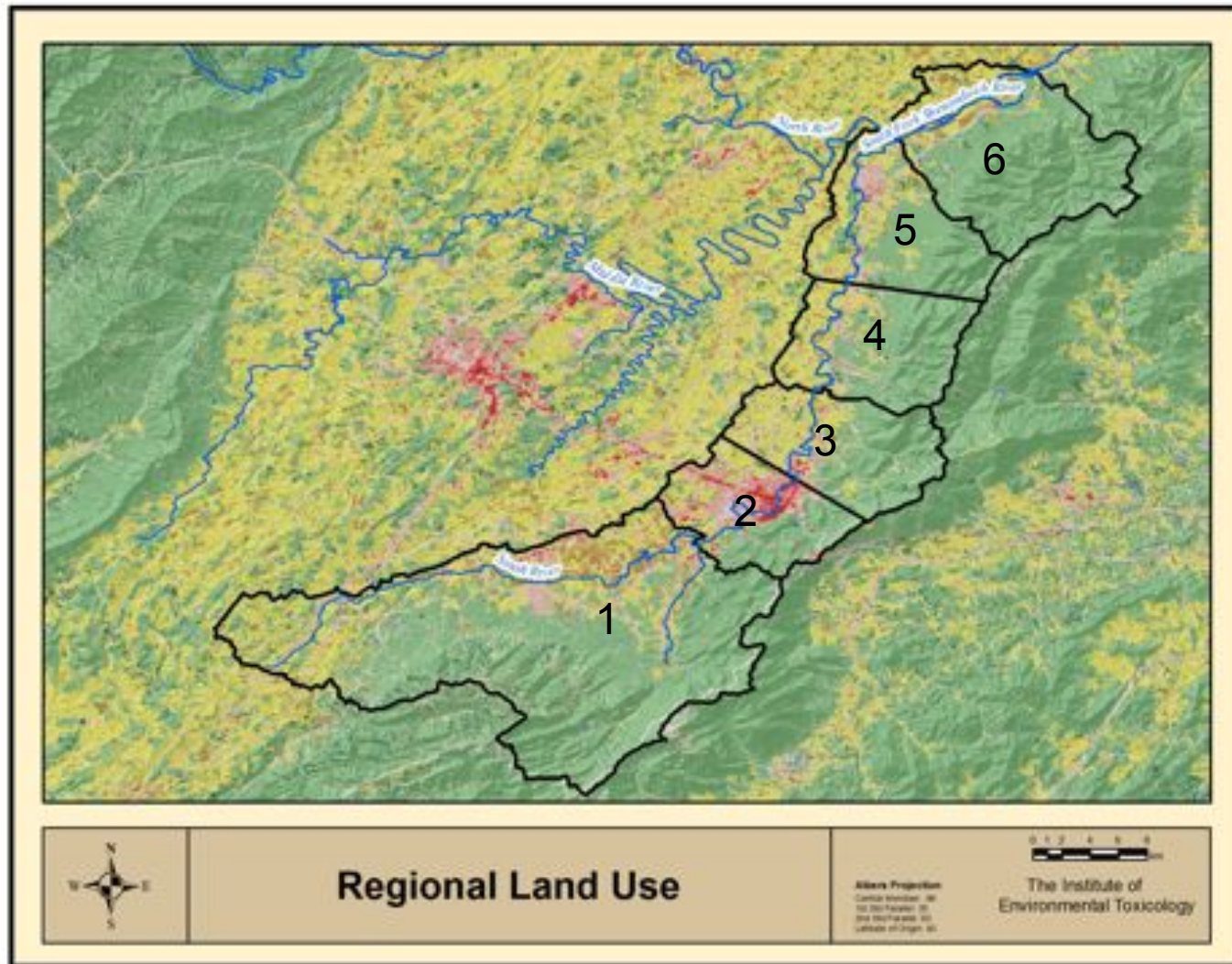
Land use-Sources
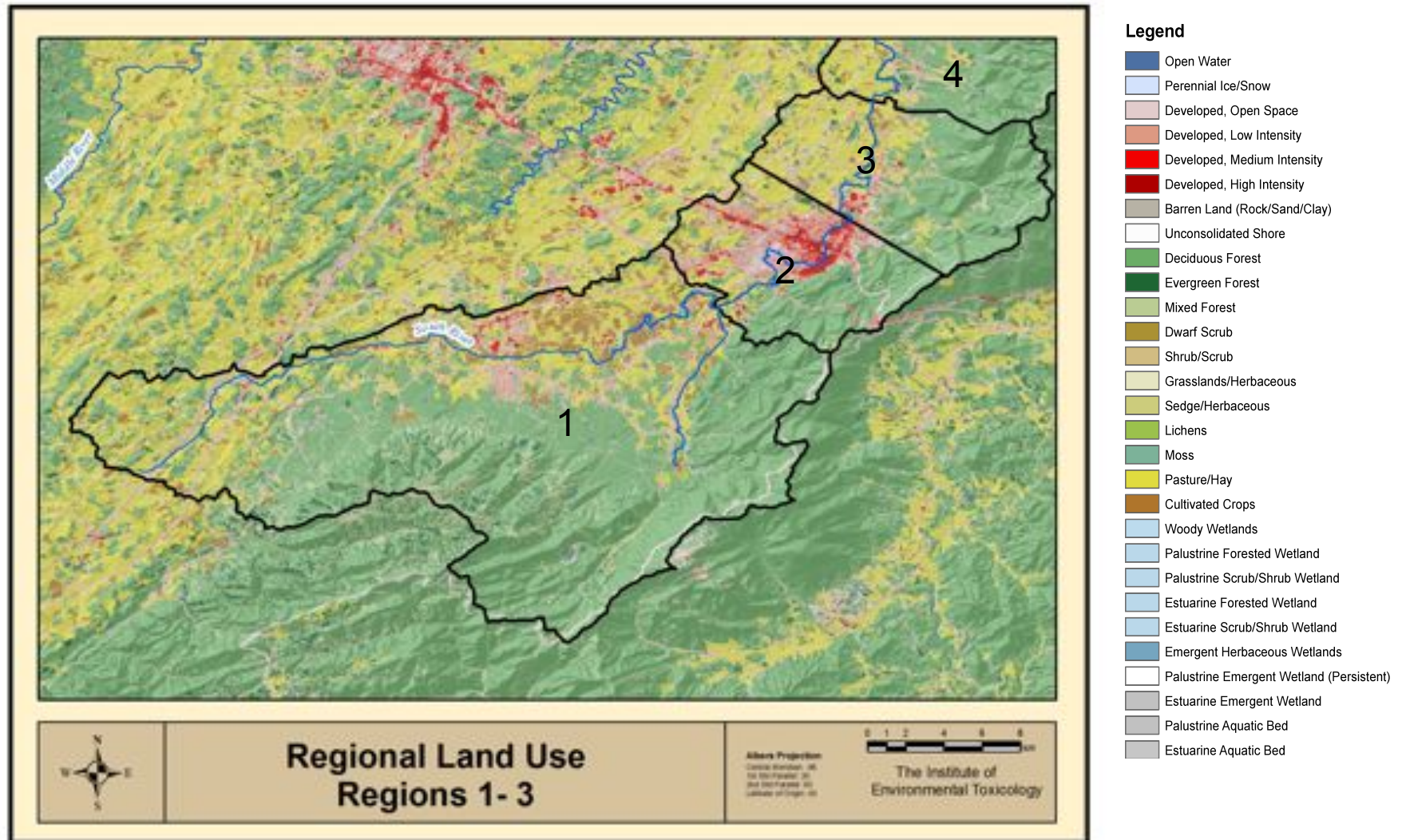
Chemistry
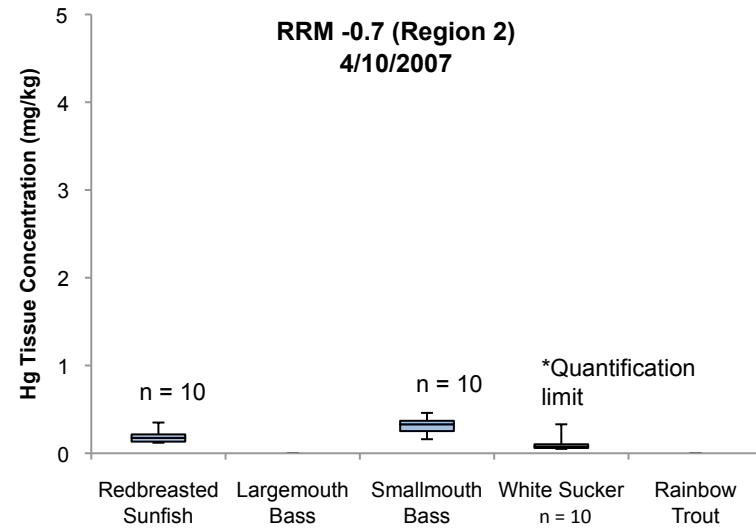
Habitat-Endpoint Specific

Land use type and cover for the study area

Legend

- Open Water
- Perennial Ice/Snow
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land (Rock/Sand/Clay)
- Unconsolidated Shore
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Dwarf Scrub
- Shrub/Scrub
- Grasslands/Herbaceous
- Sedge/Herbaceous
- Lichens
- Moss
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Palustrine Forested Wetland
- Palustrine Scrub/Shrub Wetland
- Estuarine Forested Wetland
- Estuarine Scrub/Shrub Wetland
- Emergent Herbaceous Wetlands
- Palustrine Emergent Wetland (Persistent)
- Estuarine Emergent Wetland
- Palustrine Aquatic Bed
- Estuarine Aquatic Bed

Regional Land Use

Albers Projection
Central Meridian: -96
1st Std Parallel: 29.5
2nd Std Parallel: 45.5
Latitude of Origin: 23

The Institute of
Environmental Toxicology

# Gradients of land use in the up-stream part of the river.

Gradients of land use

Gradients exist in the amount of cultivated land, hay and pasture, developed areas, and forest among the different risk regions.
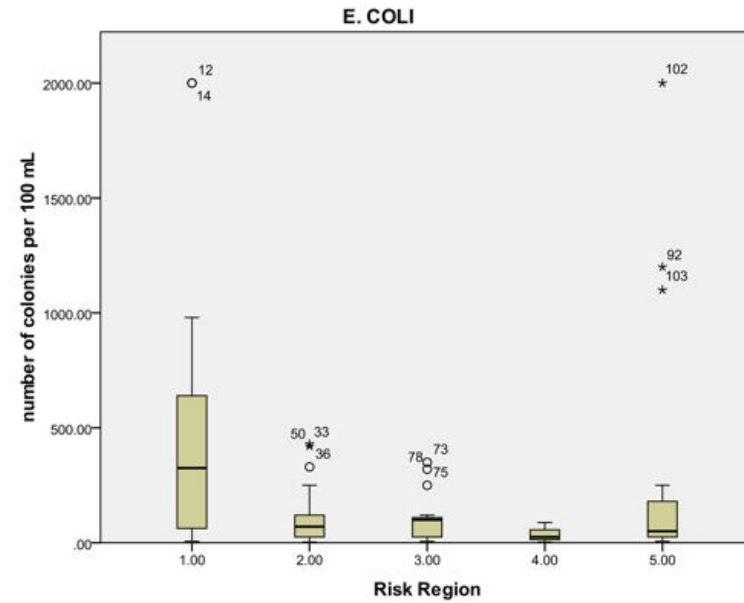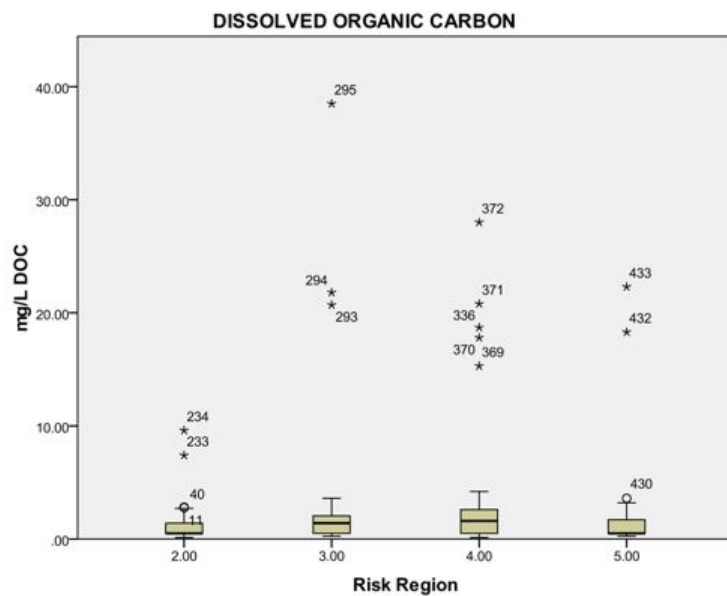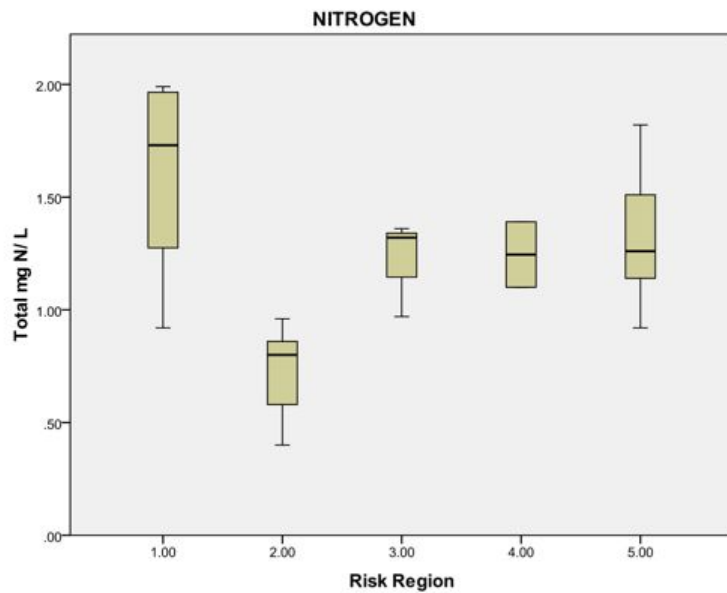
The southeast portions are largely forest compared to the northeast sections of the risk regions.

Regional Land Use Regions 1- 3

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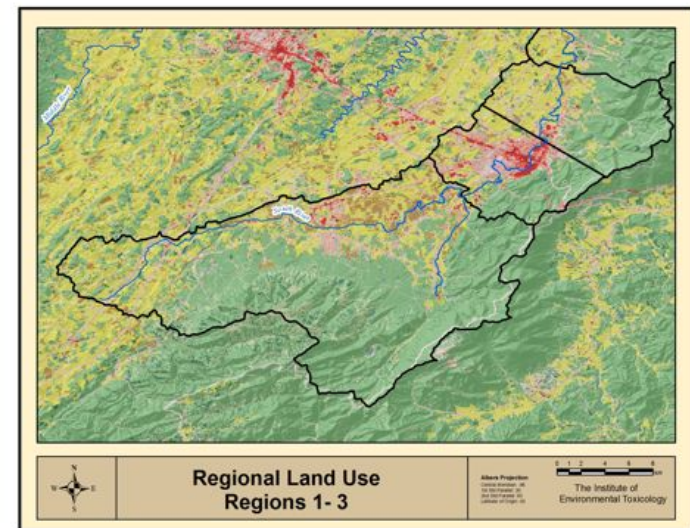
Other gradients-Tissue Hg
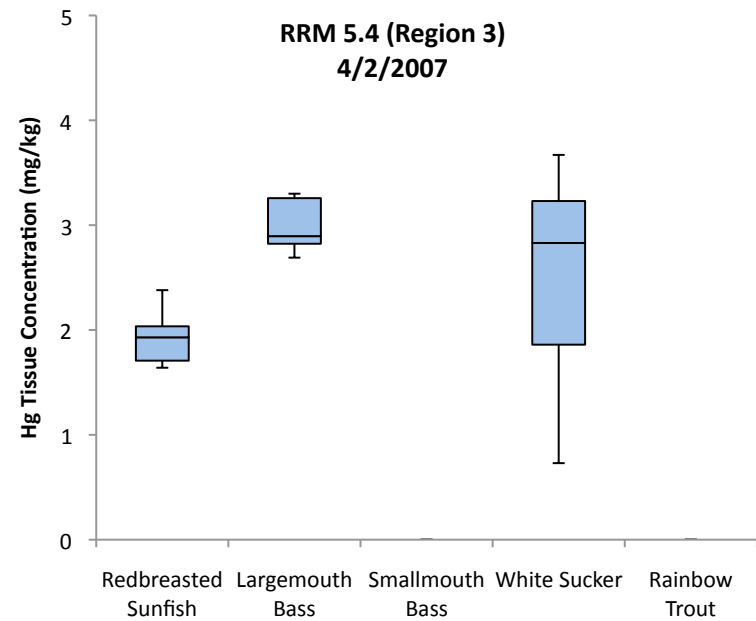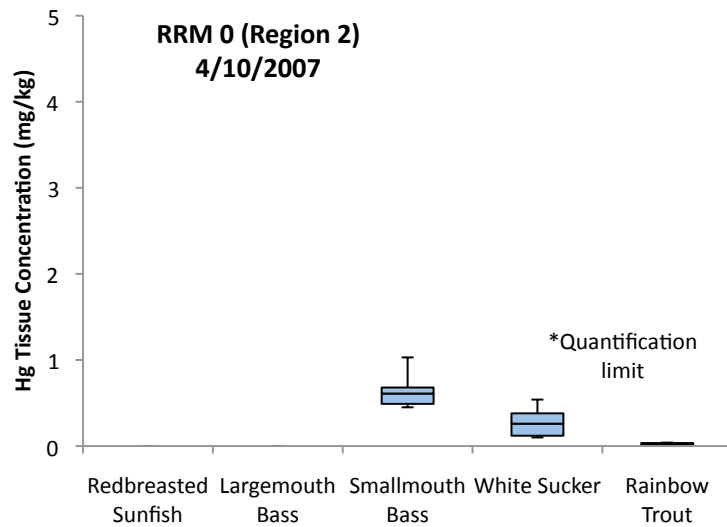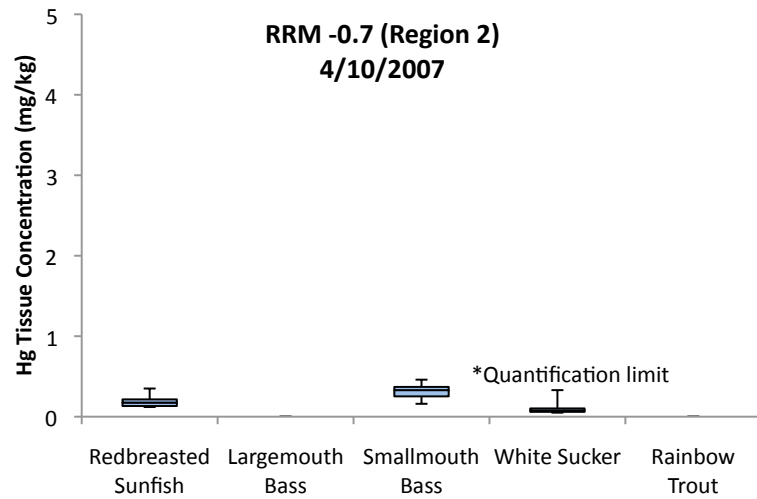
Other gradients in the risk region 2005-2009

Other gradients in the risk regions
Endpoint-Habitats

HUNTING

Dove hunting in agricultural areas (open fields) --> see land use maps to identify likely areas of dove hunting

Region 1 & 2

AREA: Glenwood-Pendlar Ranger District: S. of Waynesboro to N. of Troutville (223,000 ac)

GAME: bear, deer, grouse, raccoon, squirrel, turkey

(VADept of G & IF, findgame.org, 07/26/10)

PARKS

Park	Region
Waynesboro Country Club -2.3	2
Ridgeview Park -1.9	2
Constitution Park 0.1	2
North Park 1.3	2/3
Basic Park 2.4	3
Crimora Park 10	4
Grand Caverns 20	5
Grottoes Town Park 22	5

Update

Detailed descriptions of the endpoints so that region specific risk can be calculated.

Endpoints-Defined along with habitat

ENDPOINT	DEFINED
Water Quality	
Fish ability	"protection and propagation of fish, shellfish, and wildlife and recreation in and on the water"
Swimmability	Meet WQS protective of human health and aquatic organisms
Drinkability	Waynesboro and (assuming) surrounding areas use only groundwater sources for drinking water; South River should be protective of human health.
Fire suppression	South River as water source for fire suppression?
Biological quality	
Fish	
Mercury	Mercury (µg/l) = 1.4 (acute), 0.77 (chronic) (3)
PCB	PCB Total (µg/l) = 0.014 (3)

Endpoints-Defined along with distribution

SPECIES	DISTRIBUTION
Northern river otter (*Lontra canadensis laxatina*)	throughout Virginia
common mink (*Mustela vison mink*)	central and eastern Virginia
Big brown bat (*Eptesicus fuscus fuscus*)	throughout Virginia
Little brown bat (*Myotis lucifugus lucifugus*)	one of the most abundant insectivorous bats in VA, found in all forested regions
Eastern American toad *(Anaxyrus americanus americanus*)	
Eastern snapping turtle (*Chelydra serpentina serpentina*)	throughout Virginia

Endpoints-Warm and Cold Water Fisheries

RISK REGION		
	General Location	**Fish Type**
1 (Upstream of Hg Source)		
	Lyndherst Area:	
	Mills Creek Reservoir/Mills Creek	Stocked trout waters below reservoir, **wild trout waters above reservoir**
	Coles Run reservoir	Stocked trout
	Back Creek*	Stocked trout (*Stocked 5 times Oct 1-May 15)
	Upper Sherando Lake*, Lower Sherando Lake**	Stocked trout (**Stocked 6 times Oct 1-May 31)
2 (Waynesboro and Hg source)		
	Urban Trout Fishery: Constitution Park Special regulation waters: Commonwealth's 2st delayed-harvest trout fishery starts after Rife Loth Dam (small dam between Ridgeview park and Baker springs basin) to North Park	Rainbow and brown trout ***Stocked 6 times during catch-and-release period, Oct 1-May 31; Catch-and-keep June 1-Sept 30
		Fishing trips: small/largemouth and rock bass, sunfish, rainbow and brown trout, bullhead catfish, carp
3 (Downstream of source)		
		Fishing trips: small/largemouth and rock bass, sunfish, rainbow and brown trout, bullhead catfish, carp

Lists of Effects-Biological

Effects-Biological-Ecological	Abbreviation	Description
Acute or Chronic Toxicity	Tox	Mortality, changes in behavior, reproduction, immunosupression etc.
Habitat Loss (Structure)	HL	Structure includes loss of breeding sites, siltation, loss of cover, temperature and oxygen alteration beyond tolerance. Can also include the creation of barriers to movement.
Food Resources	FR	Loss of prey items
Contamination	Con	Levels of a contaminant that makes the organism not fit for human consumption or puts a limit on consumption rates.
Productivity	Prod	Lowers the productivity of a species making it less available for hunting or fishing.
Disease	D	The introduction of novel disease organisms
Competition	Comp	The introduction of competitors either native or non-indigenous.

Issues and Decisions-1

- Decided to use most recent data for chemical concentrations to start to set rankings.

- Spatial resolution is uneven, Regions 1 and 6 are not as extensively sampled.

- Landuse is now extended to the entire watershed.

- Cold and warm water fisheries are included. Reproducing trout fisheries do exist in the study area.

Issues and Decisions-2

- Birds and other wildlife endpoints require data on exposure and effects.

- Wildlife habitat are not spatially defined at the resolution of the other data.

- The only ecological effects data are the macroinvertebrates, perhaps other information will be available in the near term.

Issues and Decisions-3

- Need to start to define management options.

- The current draft of the TMDL needs to be specific in its management actions in several cases. The more specific the management activity the clearer will be the risk calculations.

- Are there going to be other non-related TMDL management activities?

Next steps

Characterize the uncertainty with the information going into the model/

Setting ranking schemes for both the conventional and Bayesian calculations.

Progress reports at SETAC and the Society for Risk Analysis annual meetings.

Next steps

Crunch the numbers!!!!!

Questions and Comments?