Causal Analysis of Fish Kills in the Shenandoah and Potomac Rivers 2007 Workshop Results

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Disclaimer: The views expressed in this abstract are those of the author and do not necessarily reflect the view or policies of the U.S. Environmental Protection Agency

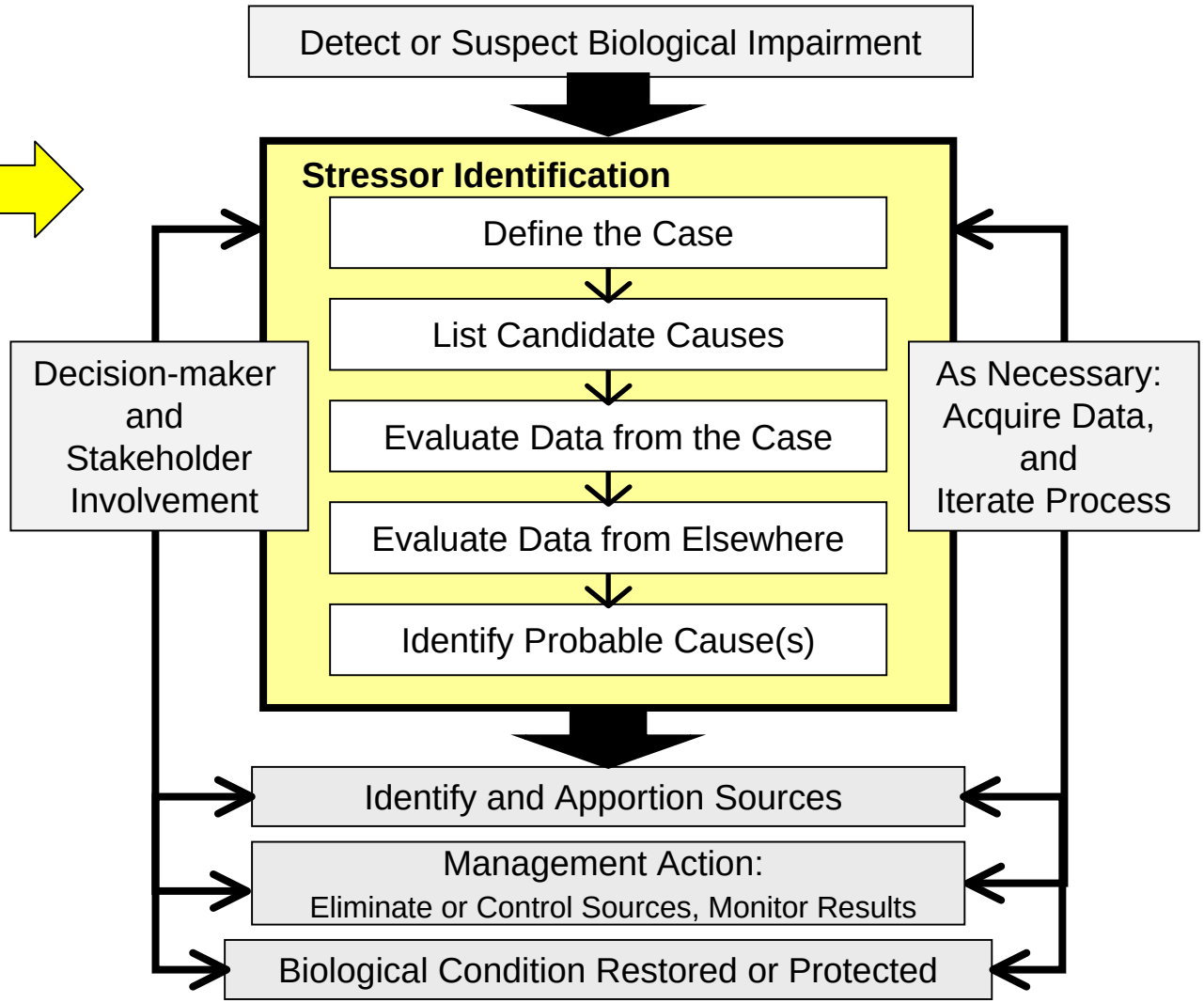
Motivation

- Fish kills in Shenandoah River or South Branch Potomac since 2002.
- Reports of intersex in male small mouth bass
- Apply Stressor Identification process to
  - Organize available information
  - Identify the cause, or reduce list of suspects
  - Inform 2007 sampling season

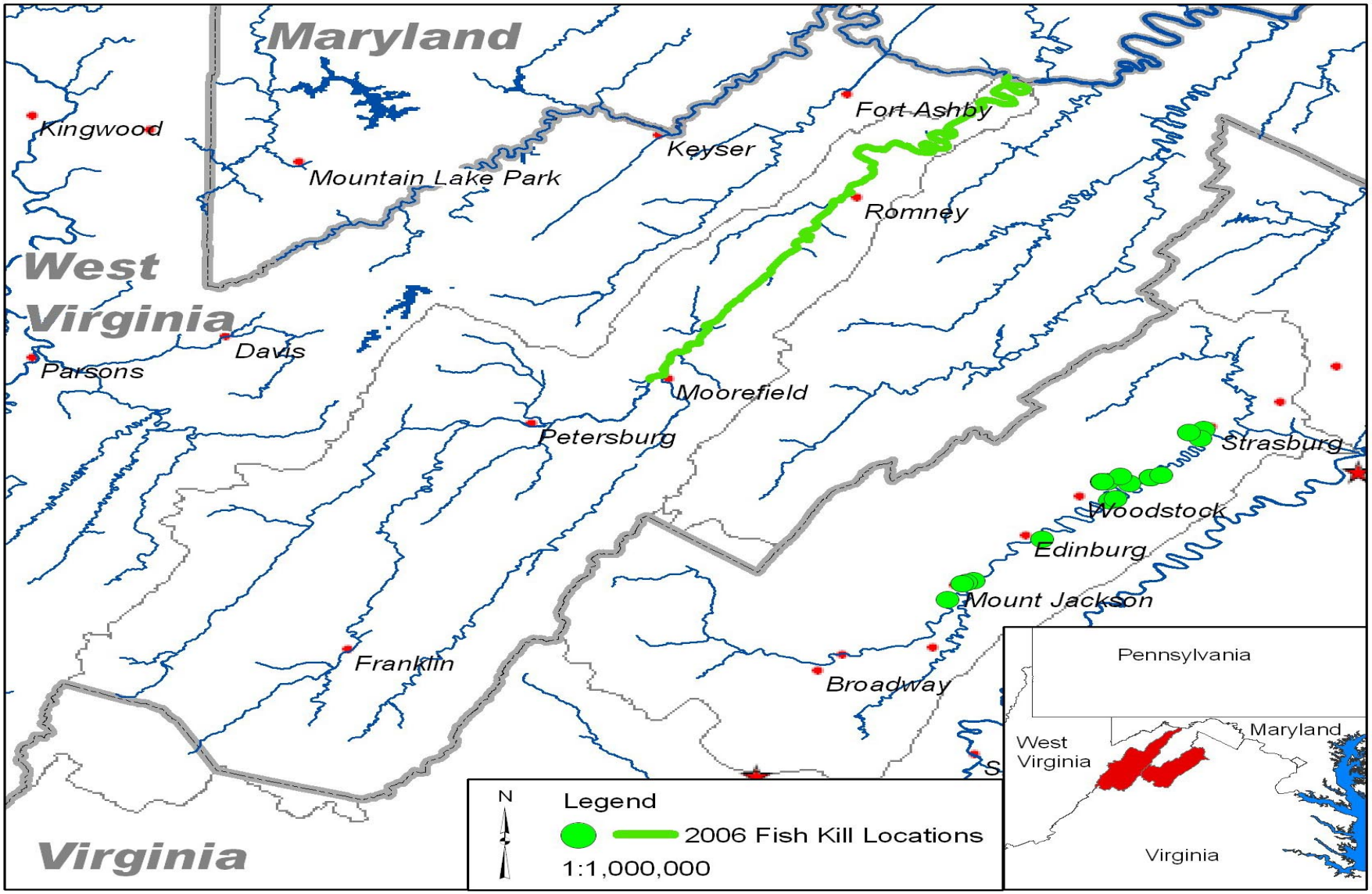
Stressor Identification

www.epa.gov/caddis

5 Easy Steps

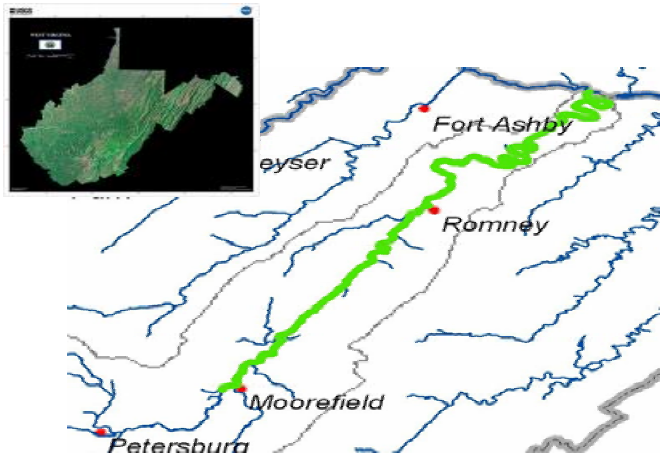


Step 1: Define the Case
2006 Fish Kills



West Virginia

Where?



Who?

Redhorse suckers

Smallmouth bass

Northern hogsuckers

When?

May 25 to 31

- Acute only

Virginia

Where?

Who?

Smallmouth bass

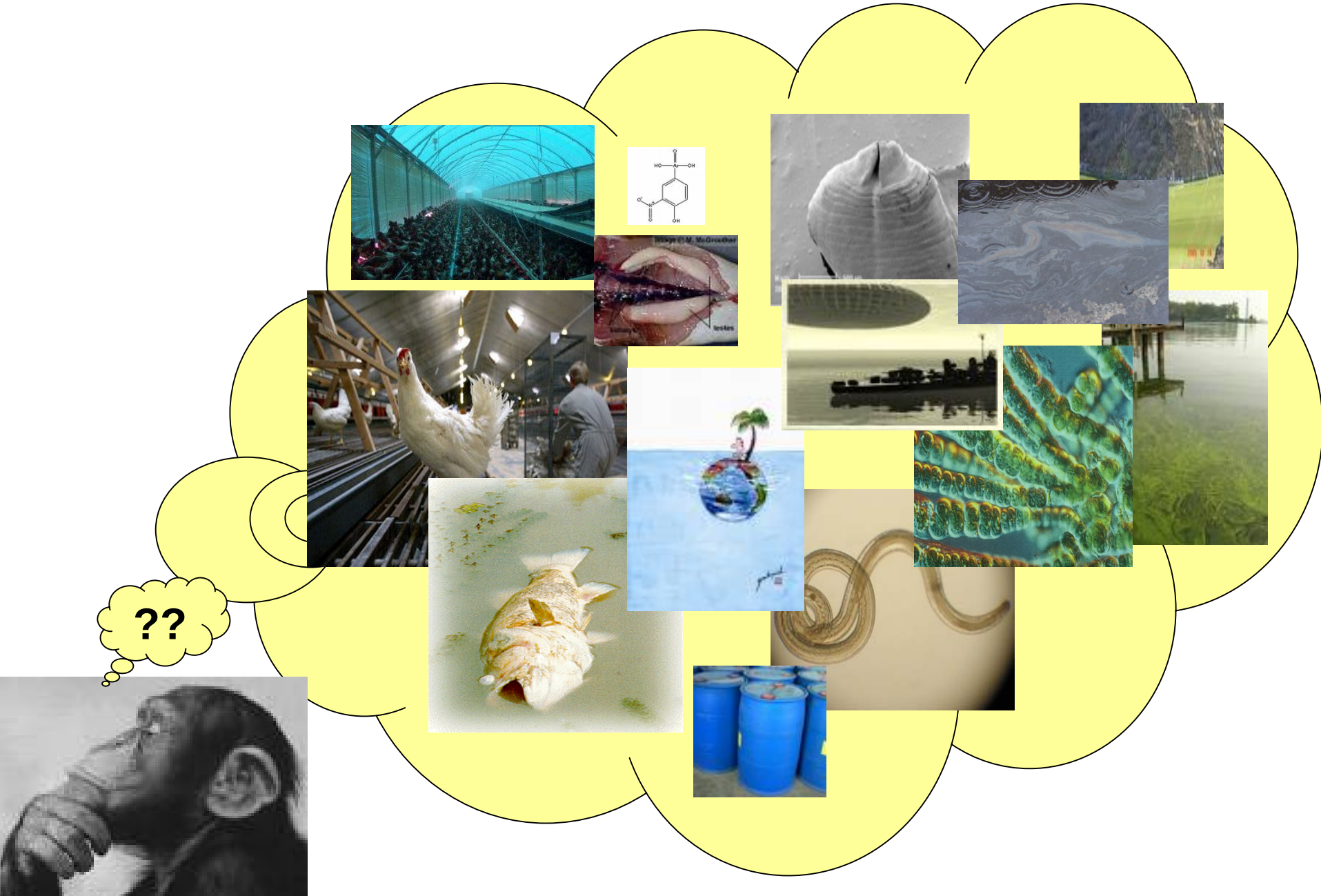
Redbreast sunfish

When? March to May 2006

2 Distinct Clinical Phases

- Acute (mid- March)
- Chronic (through late May)

Step 2: List Candidate Causes



Step 2: Candidate Causes

1. Low dissolved oxygen in the water
2. Gill damage from ammonia, high pH or other mechanism prevents fish from taking up oxygen
3. Altered blood chemistry from nitrite exposure prevents fish from using oxygen
4. Viral, bacterial, parasitic, or fungal infections
5. Mortality from high pH
6. Mortality from pH fluctuations
7. Mortality from ammonia toxicity
8. Unspecified toxic substances
9. Starvation

Steps 3 , 4 and 5: Demonstrate Characteristics of Causal Relationships

- Co-occurrence
  - An effect occurs where and when its cause occurs and does not occur in the absence of its cause.
- Sufficiency
  - The intensity or frequency of a cause is adequate to produce the observed magnitude of effect.
- Temporality
  - A cause precedes its effects
- Manipulation-sensitive
  - The effect is altered when the cause is altered
- Coherence
  - Internally consistent
  - Consistent with scientific theory

1. Anoxia due to low dissolved oxygen

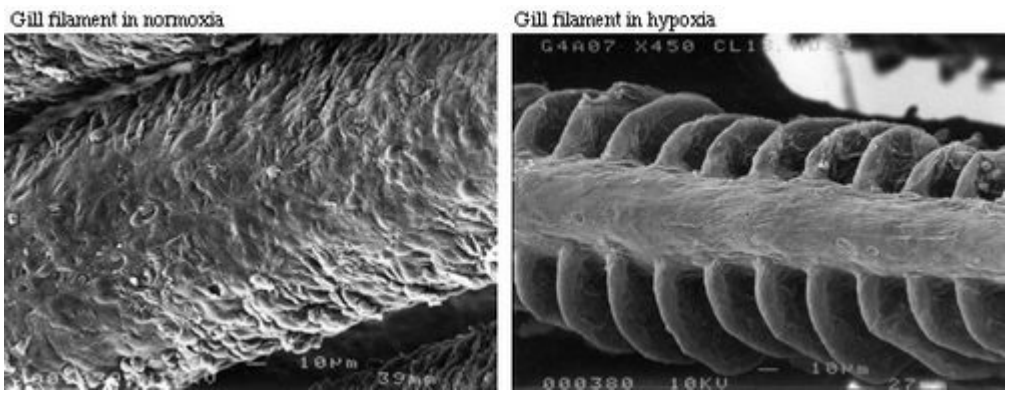
Mortality may occur:

- **DO levels fall < 4.0 mg/L**
- **Elevated amounts of plant biomass— bacteria consume O_2**
- **Point or Nonpoint Source Discharges--- high COD/BOD**
- **Elevated H_2O temperatures---**
  - **reduce O_2 solubility to lethal levels**

VA – *REFUTED*

WV – *REFUTED*

DO levels were normal, and well above 4.0 mg/L



2. Anoxia due to gill injury (gill hyperplasia)

Injuries to Gills:

Insufficient gas exchange

Death due to anoxia

(even w/ high DO levels)

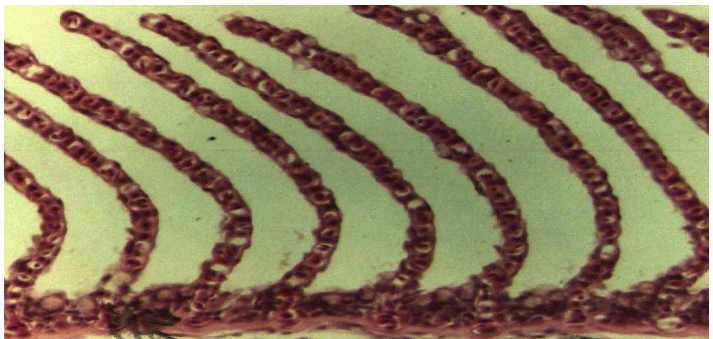
VA – *PENDING*

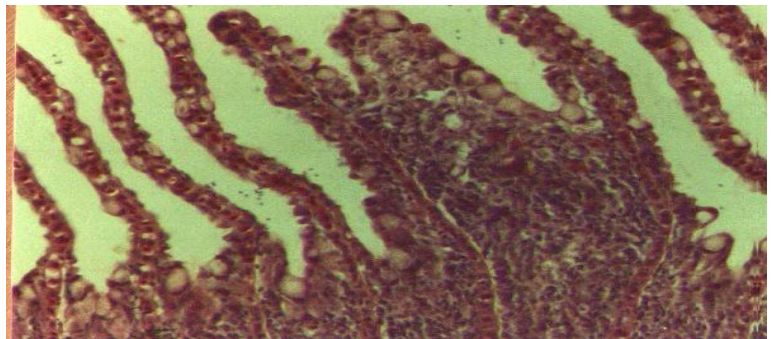
WV – *PENDING*

Some indications that gill injury was present

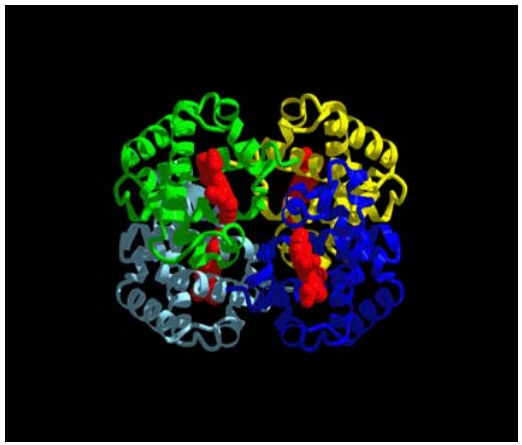
Gill injury could have been caused by several causal pathways:

- **Water Ammonia** (0.2 mg/L caused gill injury in brown trout)
- **Water pH** (9.5 prevents NH_3 excretion—autointoxication
- **Water Temperature**
- **Nitrate &/or Nitrite** (sm. bass more sensitive than lm. bass)
- **Stress, Seasonality, habitat changes**





3. Anoxia due to low blood oxygen affinity - (Methemoglobinemia)



Nitrite is an oxidative stressor

- **Blood nitrite levels are not indicative of environmental nitrite levels.**
- **Species sensitivity depends on their branchial Cl- uptake rates.**
- **DO levels can be normal, gas exchange unimpaired, and death may still result from the reduced ability of the blood to carry O_2**

Oxidative Stressors:

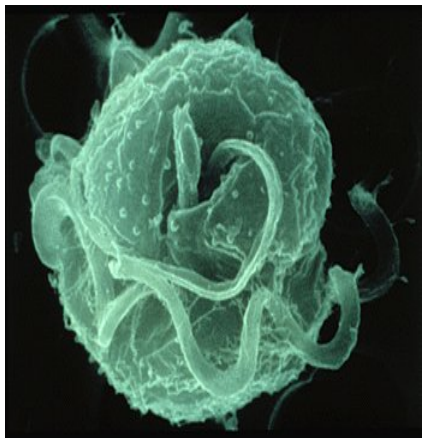
- **Heme group oxidized from the oxygen carrying ferrous ion (Fe^{2+}) to the ferric state (Fe^{3+})**
- **Methemoglobin will bind H_2O instead of O_2**
- **May induce hyperventilation and oxygen starvation**

VA – *PENDING*

WV – *PENDING*

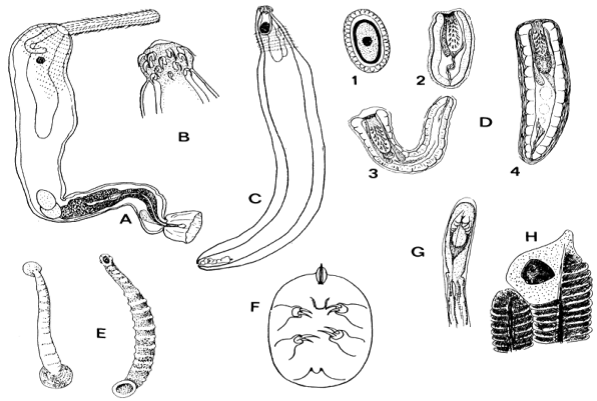
Brown blood not observed but more definitive data is needed from the pathology reports

4. Mortality due to other pathogenic modes of action



Compromised homeostatic functions via:

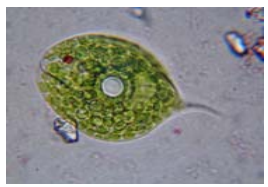
- **Bacterial infections**
- **Viral infections**
- **Parasitic infections**
- **Fungal infections**



Tissue damage

Septicemia

Role of stress?



Higher susceptibility to infections, environmental perturbations

Spawning, overwintering, EDCs?

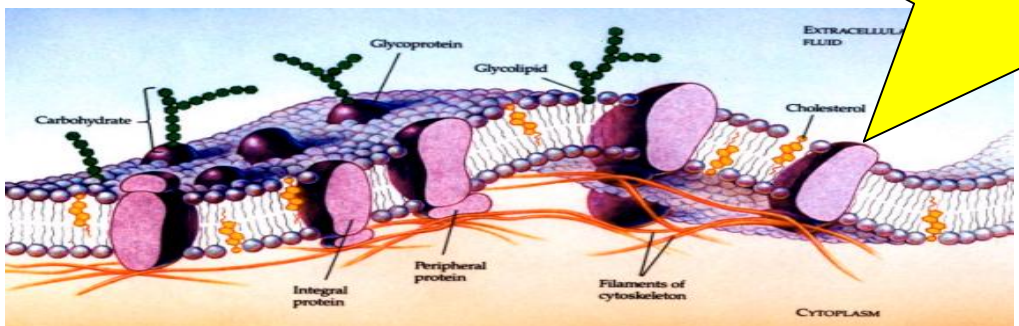
VA – *PENDING*
WV – *PENDING*

5. Mortality due to High pH

- **Disrupts blood chemistry**
- **Reduces O_2 delivery to tissue**
- **Reduce the effectiveness of the gill ion exchange and excretion**
- **Inhibits excretion of NH_3 (see CC#3)**

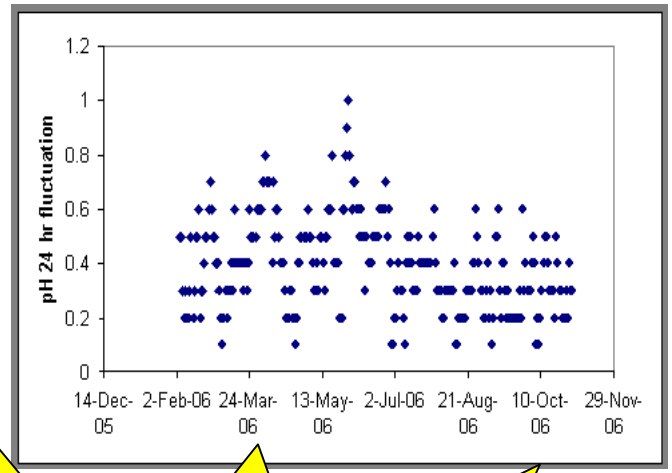
VA: Not supported (-)
WV: Not supported (-)

No difference in pH extremes in locations/times of fish kills vs. no fish kills
High pHs in experiments not lethal



6. Mortality due to pH fluctuations

- **Rivers exhibit diel fluctuations from photosynthesis**
  - **typical fluctuations range from 8.0 – 9.3**
- **Extremely high pH and substantial fluctuations can challenge the fish's ability to maintain homeostasis**



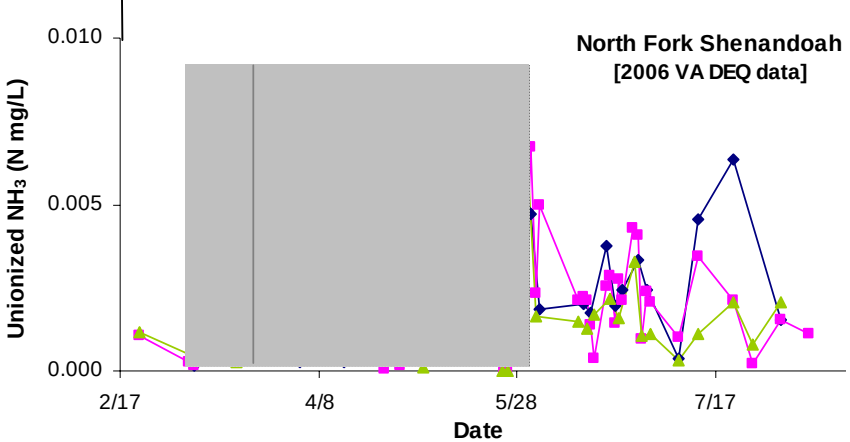
VA: Not supported (-)
WV: Not supported (-)

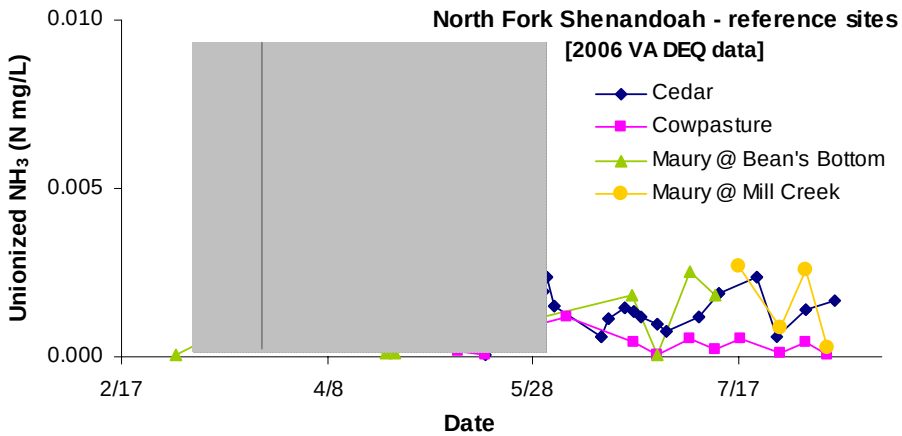
No difference in pH ranges in locations/times of fish kills vs. no fish kills

7. Mortality due to high ammonia concentrations

0.200 concentration of unionized ammonia associated with gill damage in lab tests

VA: Not supported (-)
WV: Not supported (-)





Example analyses from North Fork Shenandoah River case

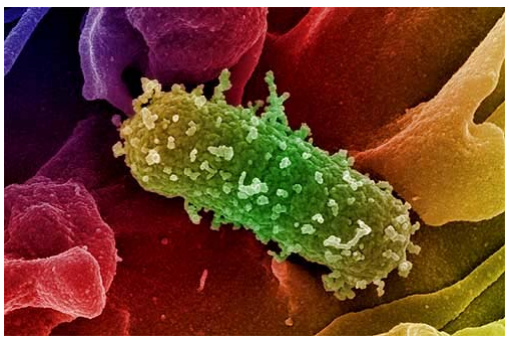
8. Mortality due to unspecified toxic chemicals

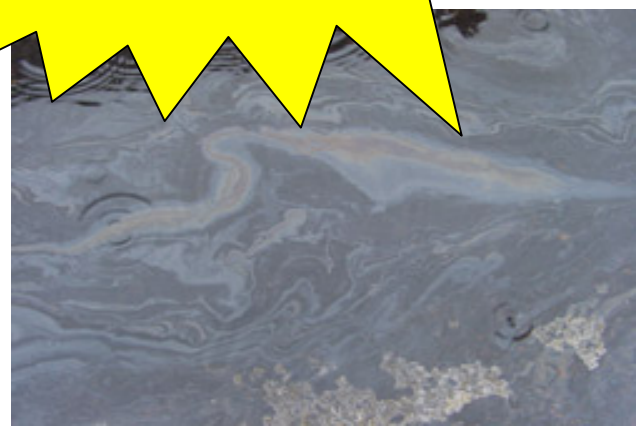
Episodic increase in exposure to an unknown pollutant?

Sources:

- **Agriculture**
- **Poultry, poultry processing**
- **Highways**
- **POTWs**
- **Industrial**
- **Legacy**
- **Accidental/Illegal Dumping**
- **Golf Courses**

VA – *Need Data*
WV – *Need Data*





9. Mortality due to starvation

- **Lack of food**

- **Inability of fish to capture or ingest food**

- **Inability to assimilate nutrition from ingested material**

VA: Not supported (-)
WV: Not supported (-)

Outcome: Narrowed List of Candidate Causes

1. Low dissolved oxygen in the water
2. **Gill damage from ammonia, high pH or other mechanism prevents fish from taking up oxygen**
3. **Altered blood chemistry from nitrite exposure prevents fish from using oxygen**
4. **Viral, bacterial, parasitic, or fungal infections**
5. Mortality from high pH
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Top Data Needs

Fish diagnostics (blood, tissue, gross & histopath)
- Generate baseline & archive
- Samples from sites with and without kills

Fish community conditions and structure

Broader geographic assessment during kills
- Define spatial extent of kills
- Combine VA and WVA databases
- Look more broadly within Potomac River

Temporal concerns
- Rapid response kits

Toxic chemicals

Algae

Viruses

Test hypotheses in laboratory

Workshop Participants

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Chris Barry	WVDEP
Patrick Campbell	WVDEP
Jim Hedrick	WVDNR
Laurie Olah	WVDA
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Lynnette Sholar	TN&A