

Water Quality and Freshwater Mussel Status in Mining-Influenced Virginia-Tennessee Rivers

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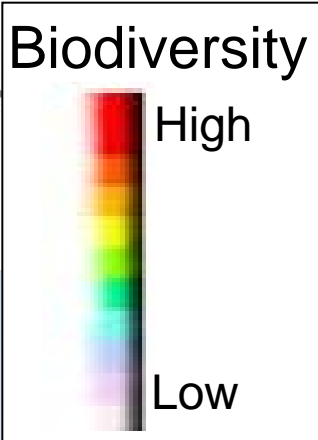
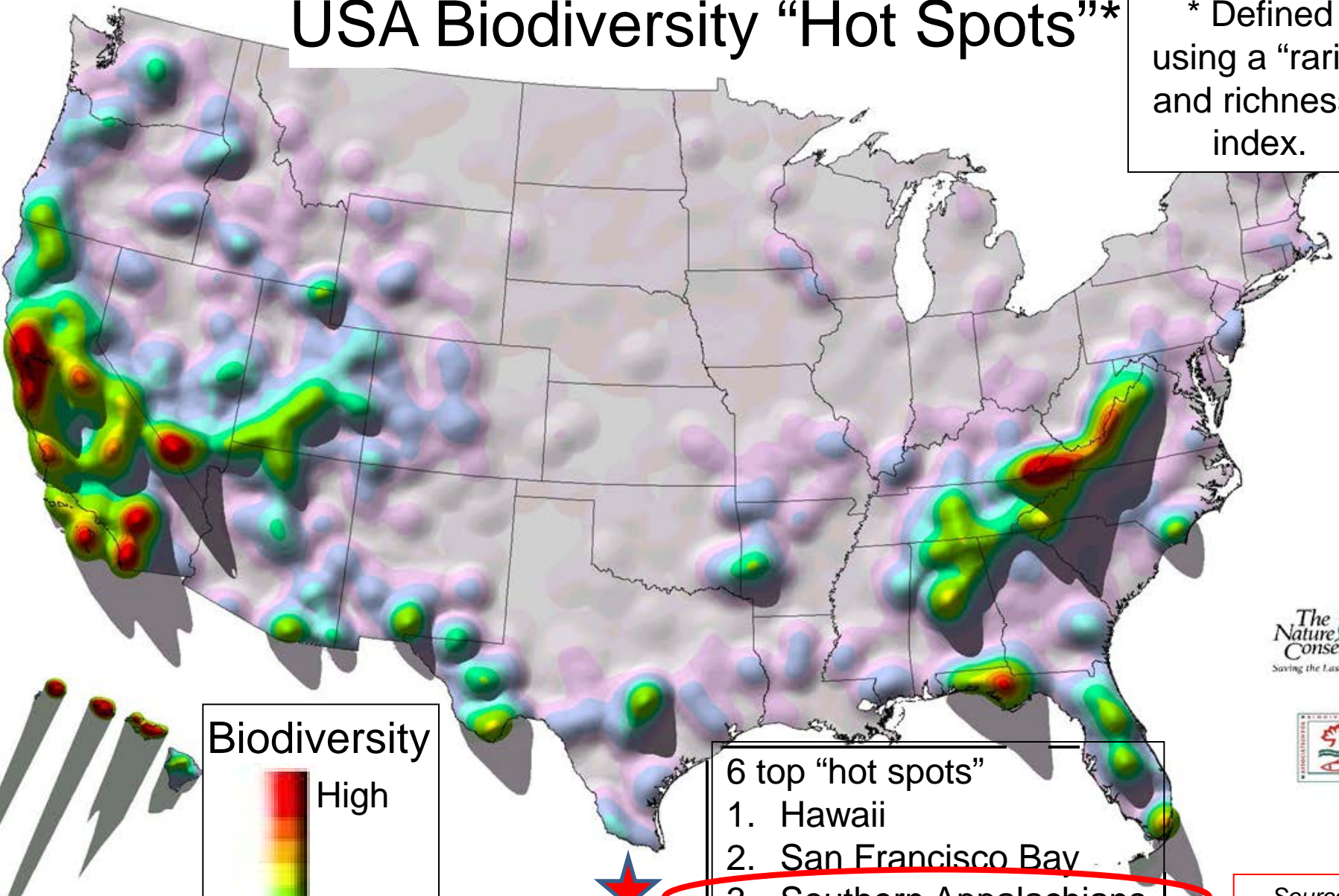
C. Lott and R. Stewart, Virginia Department of Environmental Quality



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USA Biodiversity "Hot Spots"*

* Defined using a "rarity and richness" index.



- 6 top "hot spots"
1. Hawaii
 2. San Francisco Bay
 3. Southern Appalachians
 4. Death Valley
 5. Southern California
 6. Florida Panhandle

The Nature Conservancy
Saving the Last Great Places



Source:
Chaplin et al. 2000. In:
"Precious Heritage."

Presentation Goals:

Describe status of freshwater mussel fauna in the Clinch and Powell Rivers of Virginia and Tennessee.

Review what is known about threats to the fauna in these mining-influenced rivers.

Review ongoing research that is intended to identify ecosystem stressors that are causing faunal decline in some river sections.

Freshwater Mussels - Basic Biology

- ✓ 300 species in North America (highest diversity worldwide) > 70 federally listed.
- ✓ 45 species, 20 federally listed, are extant in Clinch & Powell Rivers.
- ✓ Free-living adults, larvae parasitic on fish gills.
- ✓ Limited mobility, can move along substrate with muscular foot, stay anchored in the sediment by staying partially buried.
- ✓ Filter feeders, remove food particles and bacteria from water column.
- ✓ Long lived, usually 15 to 100+ years depending upon species.
- ✓ *Sensitive to water and sediment contaminants*, esp. metals, ammonia.



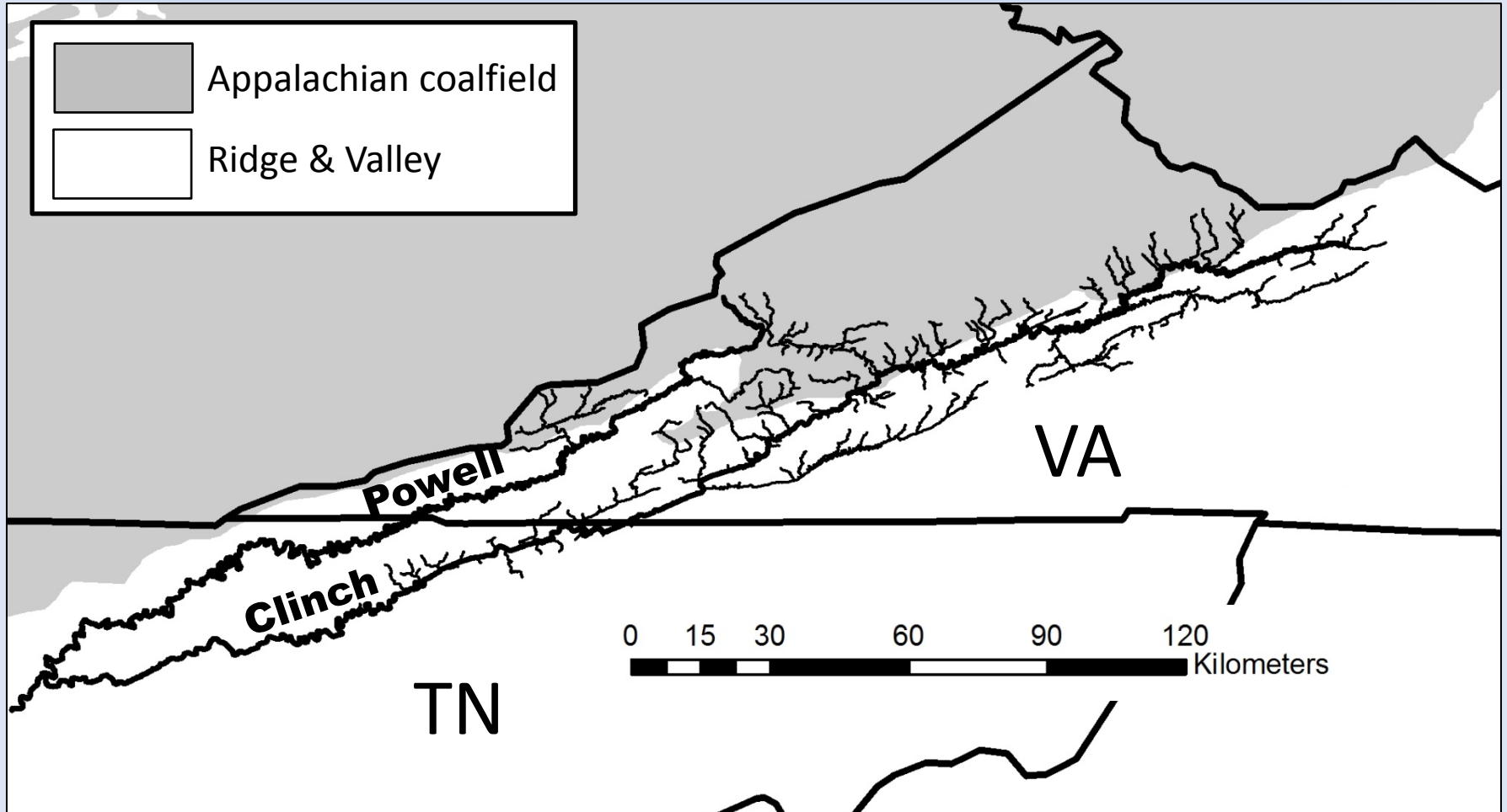
Major Threats (Global) to Freshwater Mussels

(Williams et al. 1993, Bogan 1997, Bogan 2001)

- Siltation, from erosion, runoff, unstable streambanks
- Pollution: they are particularly sensitive to some substances
- Dams, channelization
- Decline of host fishes
- Invasive species

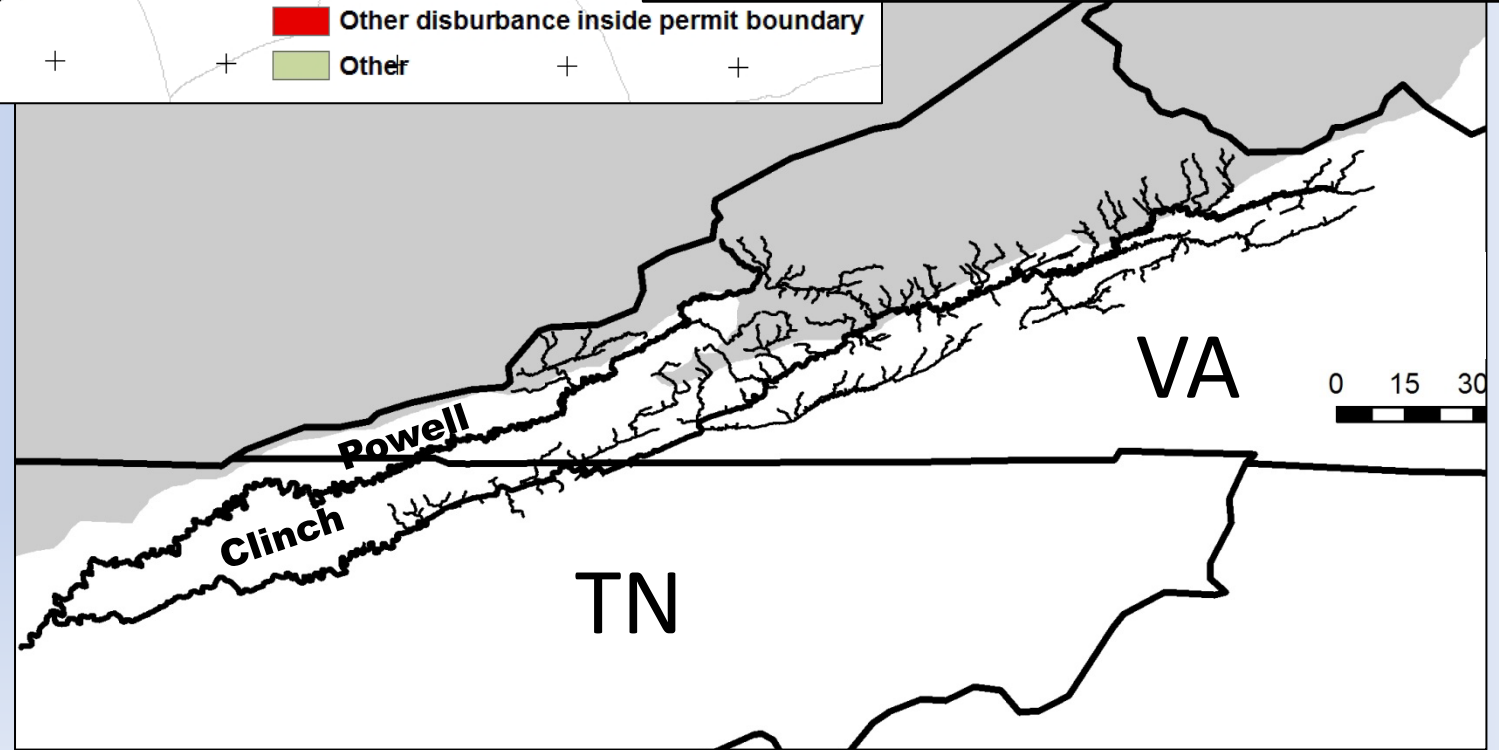
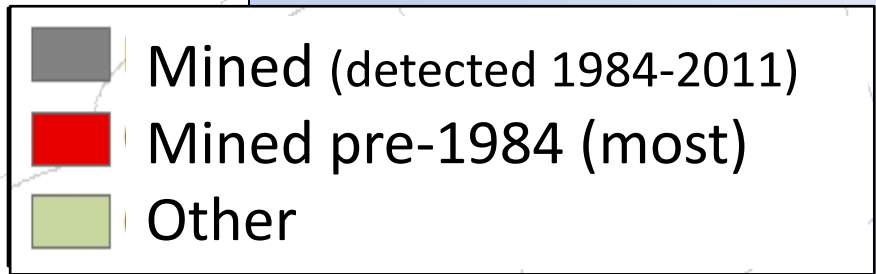
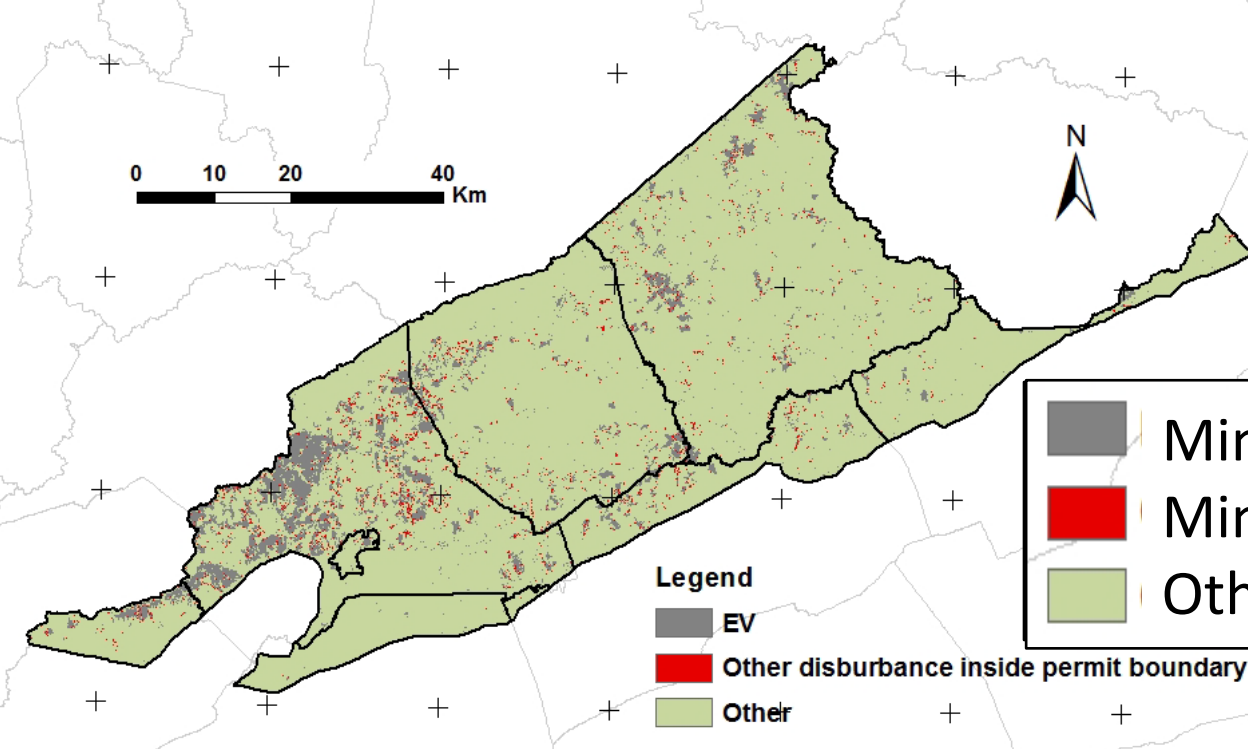


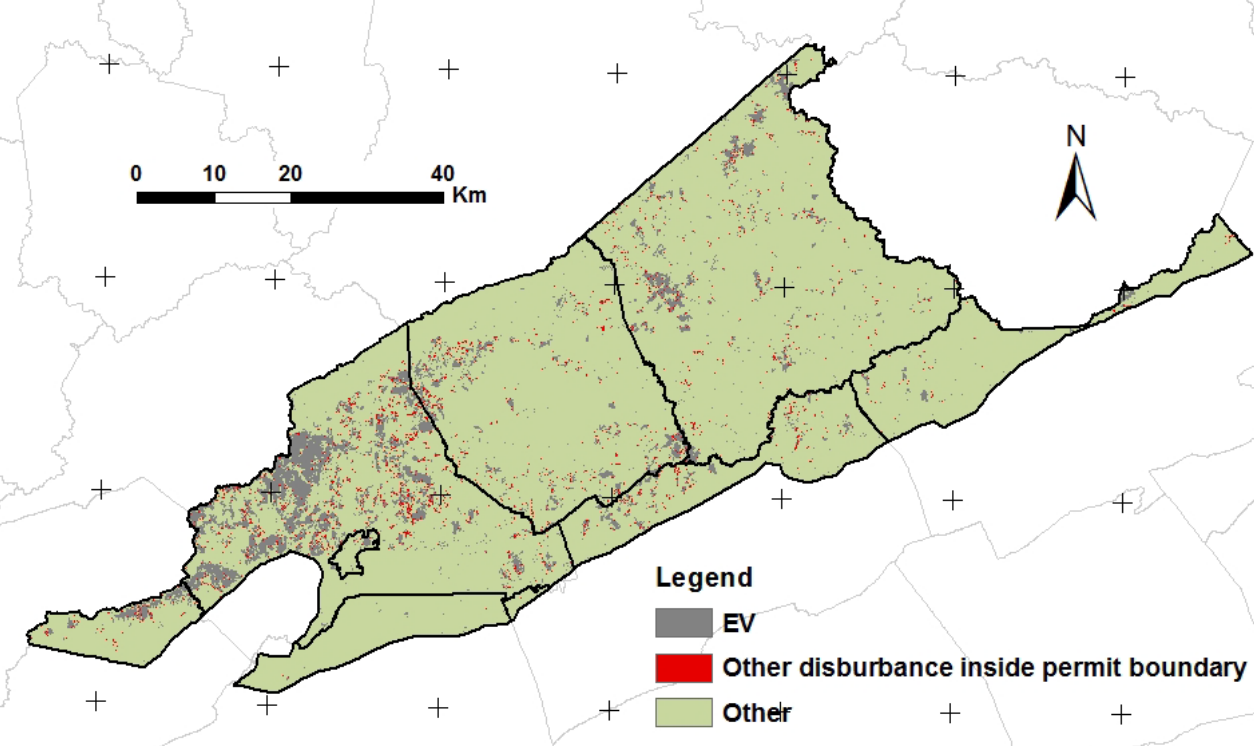
Clinch and Powell Rivers Of Southwestern Virginia and Northeastern Tennessee



Virginia coalfield surface mining, as detected by Landsat satellites

(Li et al. Env. Monit. Assess.)



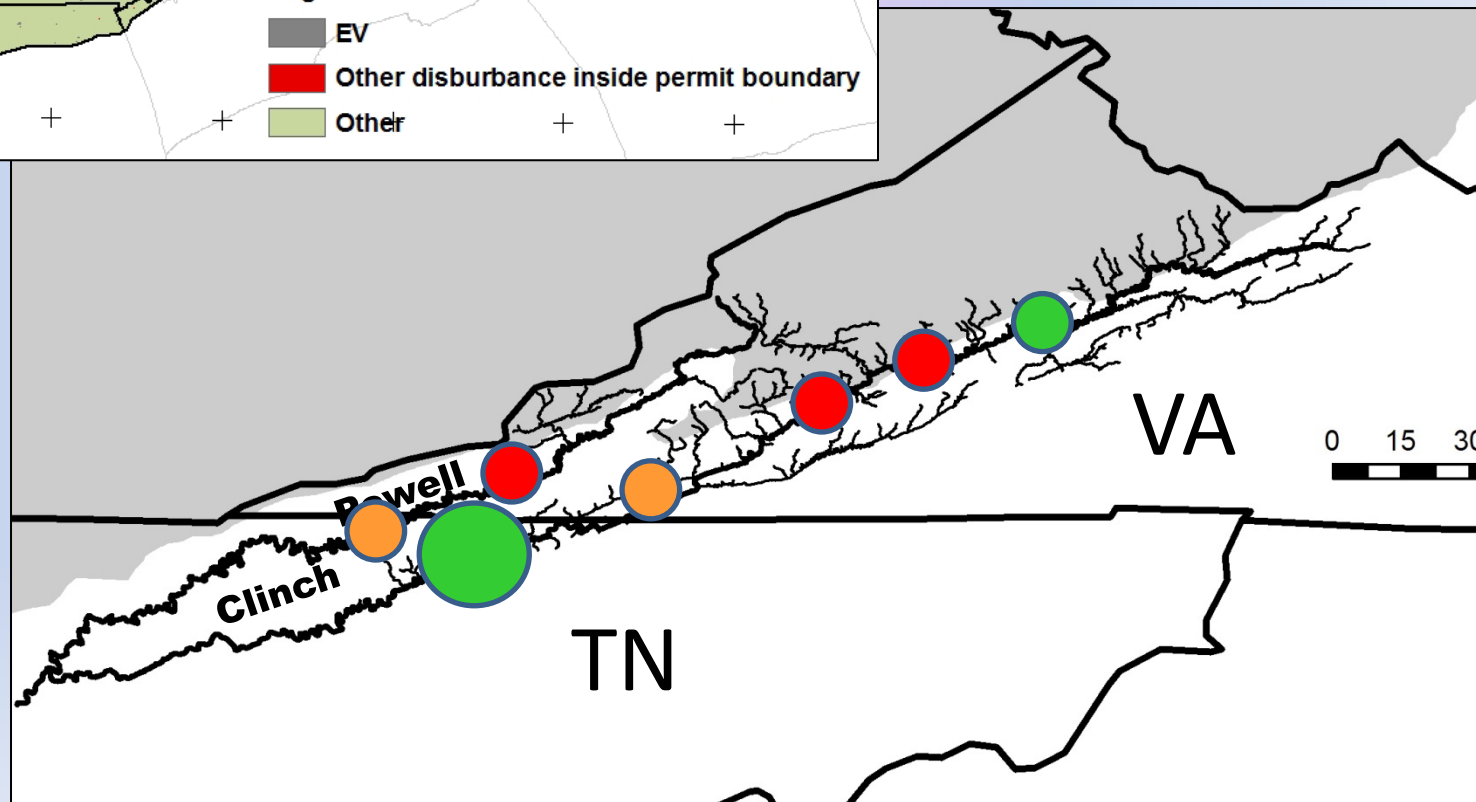


* Mussel status evaluated based in density & age structure / reproduction.

Johnson et al. 2012. Walkerana 15: 83-98

Jones et al. 2014. JAWRA 50: 820-836

Ahlstedt et al. J. Mollusk Biol. Cons. (in press)

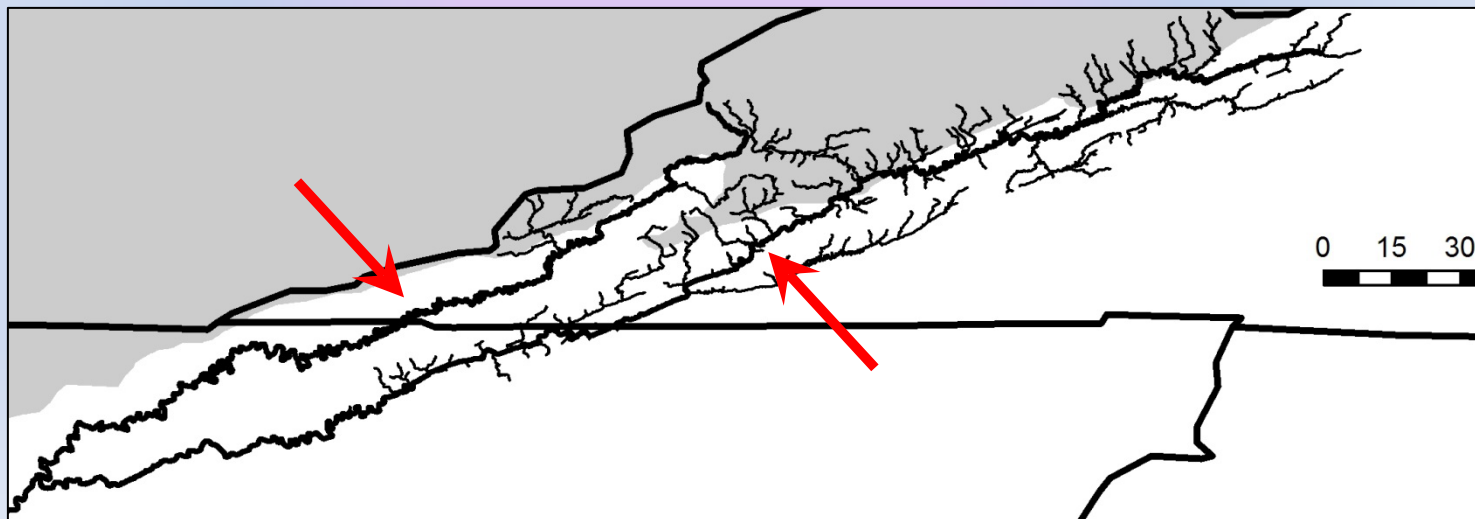
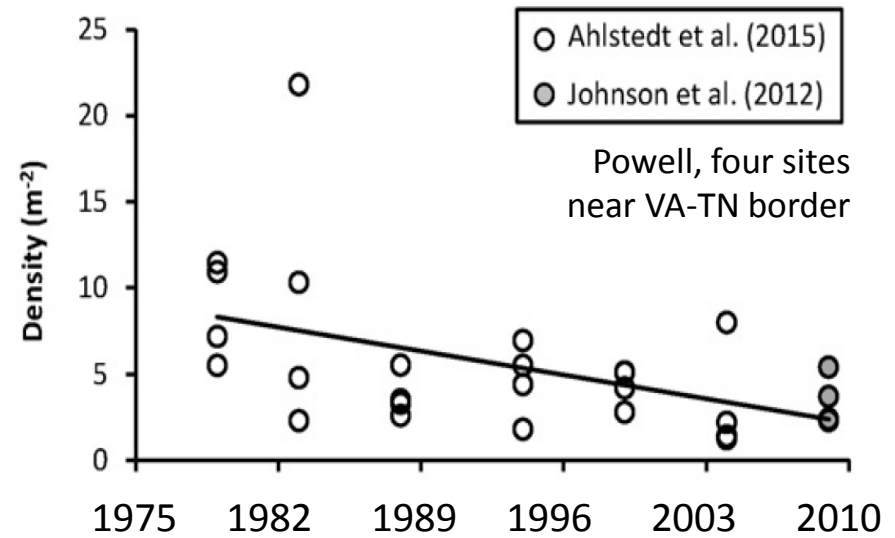
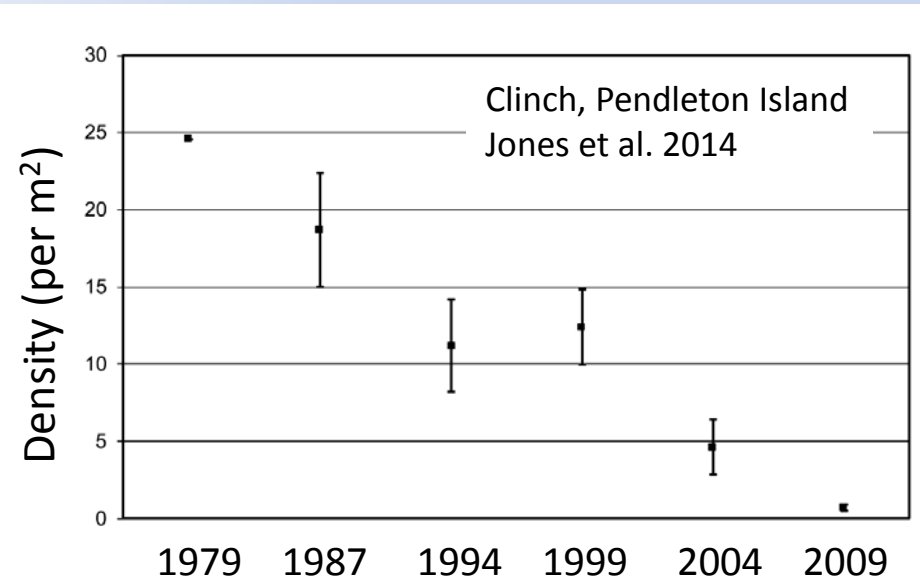


Questions:

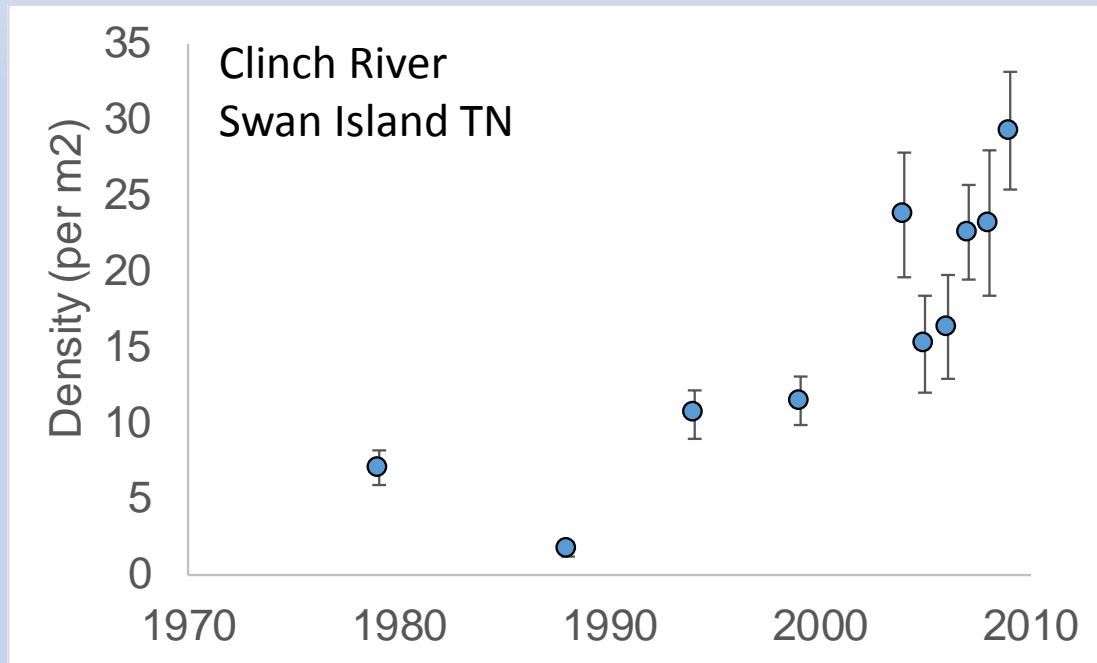
- Why are mussels doing so poorly in some areas, when they are doing well in others that are close by?
- Are specific stressors responsible for mussels' poor status in some areas?

Following slides summarize completed and ongoing research intended to answer those questions.

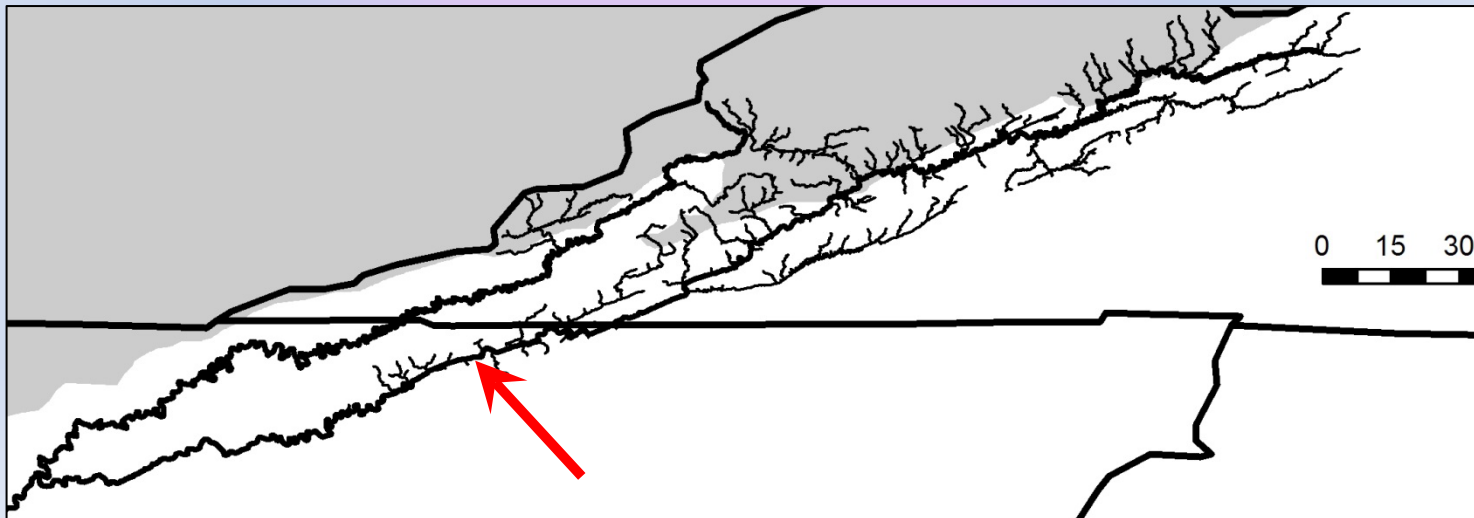
1. Mussels have experienced declines in sections of both rivers over decades.



1. Mussels have experienced declines in sections of both rivers over decades. In contrast, mussels are doing well in other areas.



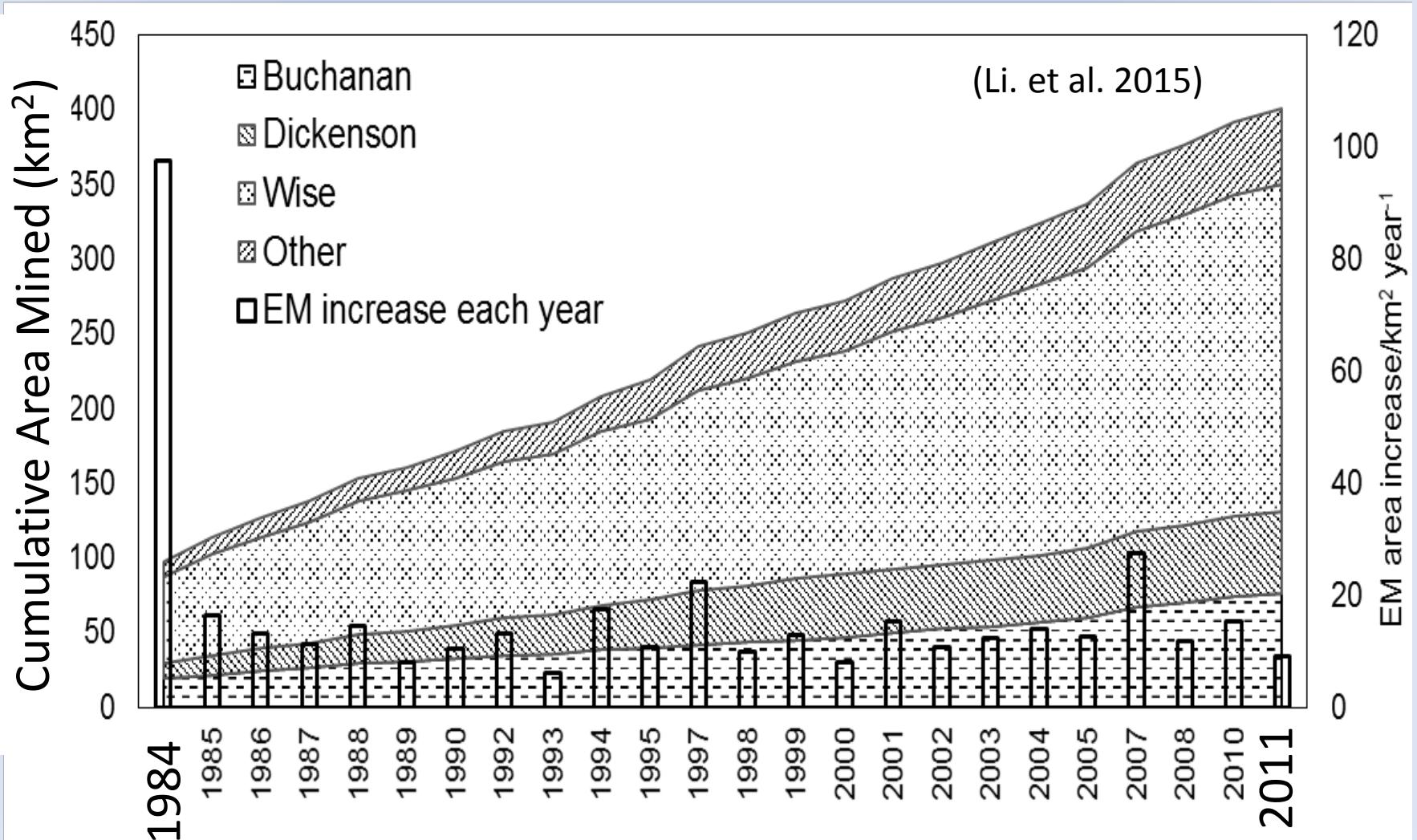
Data from
Jones et al.
2009, 2014.



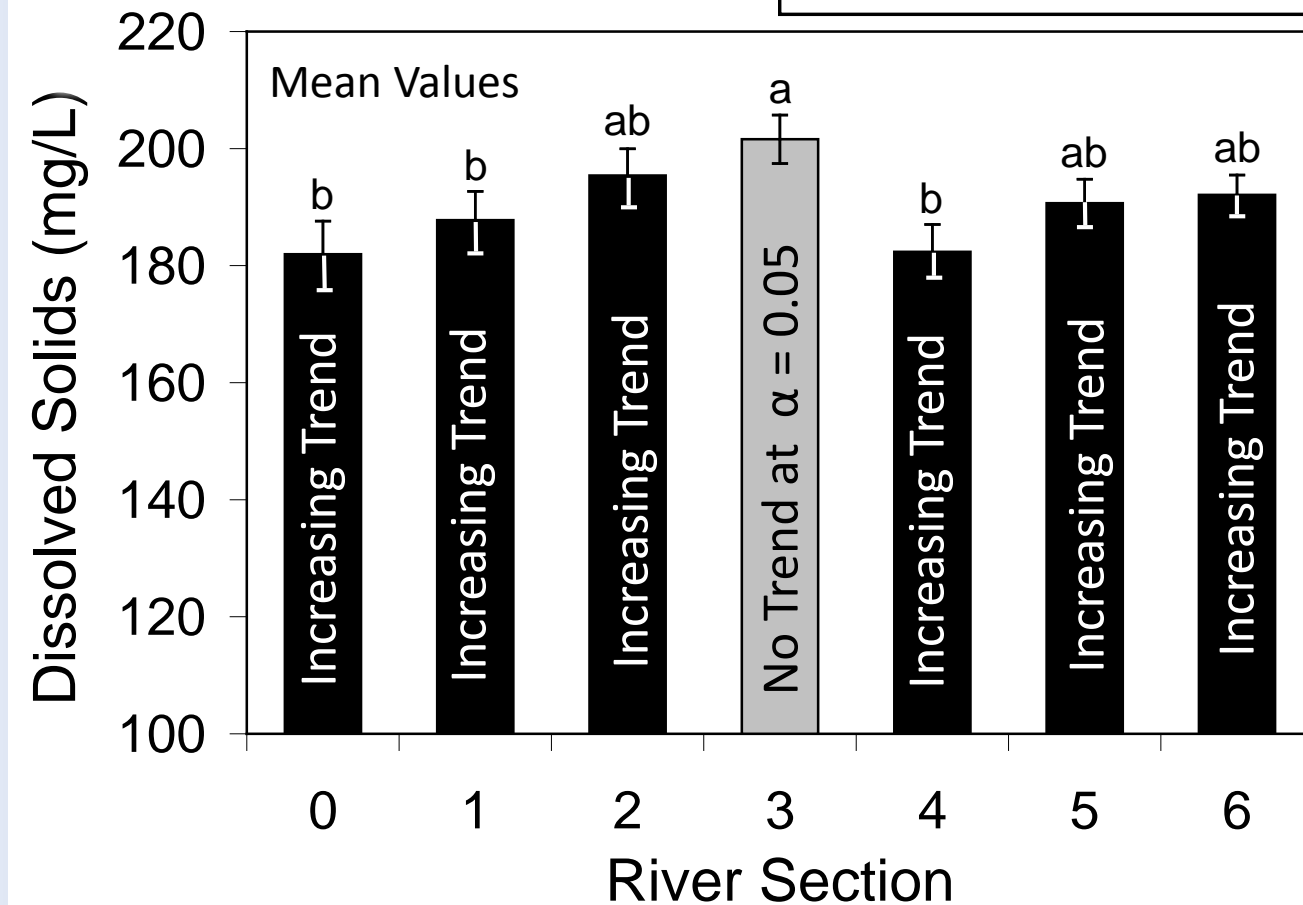
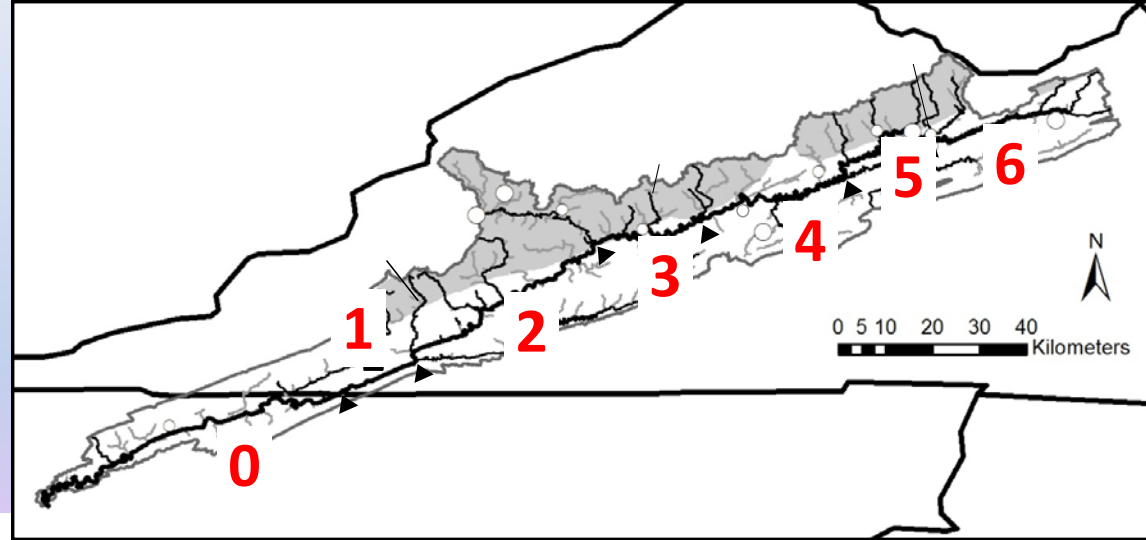
2. Watershed influence by mining, as evidenced by water conductivity and total dissolved solids, has been increasing in both rivers over periods of mussel decline.

3. Total Dissolved Solids concentrations – indicator of mining influence in these watersheds -- are negatively correlated, both spatially and temporally, with freshwater mussel status in both rivers.

Cumulative mining, VA coalfield as detected by Landsat, 1984-2011



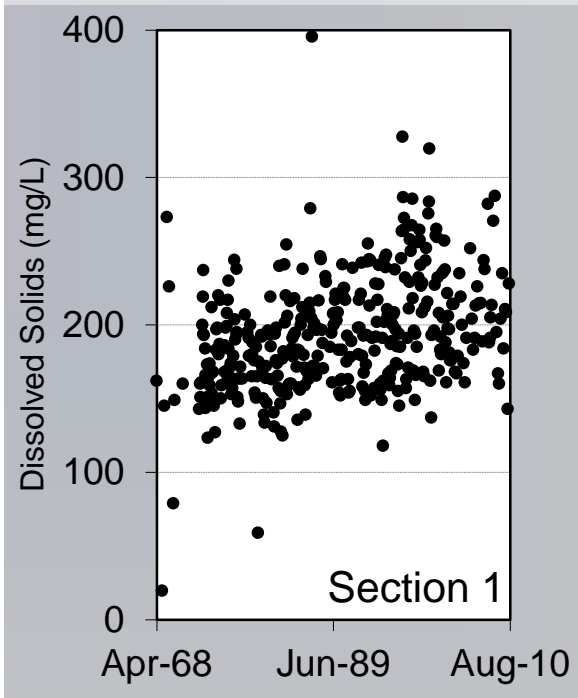
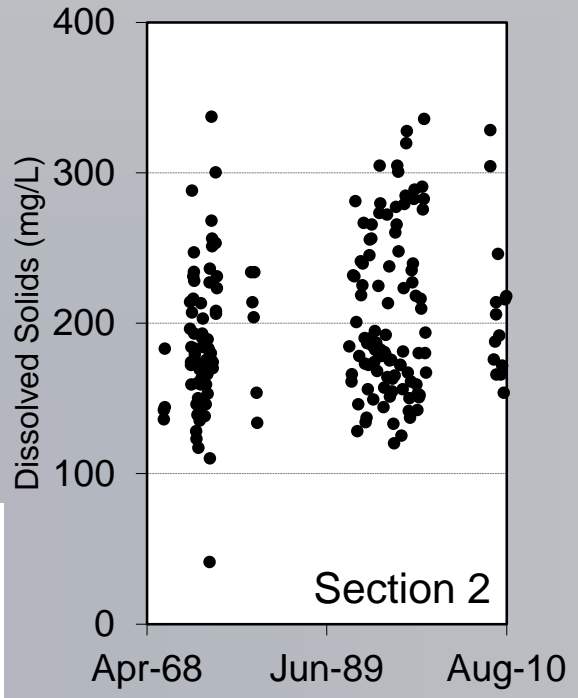
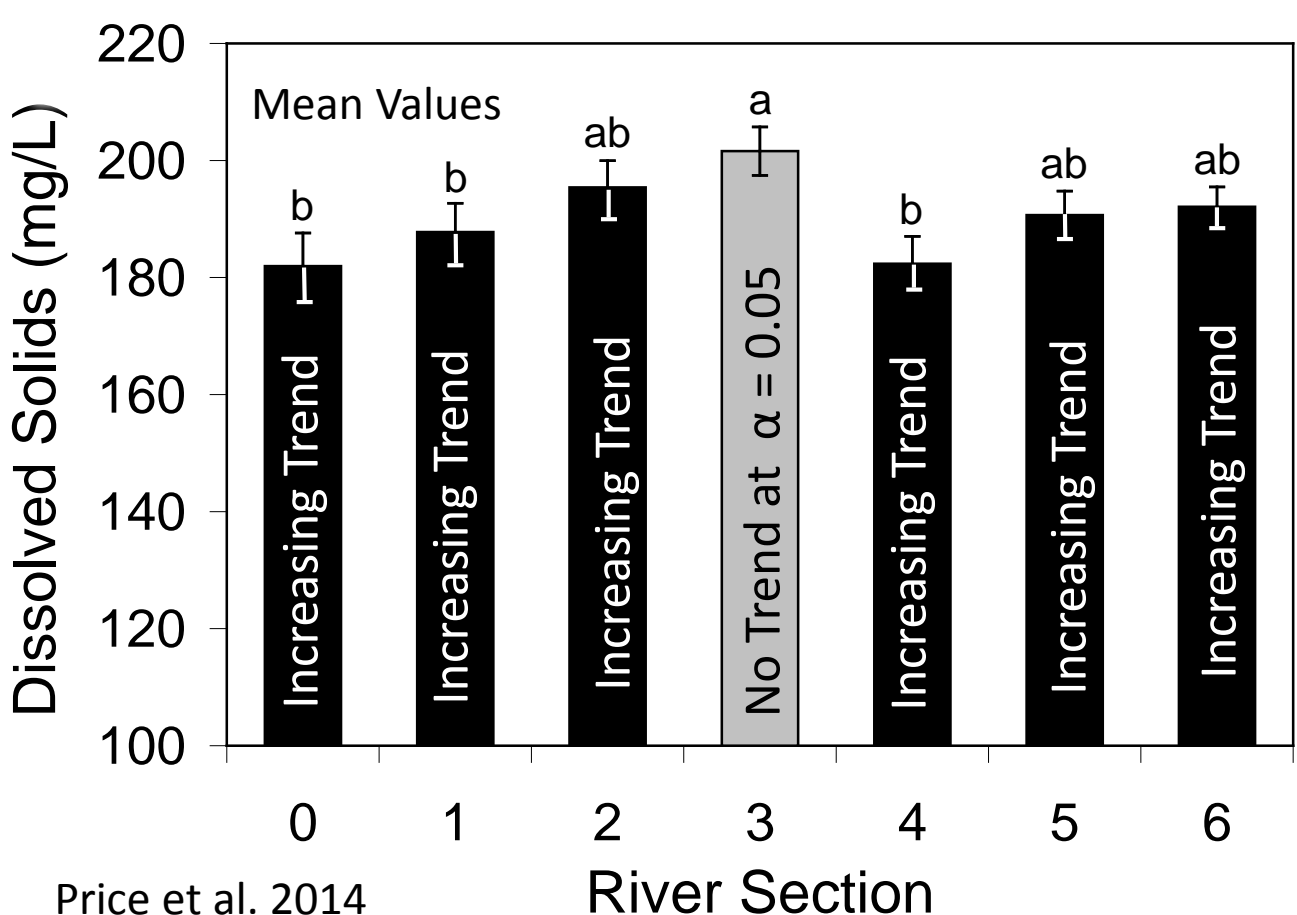
Dissolved Solids, Clinch River: Mean values and temporal trends: 1960s – 2010, by river section.



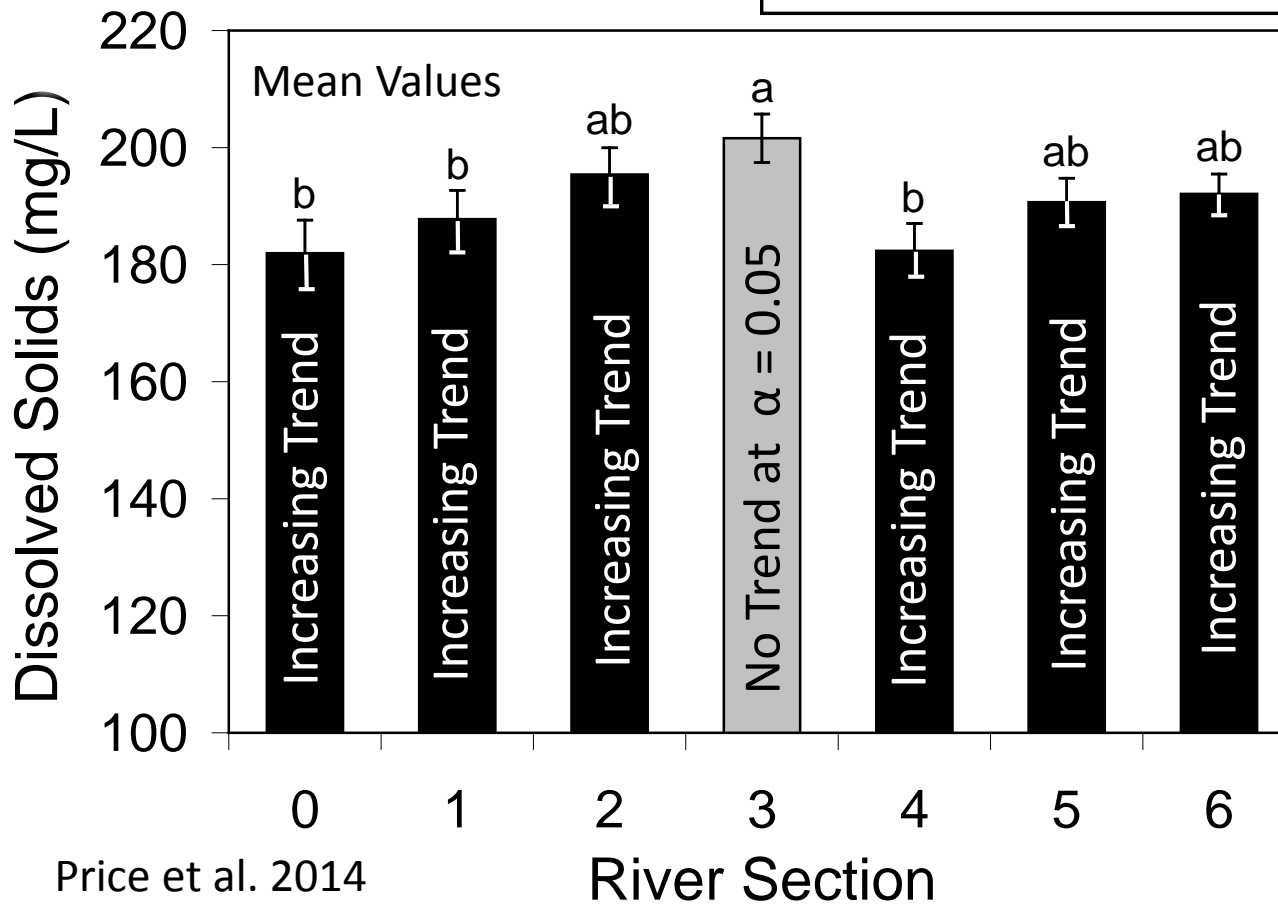
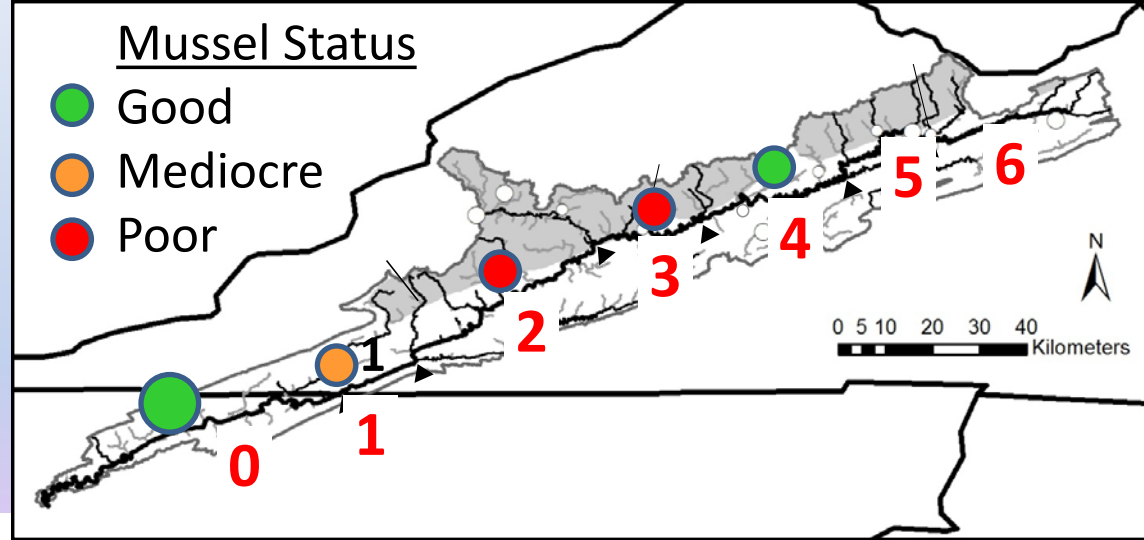
River sections designated by numbers: 0 (Tennessee) to 6 (furthest upstream)

Dissolved Solids, Clinch River: (1960s-2010)

✓ Rising trends throughout, but few differences among overall mean values.

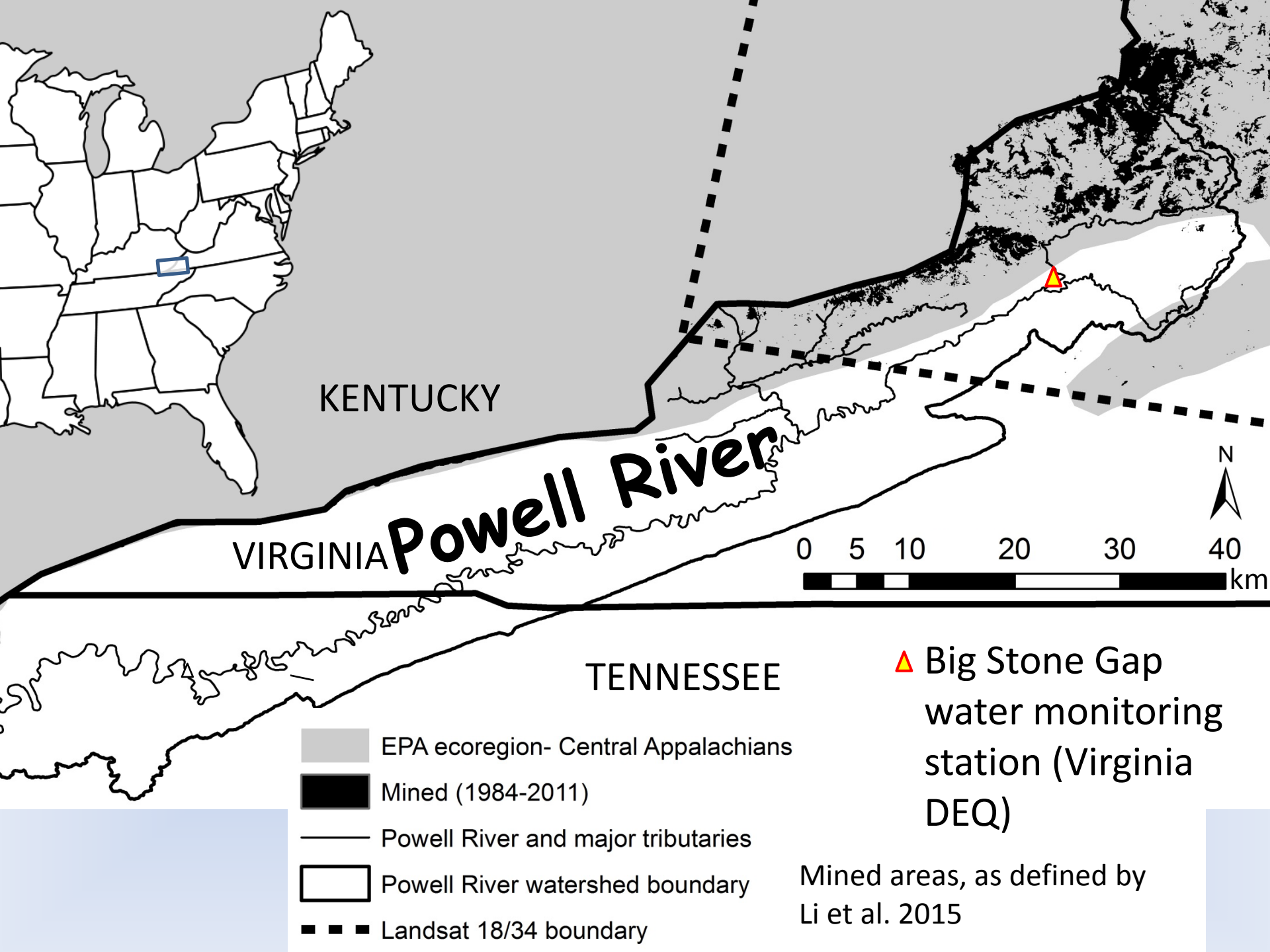


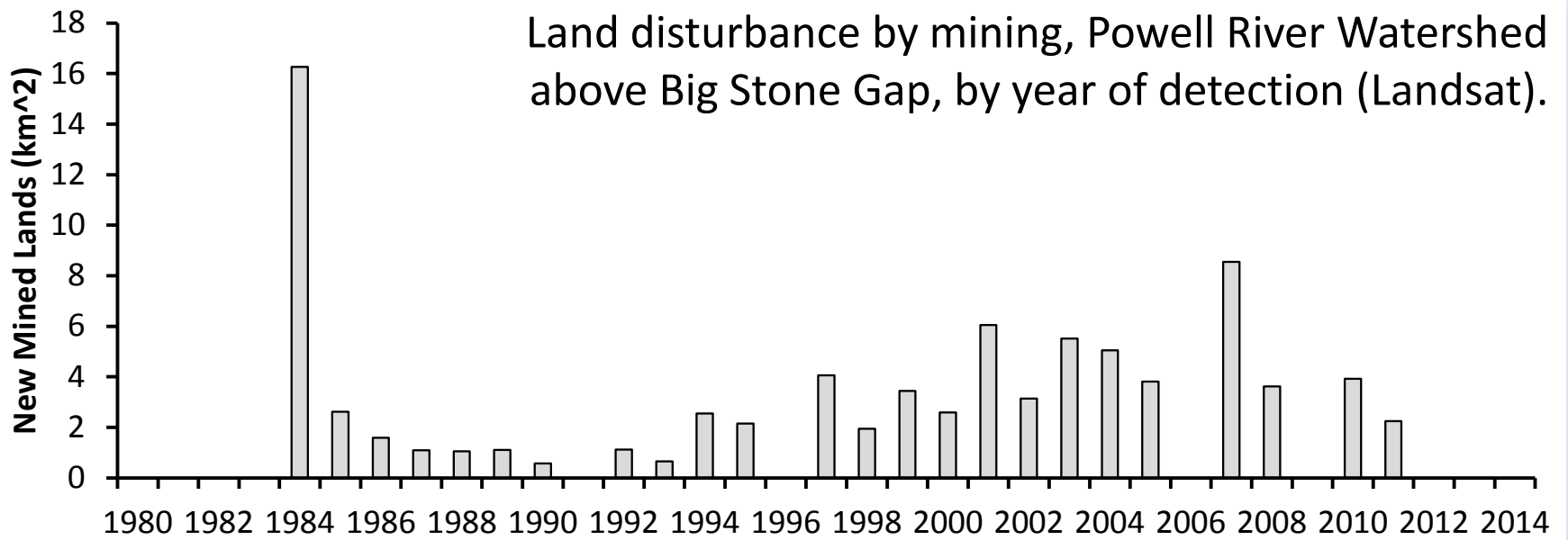
Dissolved Solids, Clinch River: Mean values and temporal trends: 1960s – 2010.



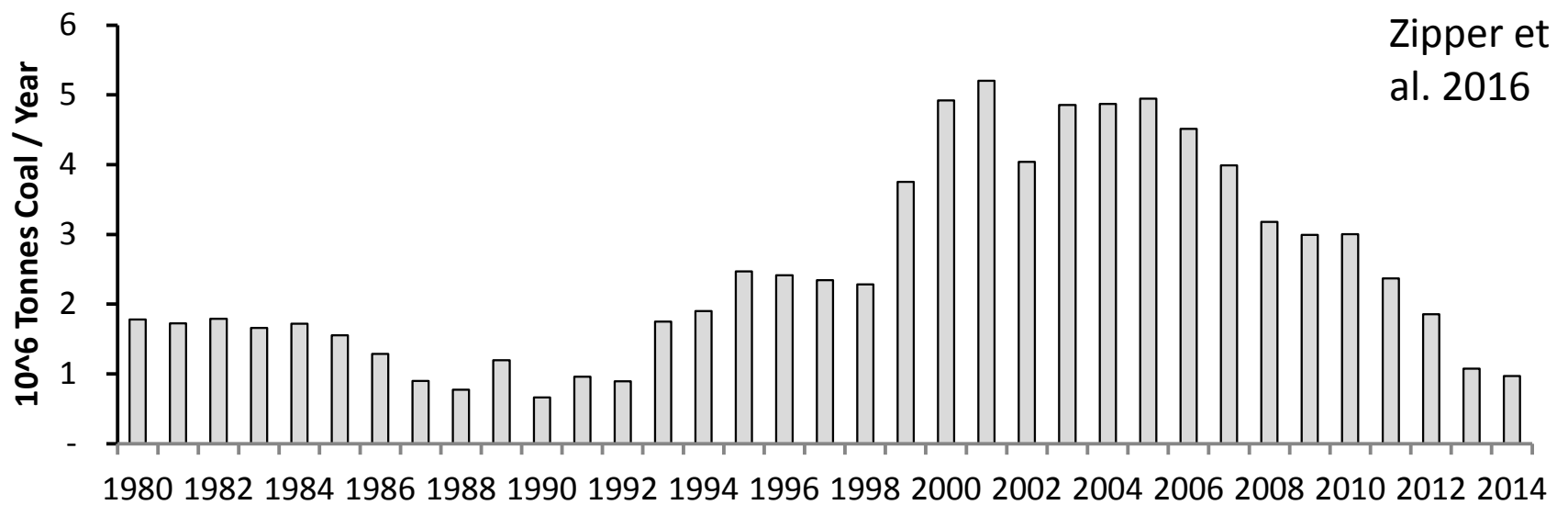
Johnson et al. (2014) measured continuous SC in Sections 0 and 2; found SC in Sec. 2 > SC in Sec. 0 ($p < 0.05$).

 Later, Sec. 2 is described as “impacted reach”

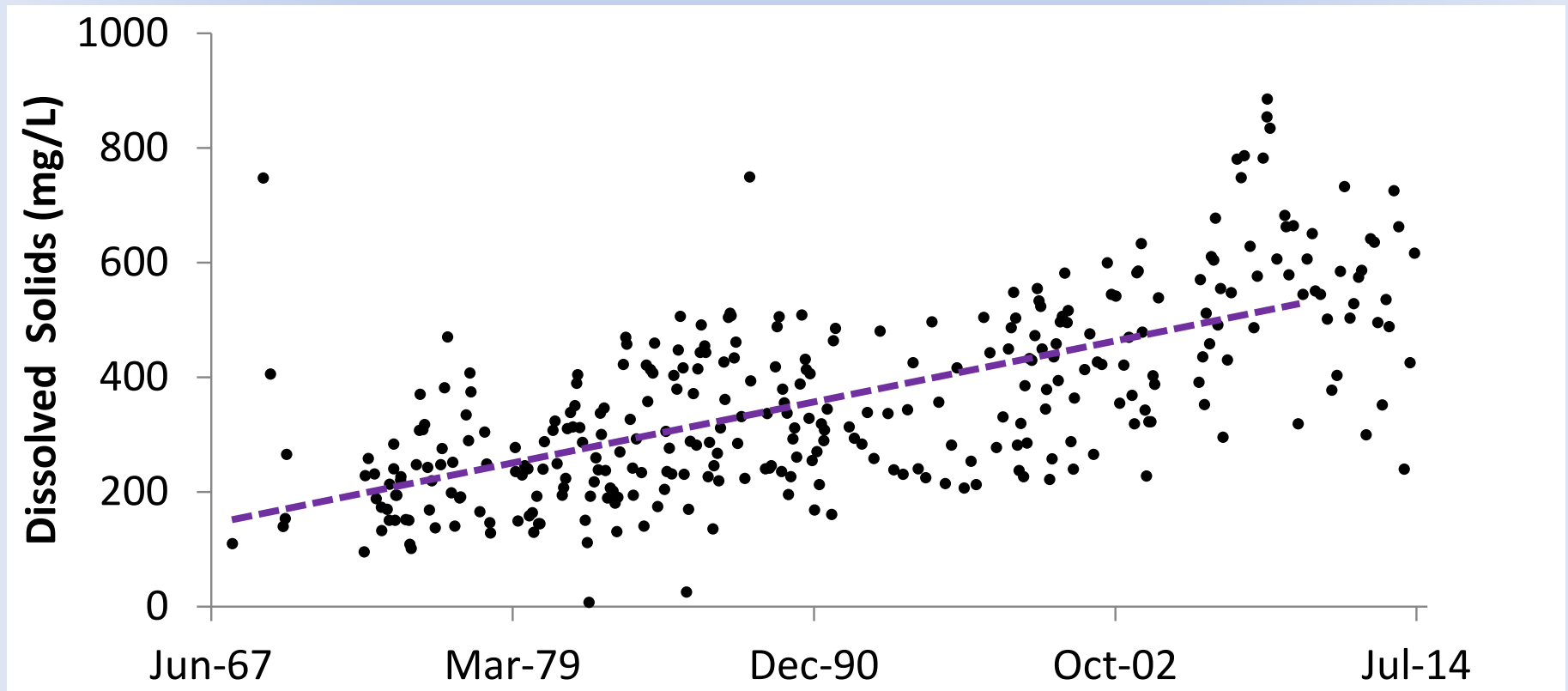




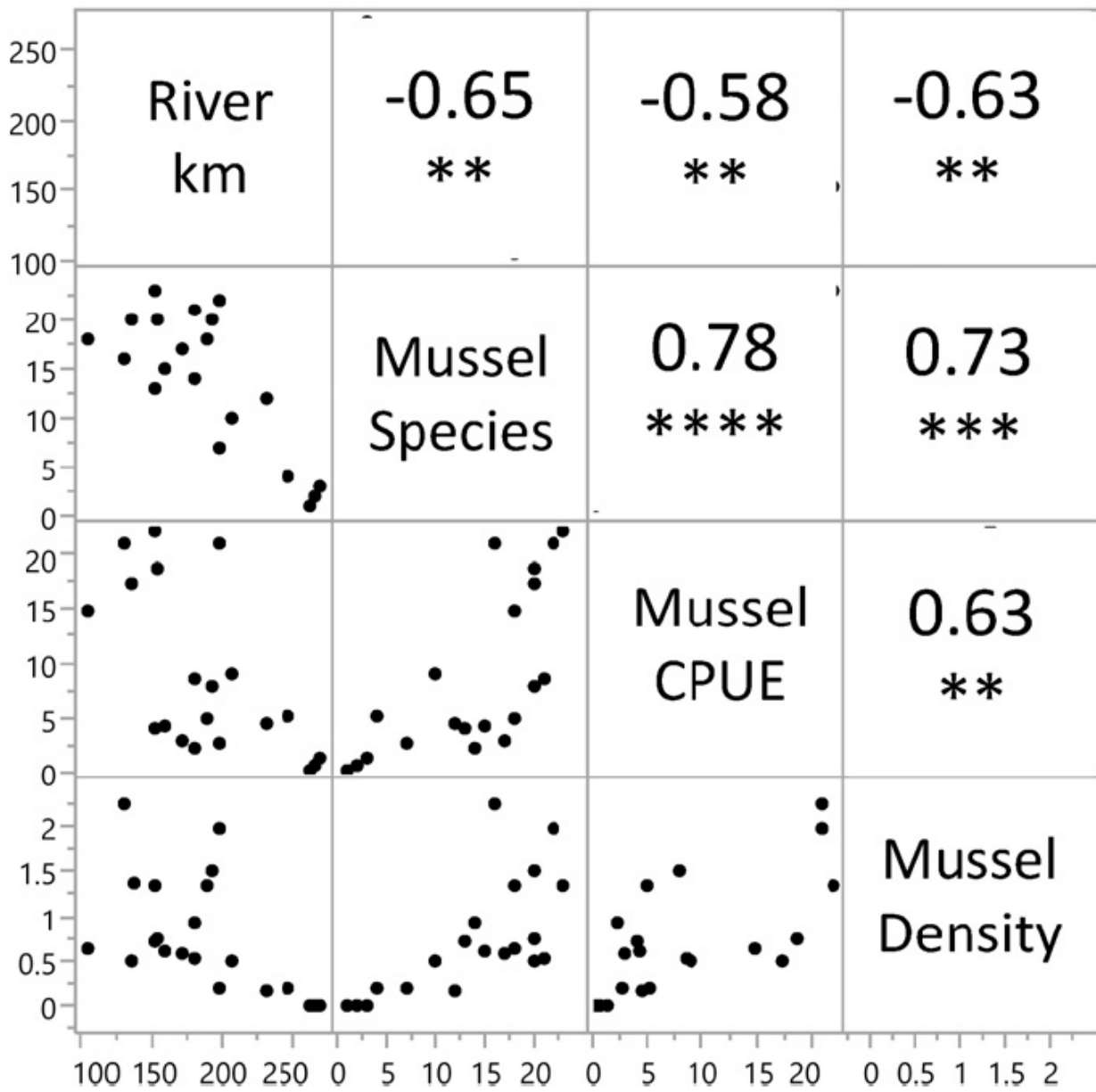
Estimate annual surface coal production, Powell River watershed -- *assuming* (a) equivalent proportions of Wise Co. totals for both mined land disturbance and coal production; (b) estimates for missing years.



Total Dissolved Solids DEQ monitoring data, 1967 – 2014:
Highly significant increasing trend at Big Stone Gap (through
6/10). Increasing trends also present further downstream.



Spatial correlations of river km with mussel metrics in Powell River



River km is proxy for mining influence / TDS, since major mining influence is in the headwaters.

Mussel data from Johnson et al. (2012) based on 2008-2009 sampling.

(chart from Zipper et al. 2016)

Temporal Correlations: Environmental Indicators vs. Mussel Status

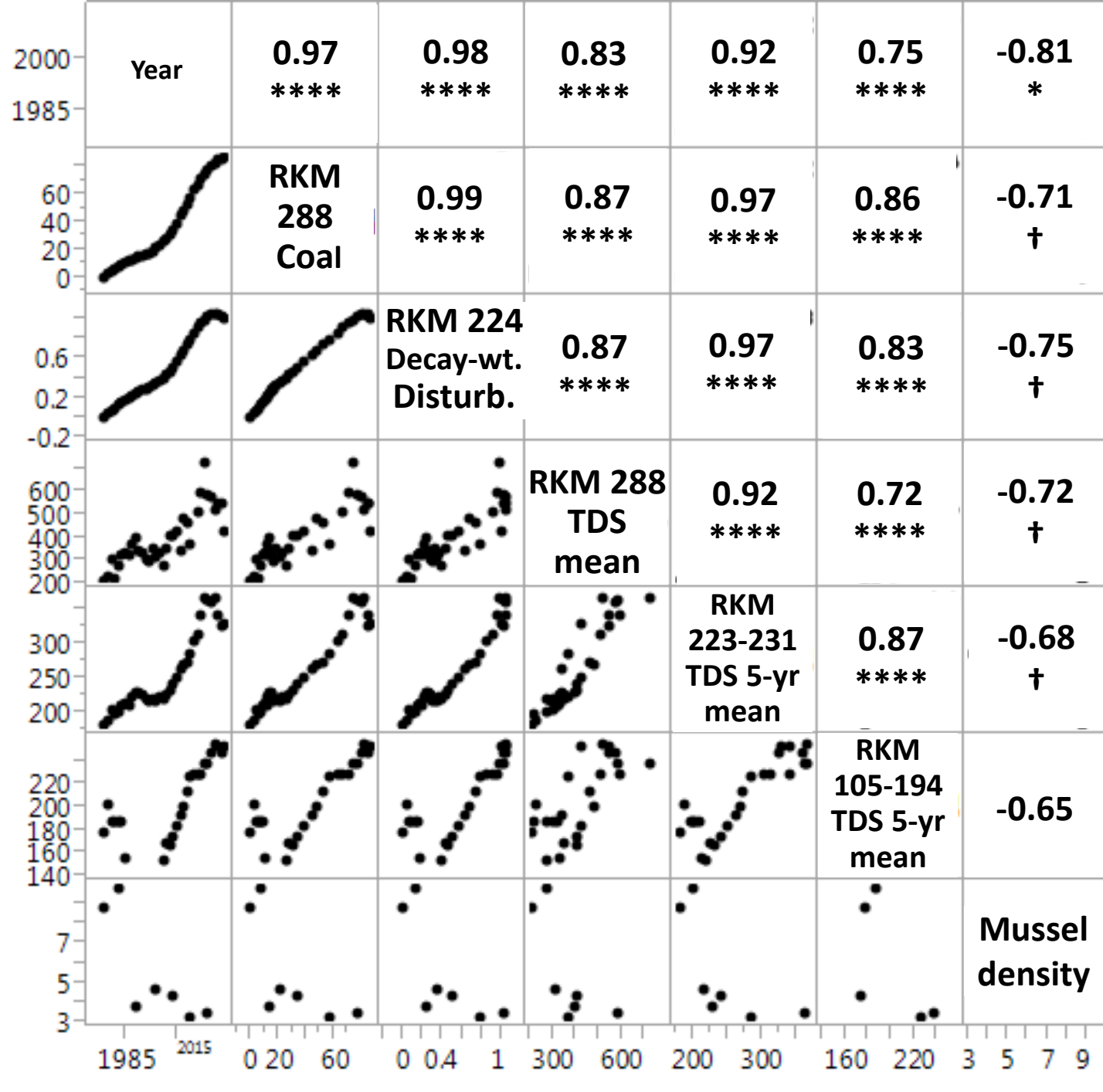
RKM 288 = Big Stone Gap

RKM 223-231 = Jonesville

RKM105-194 = Lower Virginia to Tennessee

Mussel density near VA-TN state line (4 locations; data from Alstedt et al. 2017).

† = 0.05 < p < 0.10

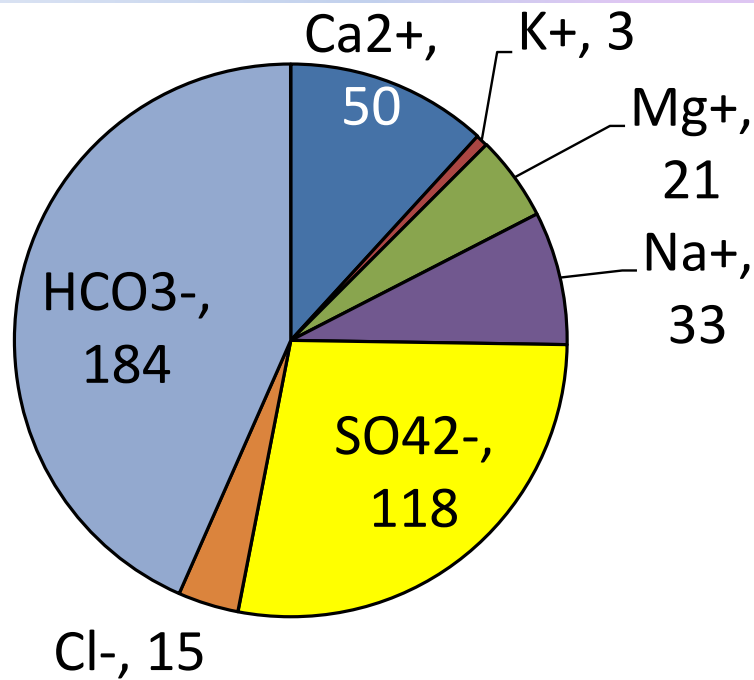


(chart from Zipper et al. 2016)

4. Bioassays to test influence of environmentally relevant concentrations of major ions (TDS) on juvenile mussel survival and growth have revealed no significant toxicity or growth impairments.

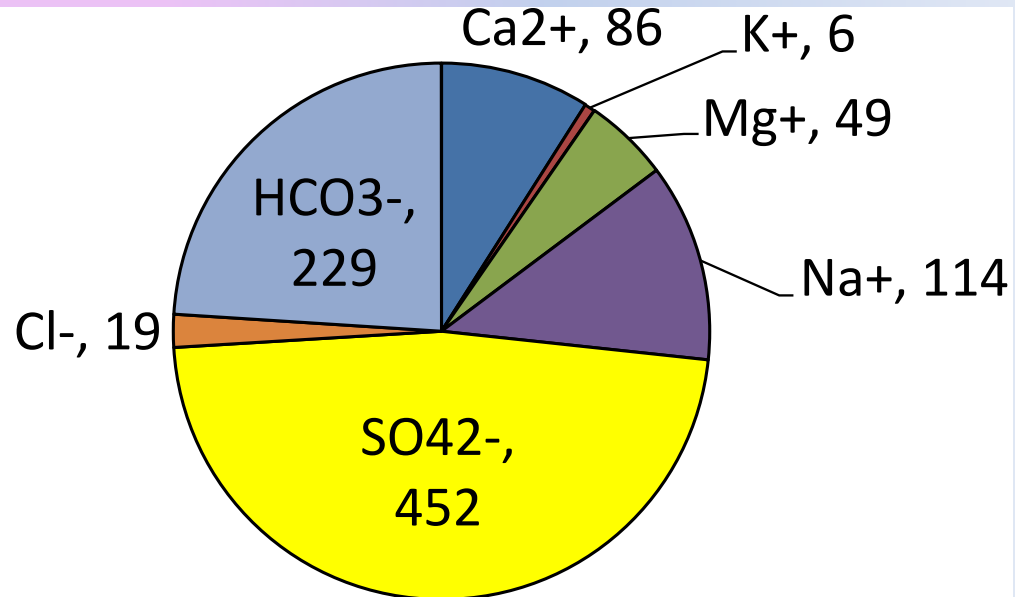
Hypothesis: Major ions / TDS / Specific Conductance are exerting toxic influence in the Clinch and/or Powell Rivers?

Investigate Hypothesis: 56 day exposure of juvenile *Villosa Iris*, a native mussel, to major ion mixtures equivalent to “worst case” measured conditions both rivers.



Clinch: 424 mg/L
Below Guest R.

Powell: 942 mg/L
Big Stone Gap



Methods (con'd): Experiment was fully replicated (6 groups for each of 4 treatments: Clinch, Powell, full pond control, ½ control); 1200 mussels total.

Results:

No statistically significant difference between either Powell or Clinch treatment with control ($\alpha = 0.05$).

Powell growth was nominally depressed, relative to Clinch and control.

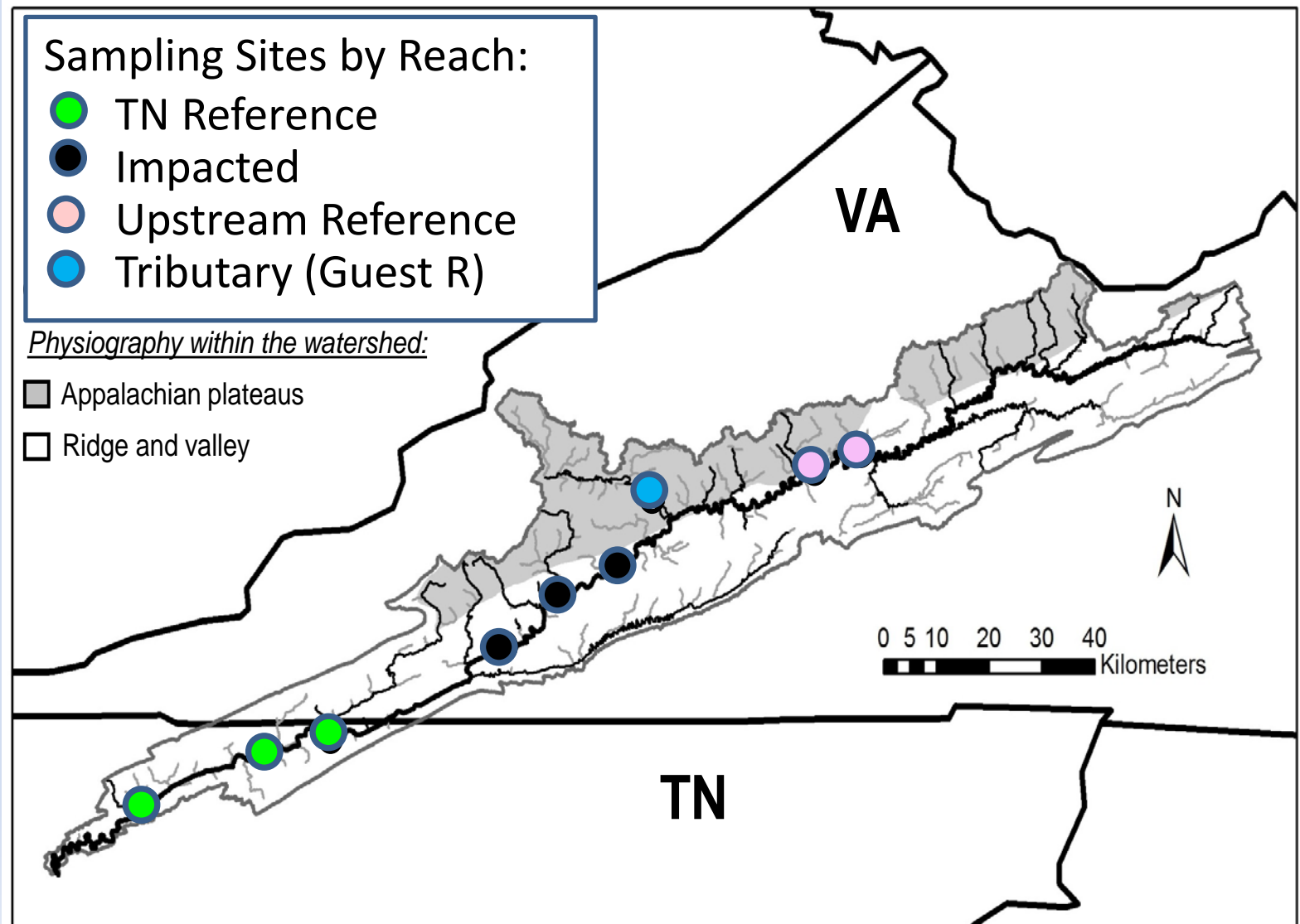
Conclusion: Results do not support the “major ion toxicity” hypothesis – at least for *V. iris* at that life stage.

5. Mussels are known to be sensitive to metals.

Both water-column and tissue concentrations of potentially toxic metals are elevated in mining-influenced sections of the Clinch River where mussel declines have been noted.

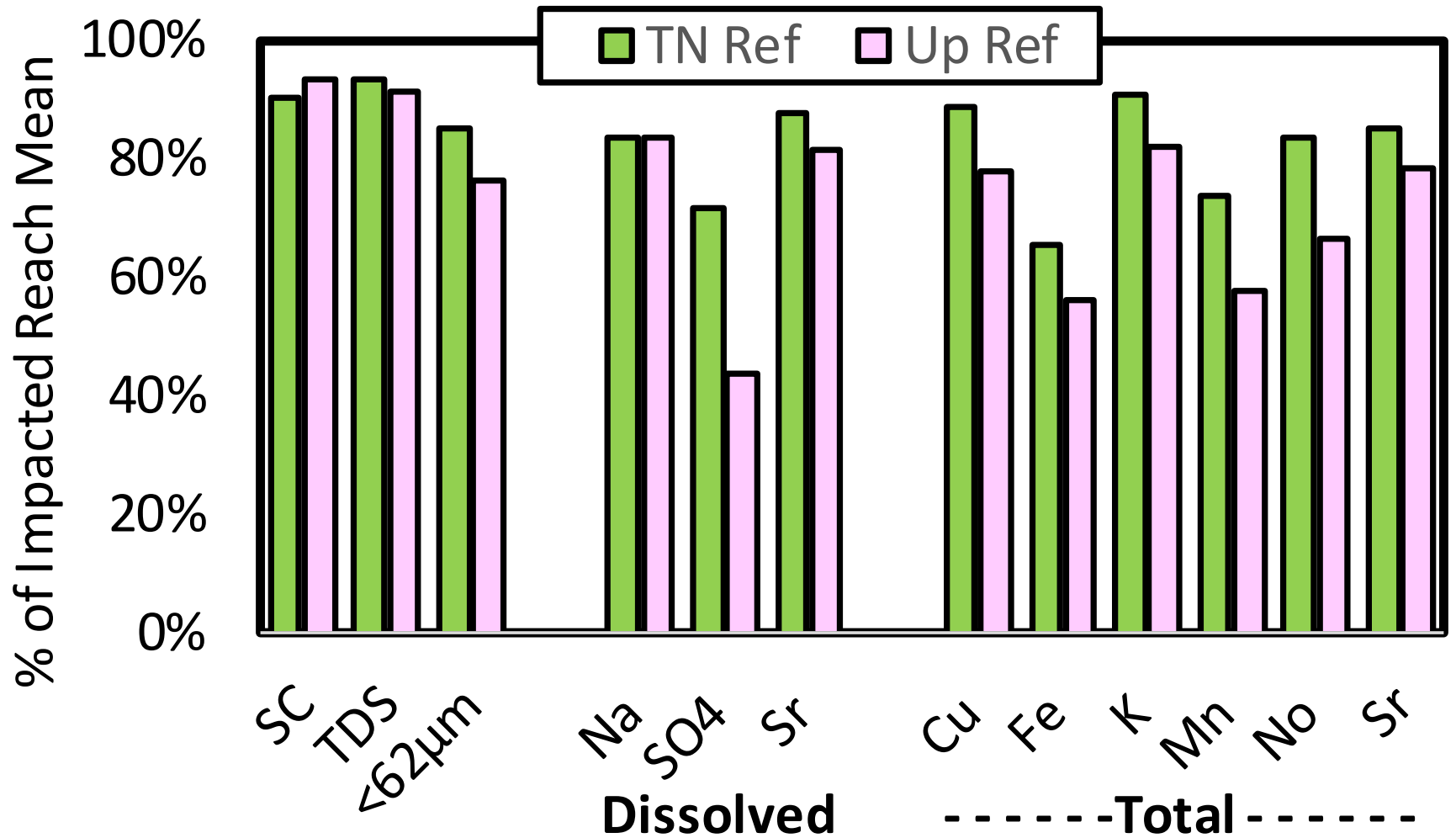
VA DEQ – TN DEC Cooperative Water Monitoring

Coordinated baseflow monitoring of Clinch River by state agencies, for the purpose of enabling interstate water quality comparisons



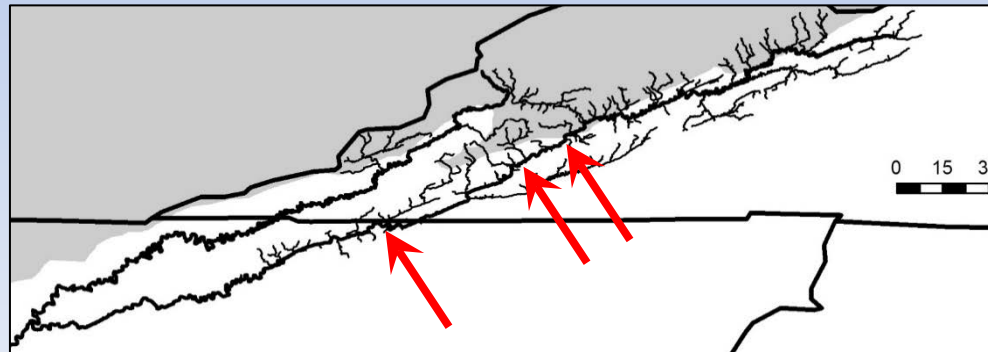
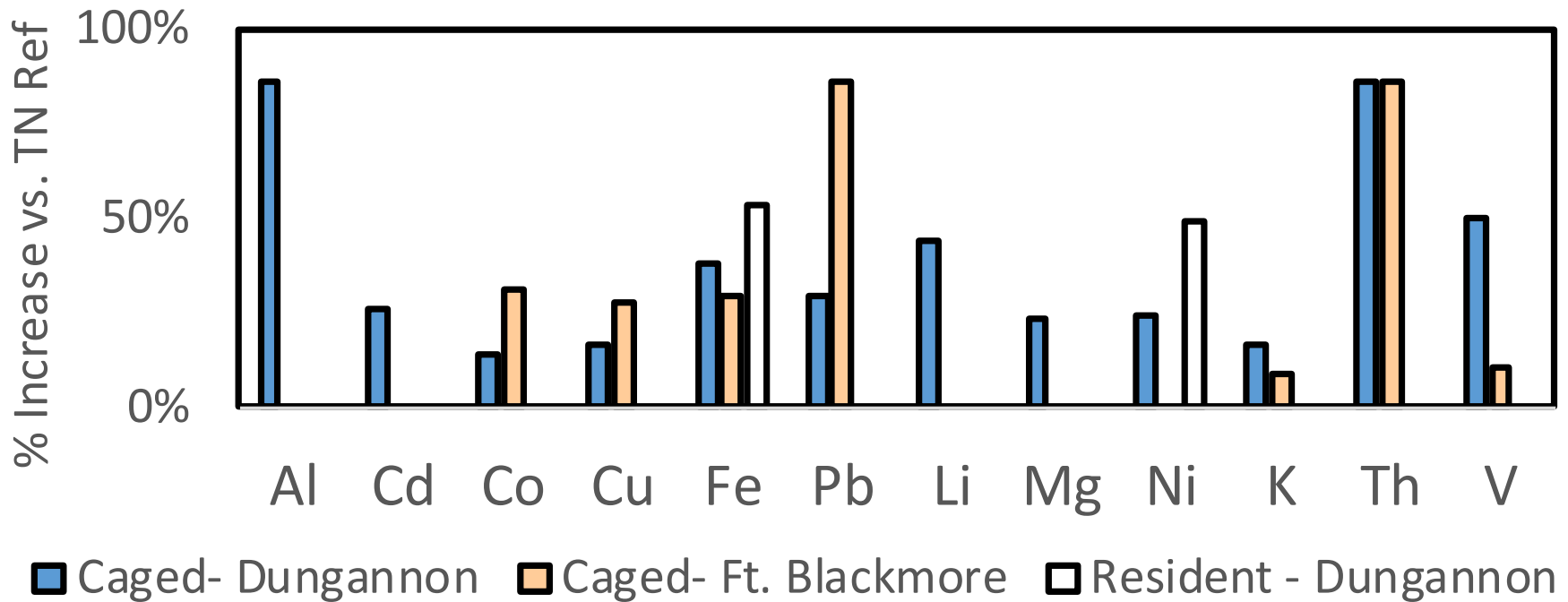
VA DEQ – TN DEC Cooperative Water Monitoring

Mean values of TN-Reference and Upstream-Reference parameters that are both significantly different from Impacted Reach means (Yr 1)



US Geological Survey Study: Clinch River

Compare tissue concentrations of caged (*V. iris*) and resident (*A. pectorosa*) mussels in Impacted Reach vs. Horton Ford (TN Reference)



Johnson et al.
2014

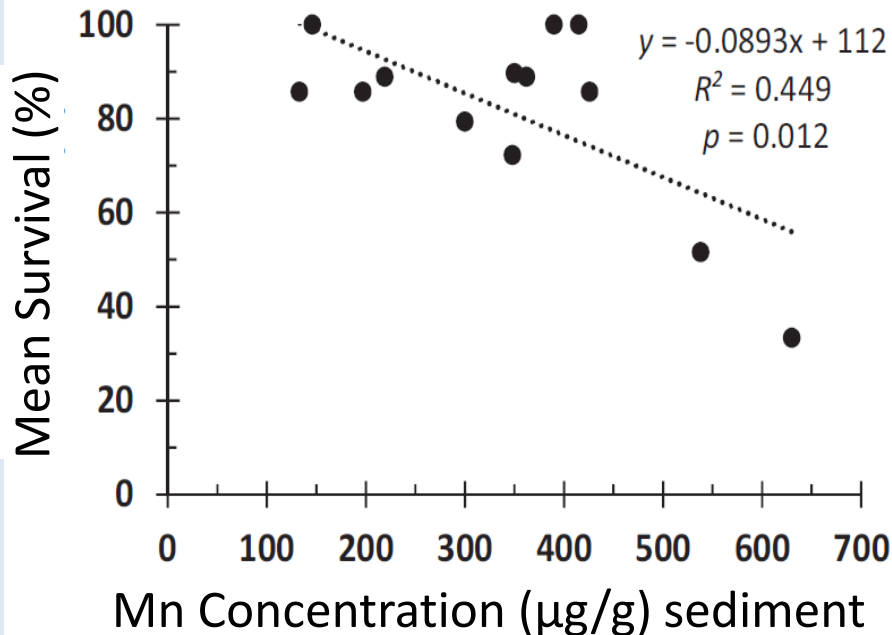
N.C. State University Study (Archambault et al. 2017)

Trap suspended sediments at multiple locations. Expose juvenile *E. brevidens* to sediments in laboratory bioassays. Assess relationships of mussel survival and biomass to sediments' extractable constituents .

Results

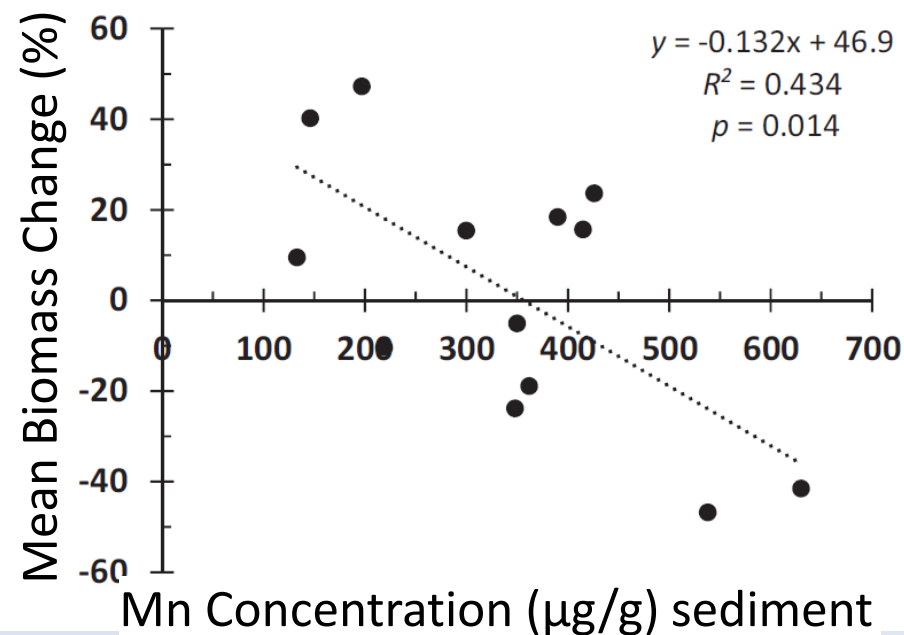
Survival was negatively correlated with:

- Mn, Co, NH₄



Biomass was negatively correlated with:

- Mn, Co, Total Organic C



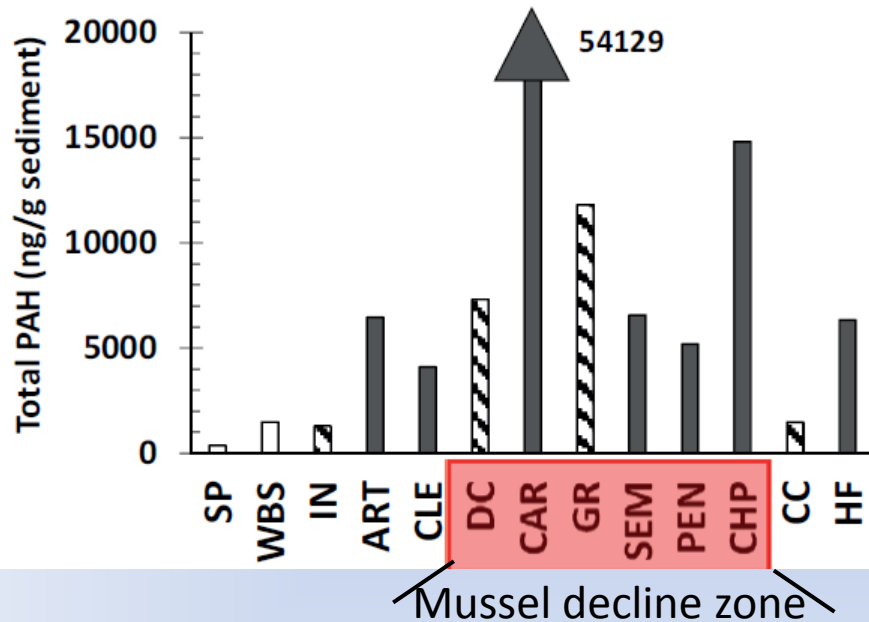
6. Recent data show that polycyclic aromatic hydrocarbon (PAHs) concentrations are elevated in Clinch River sections where mussel declines have been noted, relative to other sections.

N.C. State University Study (Archambault et al. 2017)

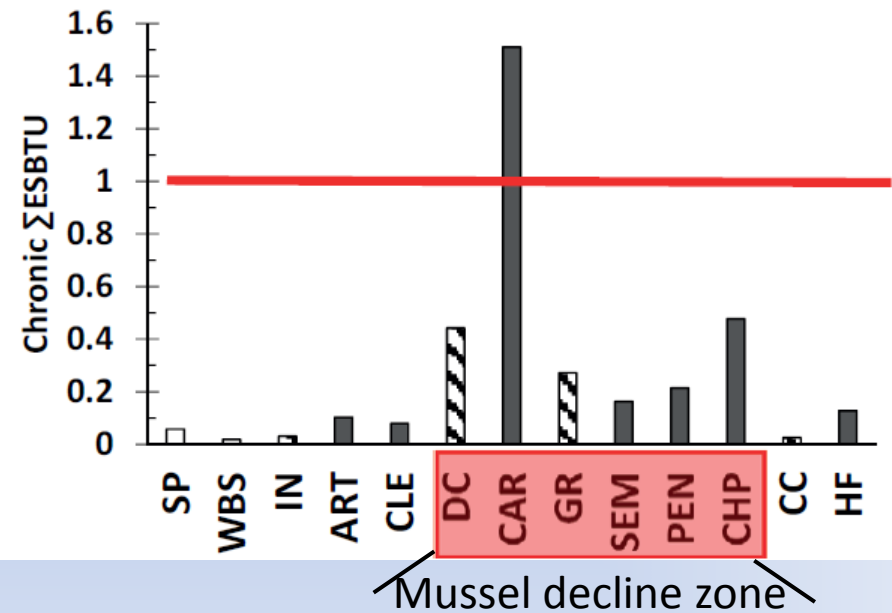
Trap suspended sediments at multiple locations ... Assess relationships of mussel status to sediments' extractable constituents .

Results: Polycyclic aromatic hydrocarbons (PAHs) are elevated in river sections of poor mussel status.

Total PAH



PAH Chronic Toxicity Units



Petrogenic PAH (i.e. derived from unburned fossil fuel -- including coal, oils, etc.) are 65-85% of total PAH at most locations.

Conclusions

- ❖ Freshwater mussel populations in the Clinch and Powell Rivers are a unique and valued biodiversity resource.
- ❖ Freshwater mussels have declined relative to historic levels in most sections of the Clinch River and throughout the Powell River.
- ❖ Mussel declines appear as correlated with coal-mining influence, but specific stressors responsible for declines are not known.
- ❖ Candidate responsible stressors include:
 - TDS/major ions (perhaps working through subtle mechanisms such as effects on reproduction).
 - Metals: Via bioaccumulative mechanisms and/or physiological interactions with fine-particulate forms.
 - PAHs derived from unburned fossil fuels.
- ❖ Observed effects may be caused by synergistic interactions of multiple contaminants.

References

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