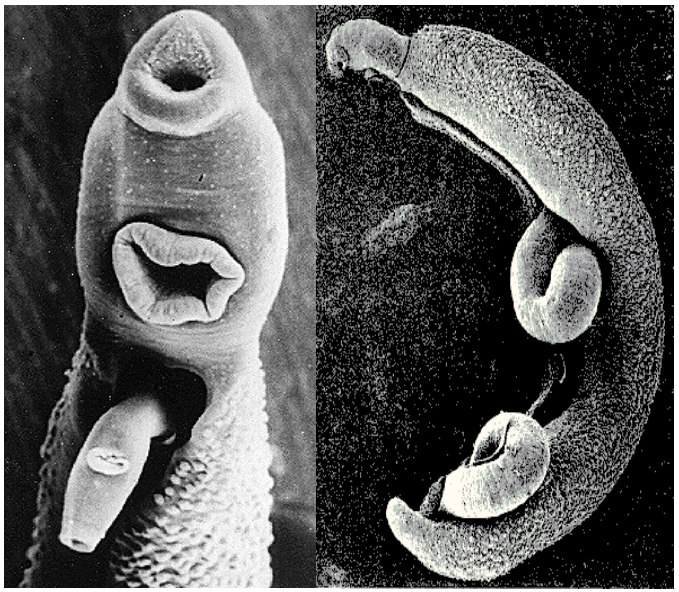
Environmental Predictors of Avian Schistosomiasis ("Swimmer's Itch") in Michigan Lakes

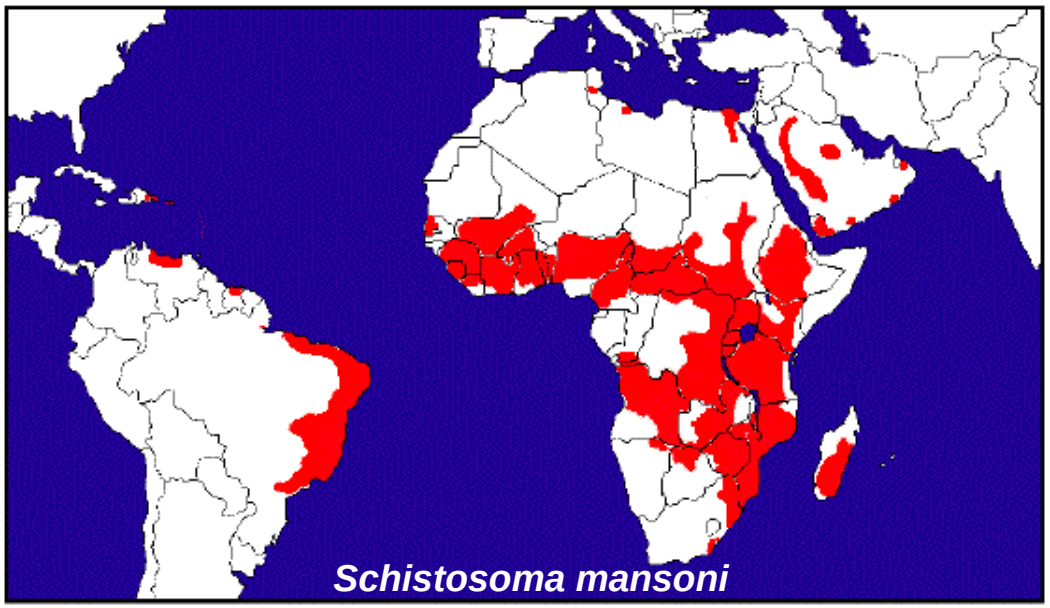
Madelyn Messner
MS Biology Candidate
Raffel Ecology Lab

OAKLAND UNIVERSITY
Biological Sciences

Human Schistosomiasis

- *Schistosoma sp.*
- Ranked 2nd most important tropical disease by WHO
- 200-300 million people infected
  - many school age children
  - 20 million severe disease
  - Estimated 800,000 deaths/year

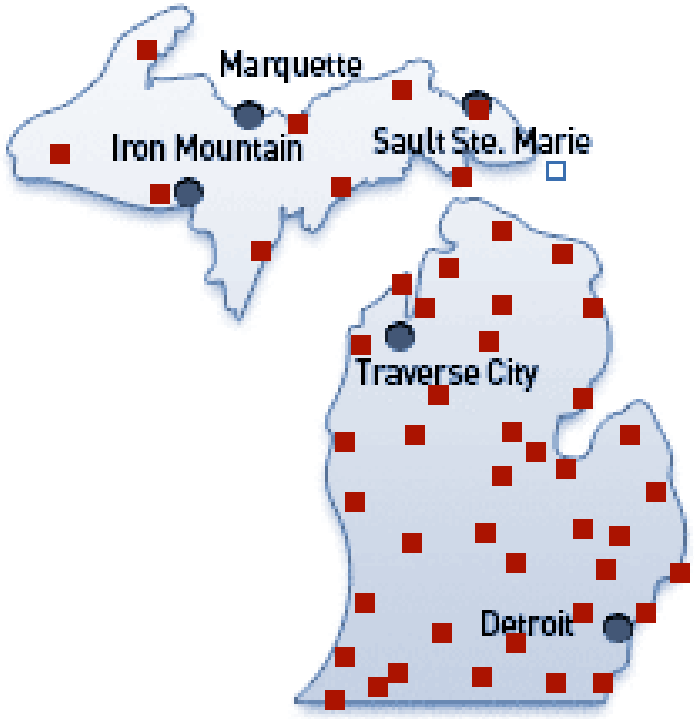


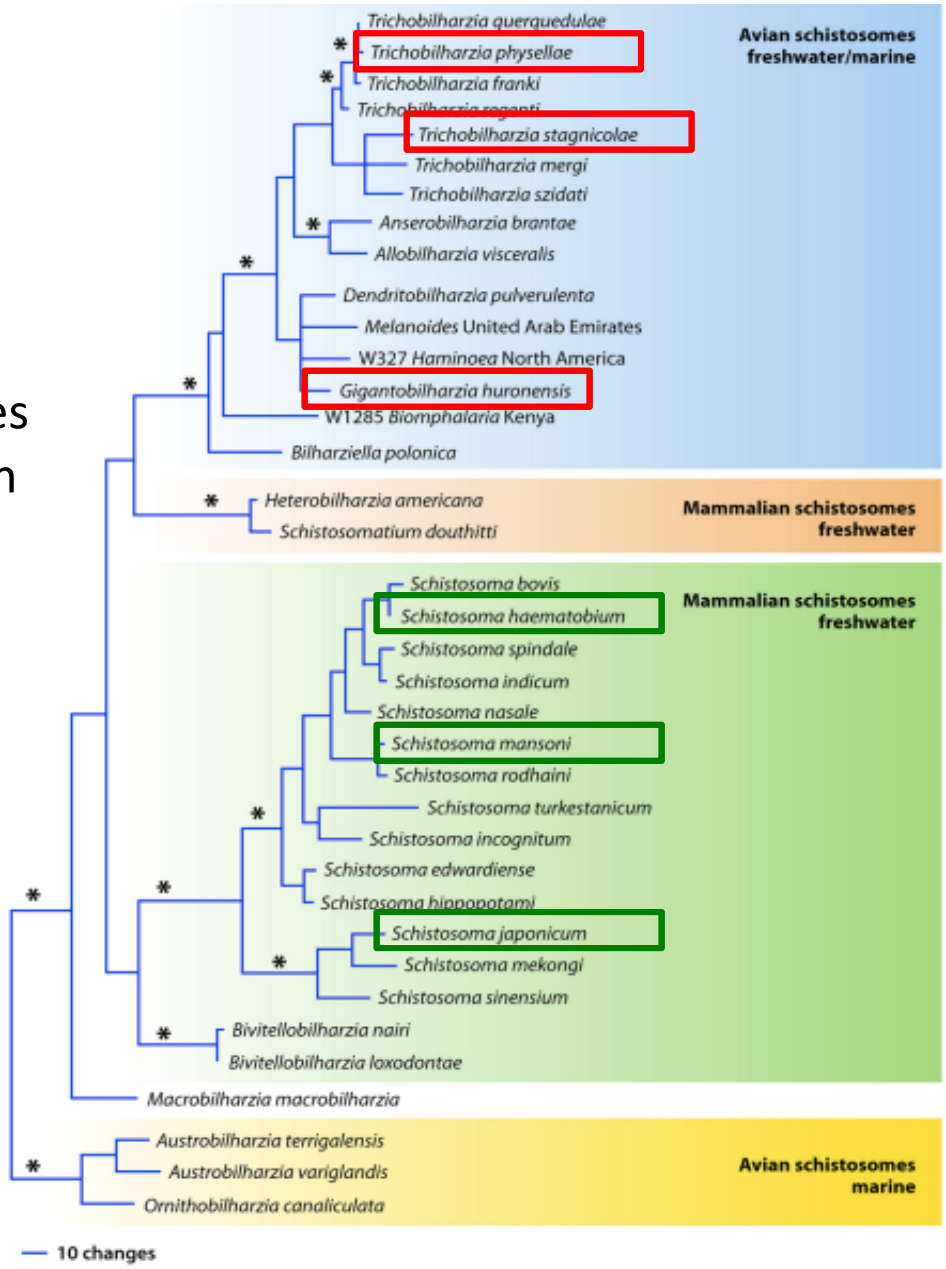


Family Schistosomatidae

- *Schistosoma sp.* infect humans in tropical regions

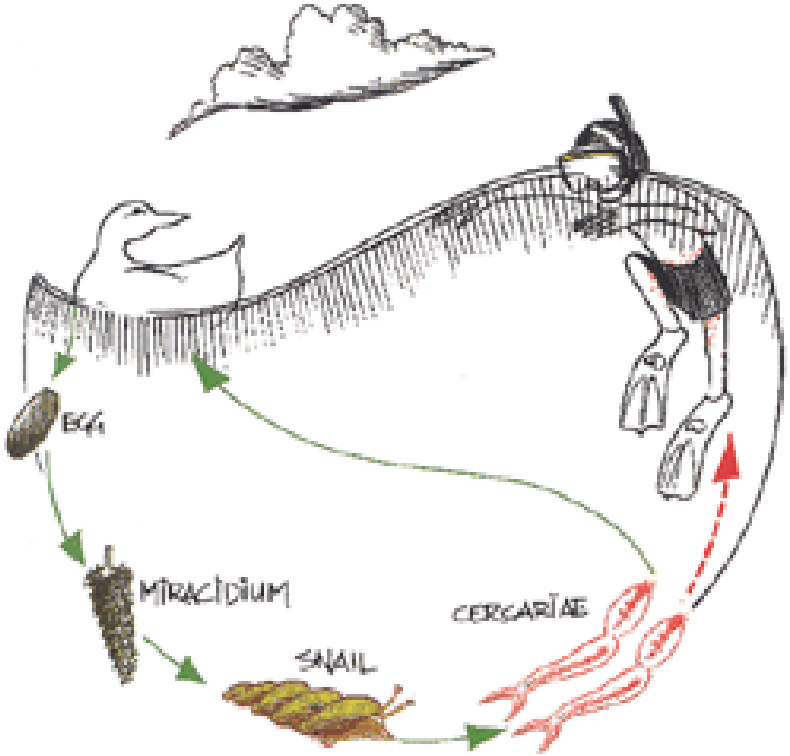
- Avian schistosomes infect birds
  - Causative agents of “swimmer’s itch”
  - Widely distributed in northern latitudes
  - Reported from ~1000 lakes in Michigan (1970s)





Swimmer's itch

- 2-host life cycle
  - Snails
  - Birds (waterfowl)
  - Humans >> accidental host
- Exposure in water (especially shallows)
- Cercariae penetrate skin and illicit host immune response
  - Tingling, itchy
  - Raised papules = dead cercariae
- Impacts lake tourism

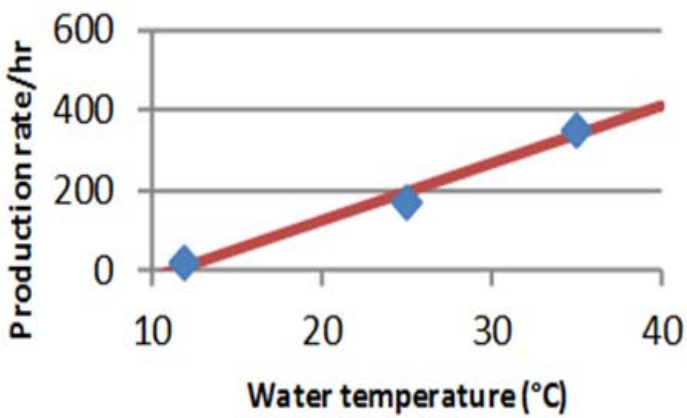


Management Strategies

- Snail control
  - Copper sulfate
  - Niclosamides
- Bird control
  - Hunt, relocate, treat, harass
- Pollution control
- Protective skin creams
- Public education
- Predictive modeling
  - ➢ Management decisions
  - ➢ Real-time alerts

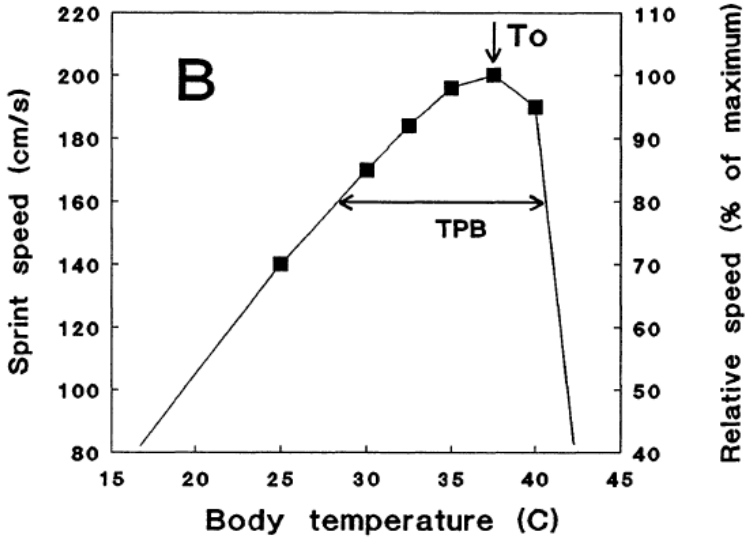
Gaps in Knowledge

- Trematode biology is temperature-dependent
  - Snail growth & reproductive rates
  - Trematode development rate
  - Cercaria production rate**

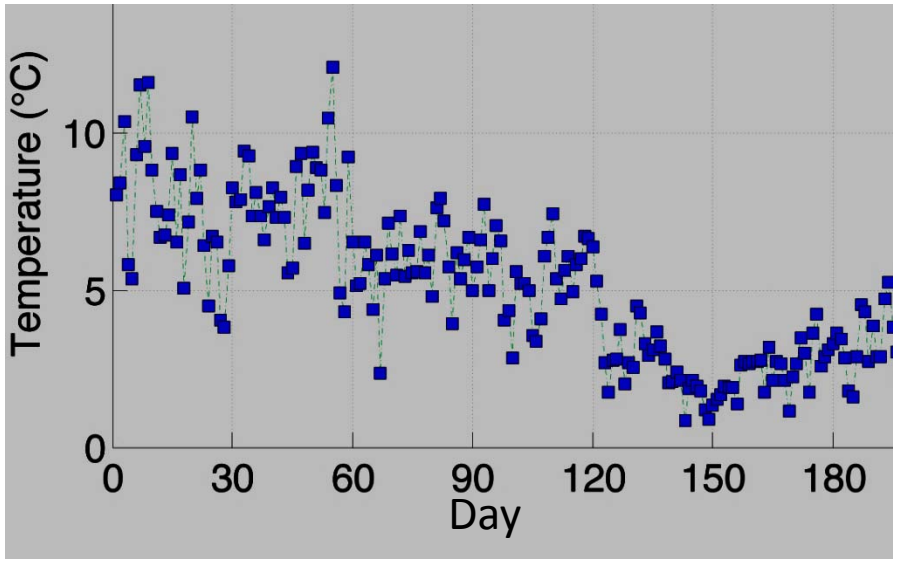


- BUT most studies ignore:

Nonlinearities



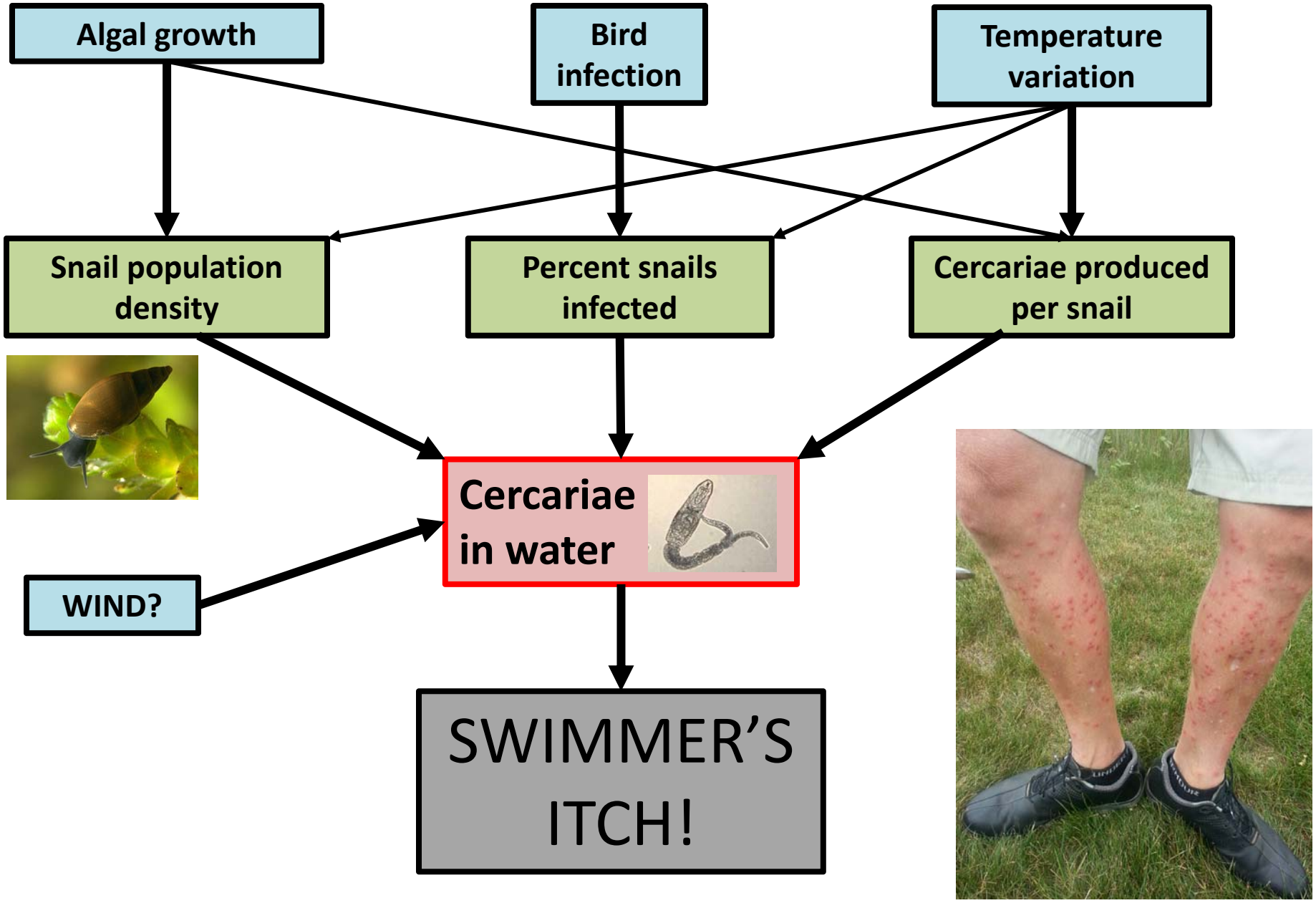
Variability



Gaps in Knowledge

- No **daily** field data for cercaria abundance
  - predictive models
- Effects of **physical characteristics** of lakes
  - Why some shorelines have higher incidence than others?
- How does **land use** and **nutrient input** impact swimmer's itch?

What determines swimmer's itch exposure?

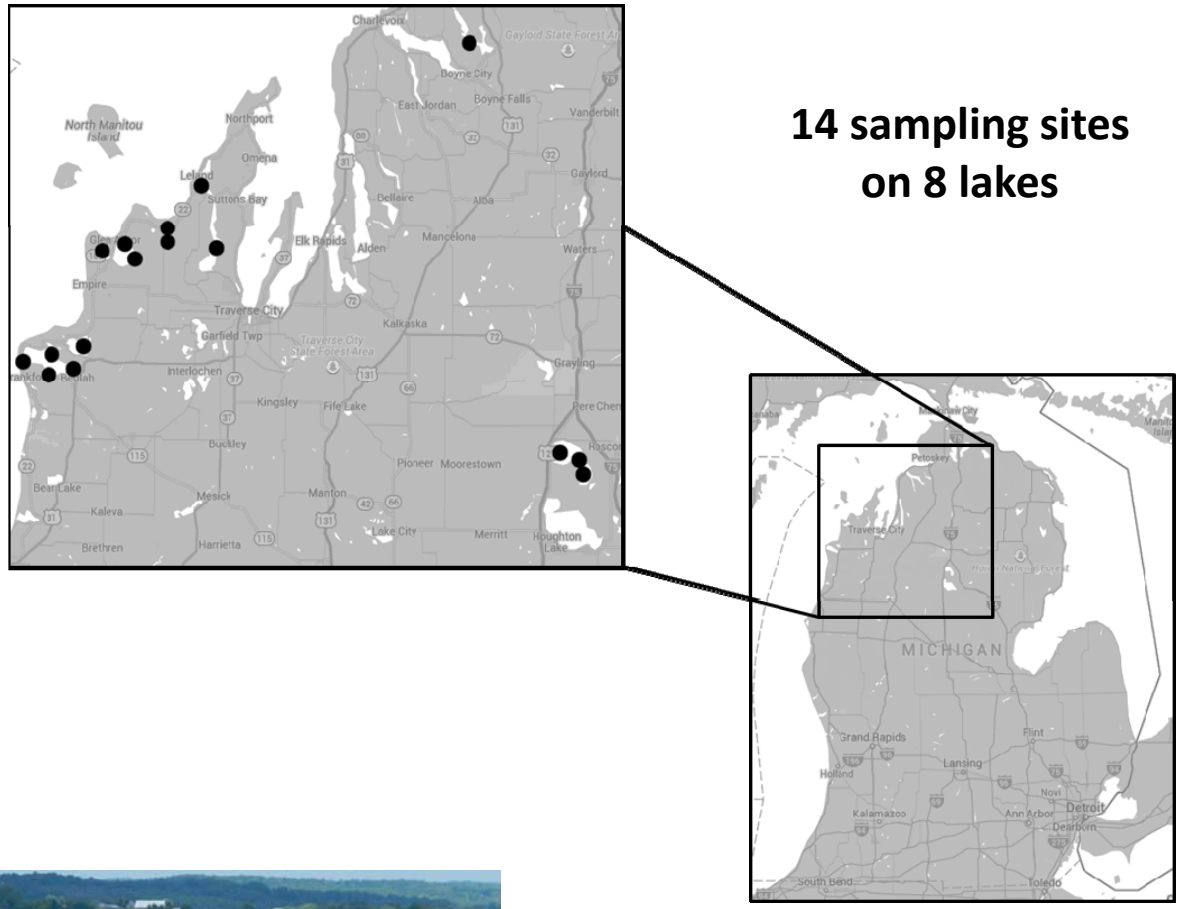


1. Temporal survey: *July 6, 2015 – August 2, 2015*

- Daily cercaria samples: filtered **50 liters** of surface water
- HOBO loggers: temp & light
- Weather conditions
- Wind speed and direction
- Bird visitation
- Wave action
- Human activity

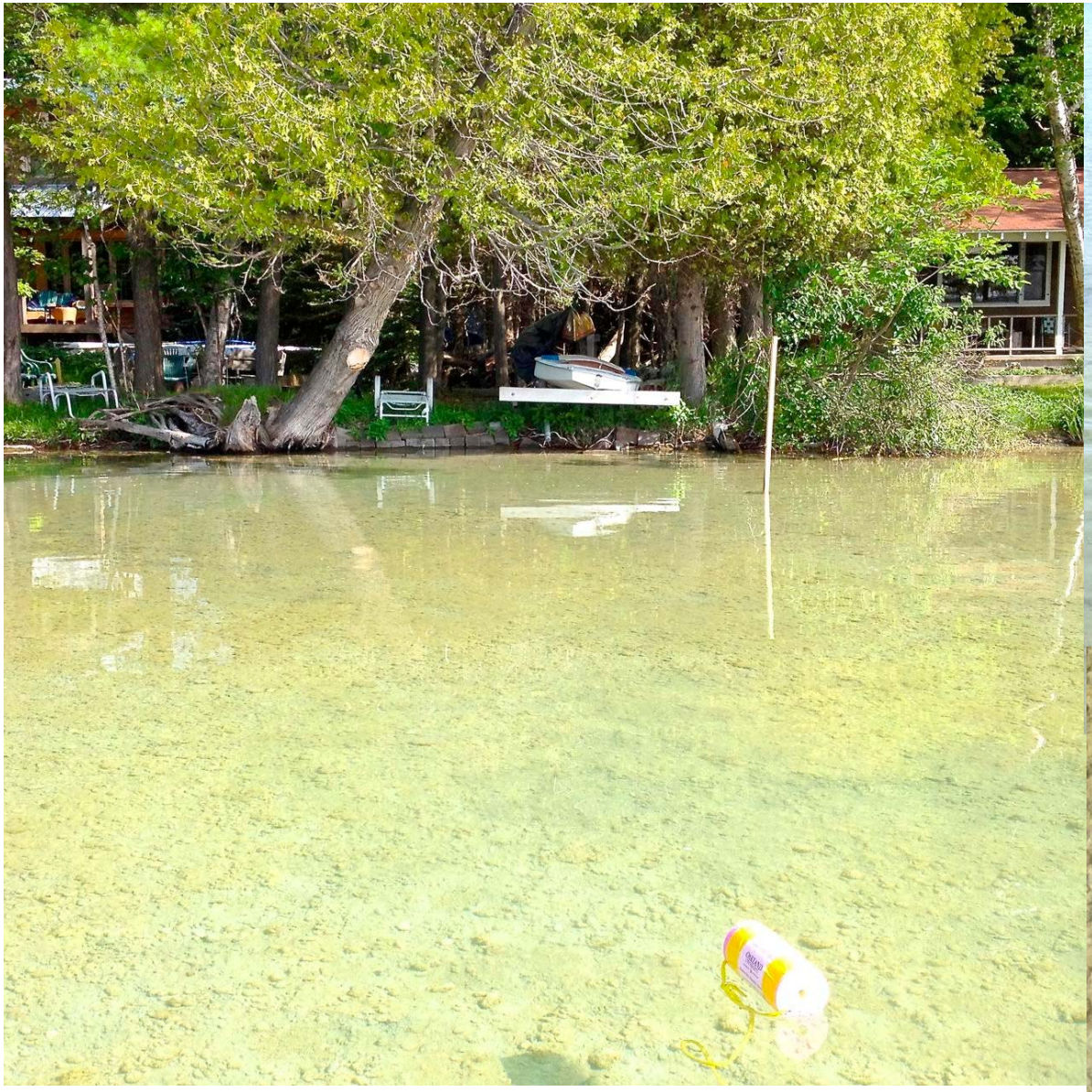
2. Spatial survey

- Lake size & depth
- Land use: riparian and watershed
- Snail densities: visual quadrat counts
- Water samples
  - Phosphorus
  - Nitrate/Nitrite
  - Ammonia
- Littoral substrate



14 sampling sites on 8 lakes

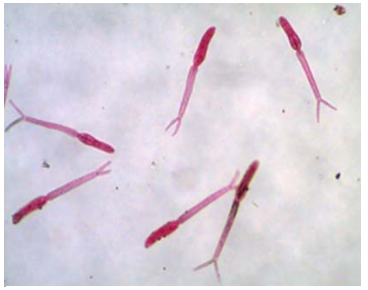
Lime Lake Site

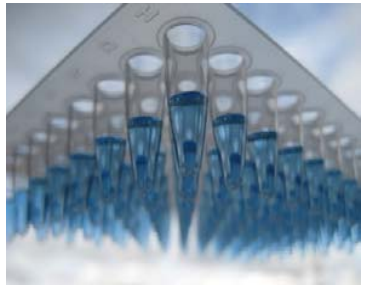


Little Traverse Lake
Photos by Len Allgaier

Platte Lake

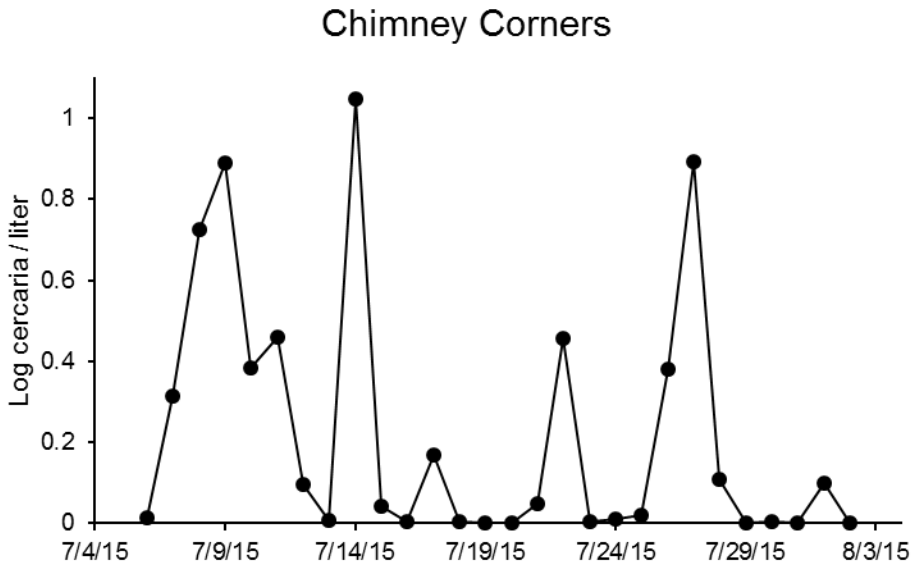
Quantitative PCR: DNA detection from environmental samples

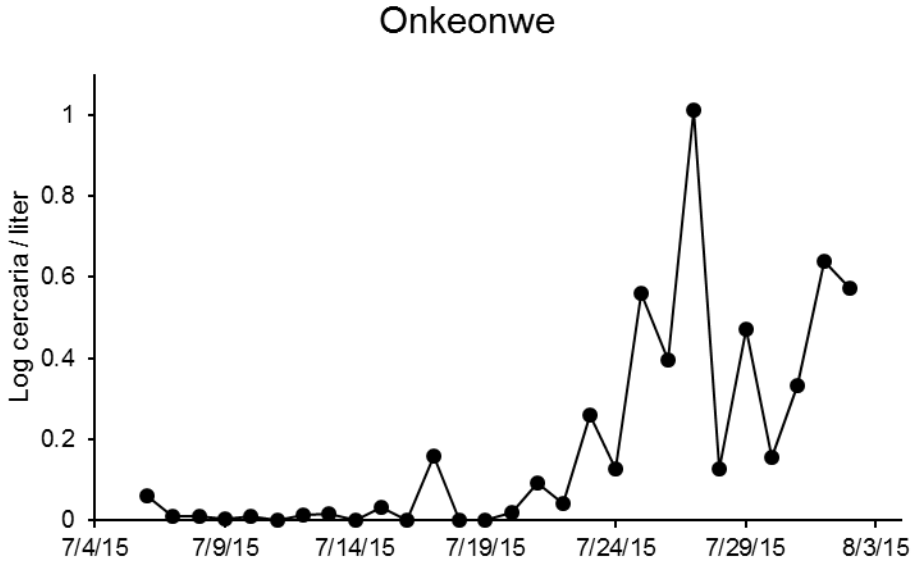




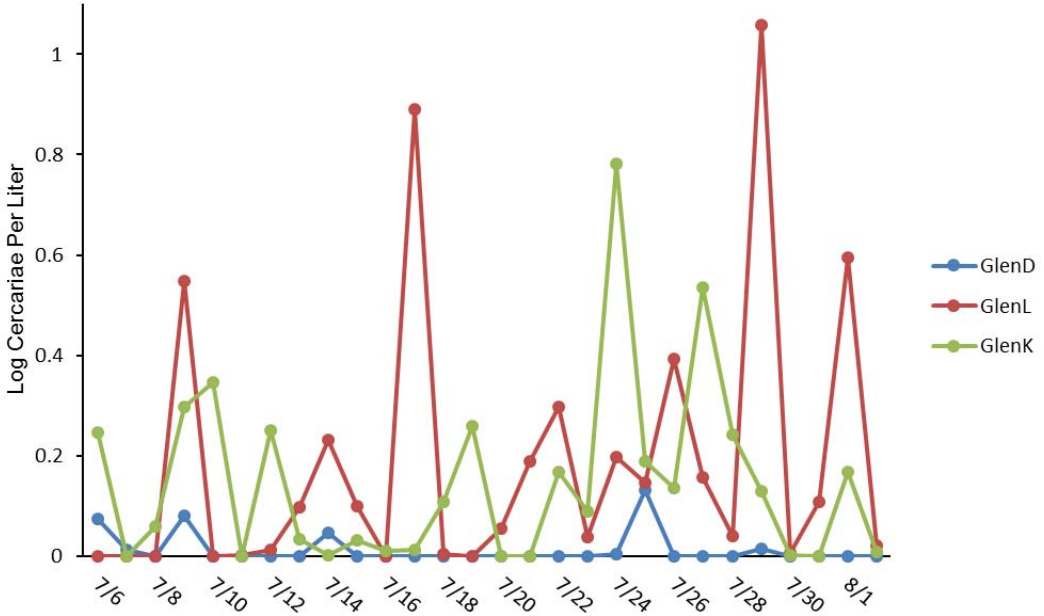
Preliminary Results – **temporal cercariae data**

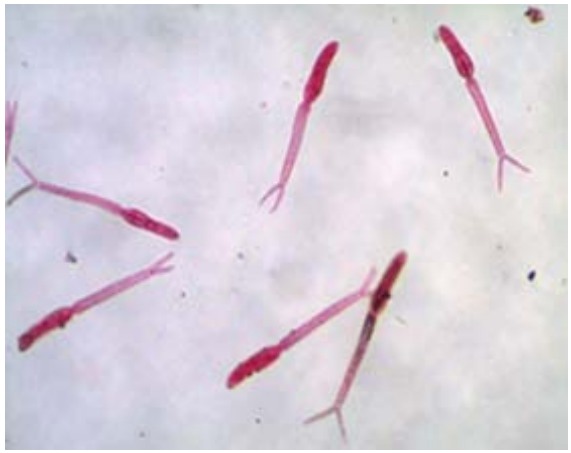
- Drastic day to day shifts
- Among-site variation
- Statistical analysis of time-series data in progress
- Sampling methods and qPCR assay successful in capturing cercaria and estimating their abundance



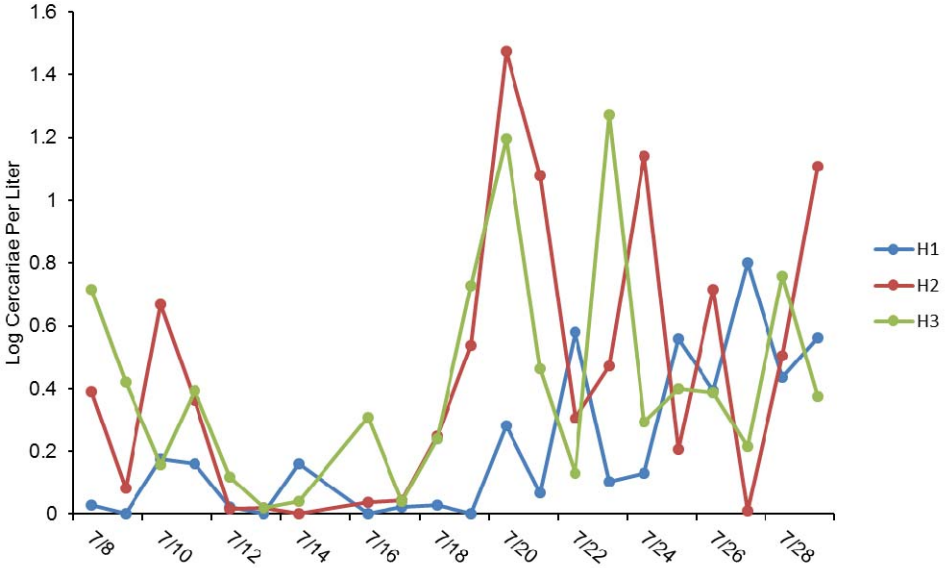


Glen Lake

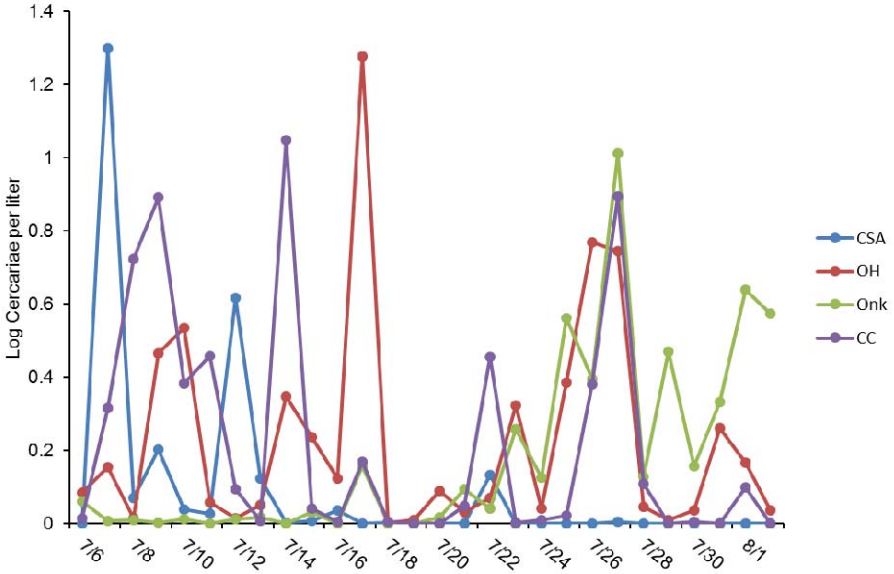




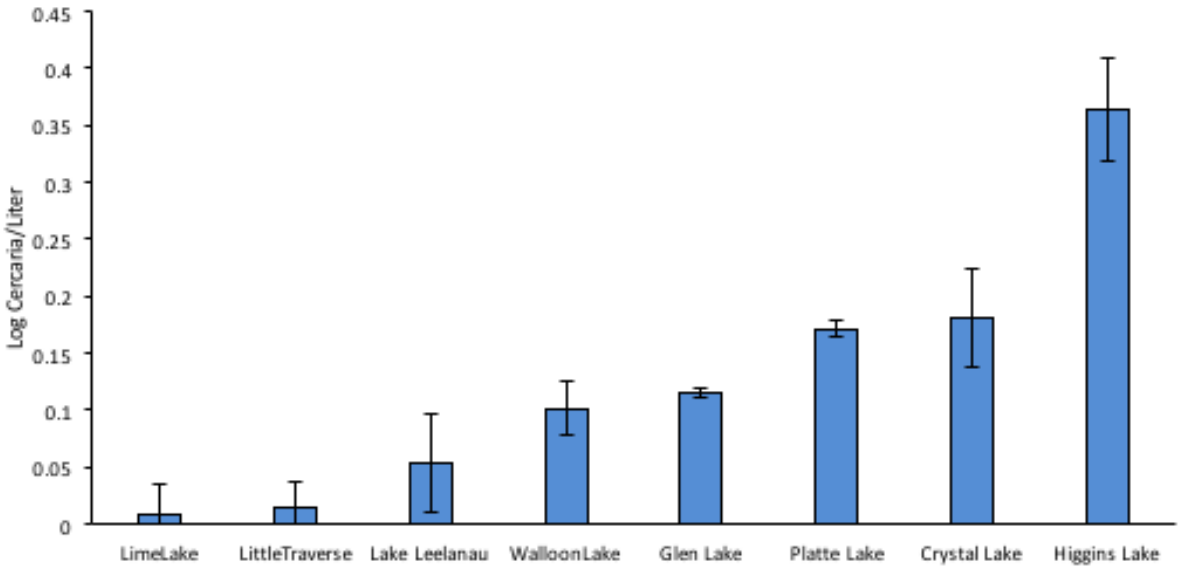
Higgins Lake

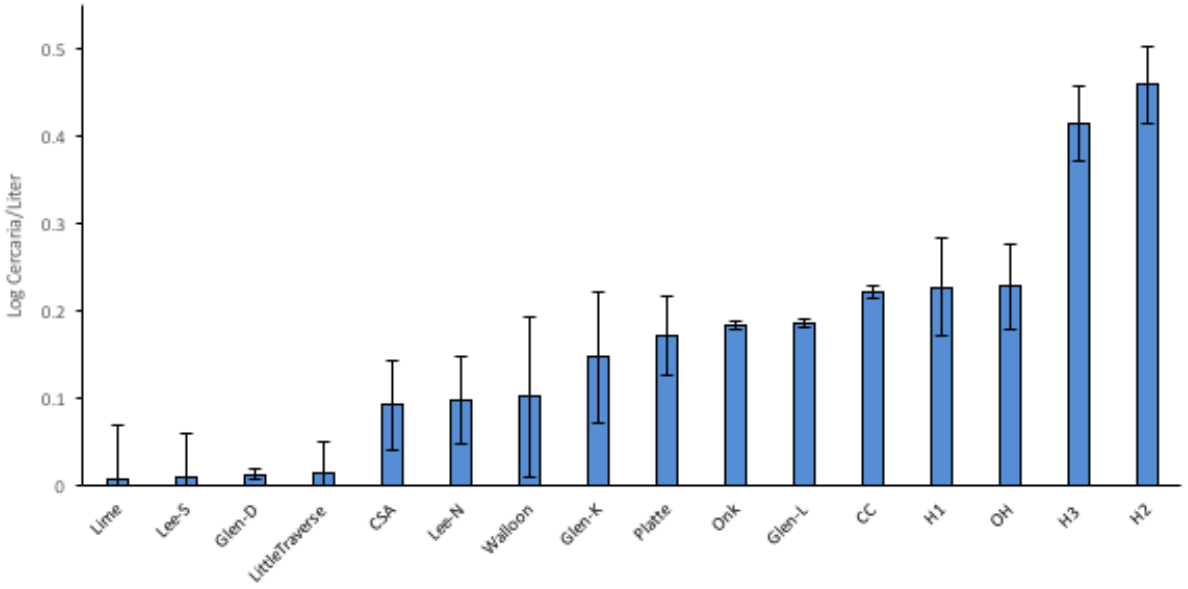


Crystal Lake

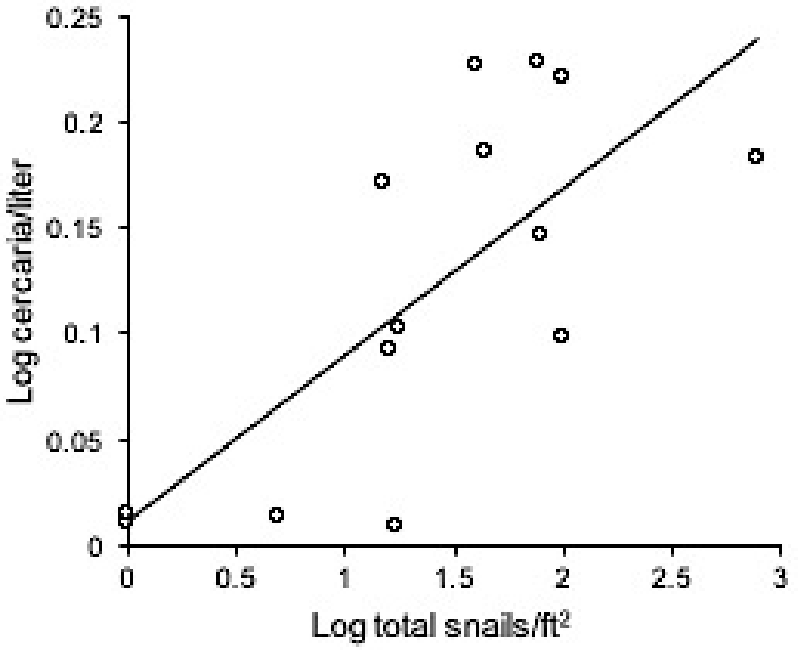


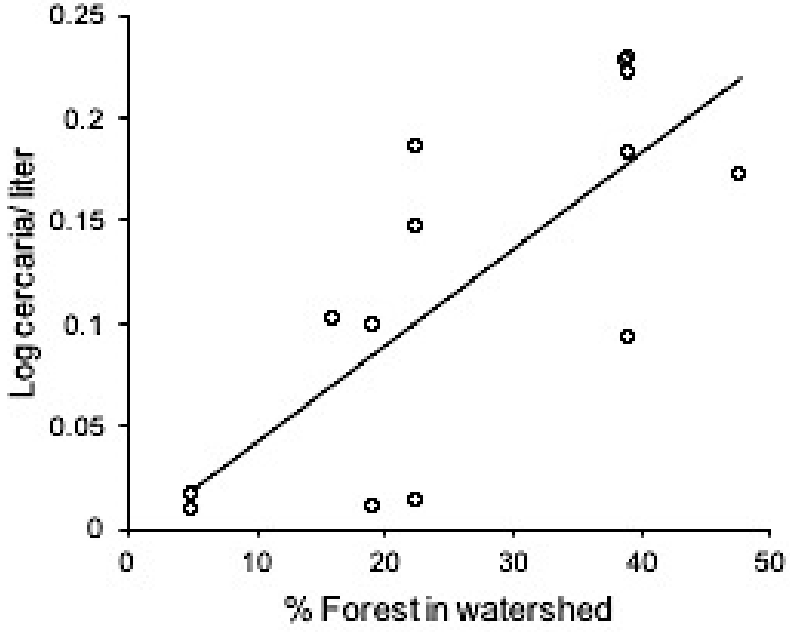
Preliminary Results – **cercaria abundance** 14 sites on 8 lakes





Best Predictors– **cercaria** abundance in water (14 sites)





Response variable	Predictor variable(s)	p-value
Log cercaria/liter	Log total snails/ft^2	0.0205*
	Percent forest cover in watershed	0.0134*

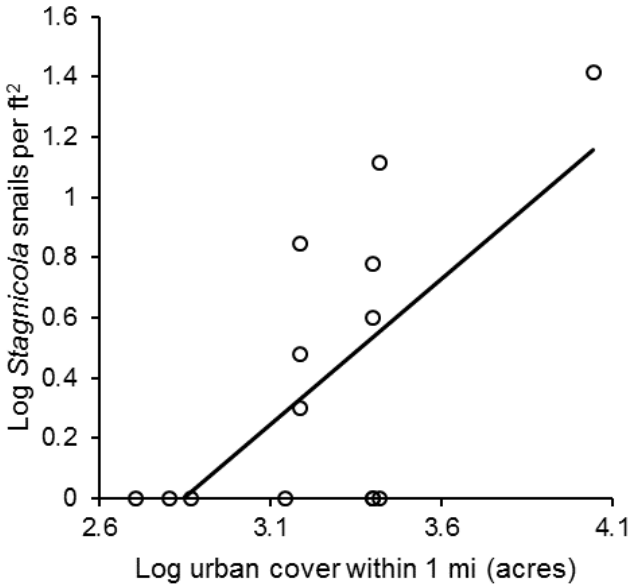
Preliminary Results: Snail Density

Response variable	Predictor variable(s)	p-value
Log total snails/ft^2	Min water temperature (°C)	0.0021**
	Average light intensity (lx)	0.0442*
Log *Stagnicola* snails/ft^2	Urbanized acres within 1 mile perimeter	0.0085**

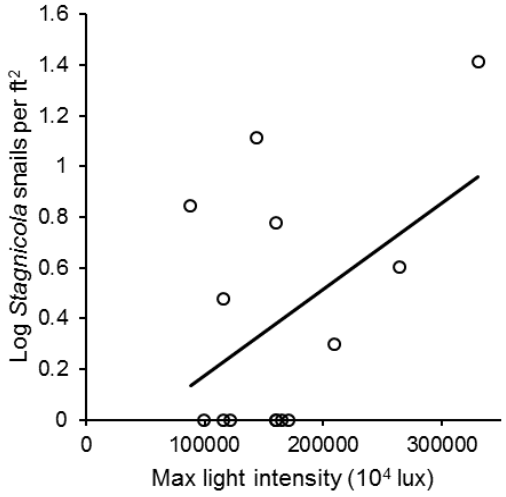
Preliminary Results – ***Stagnicola*** snail density (14 sites)

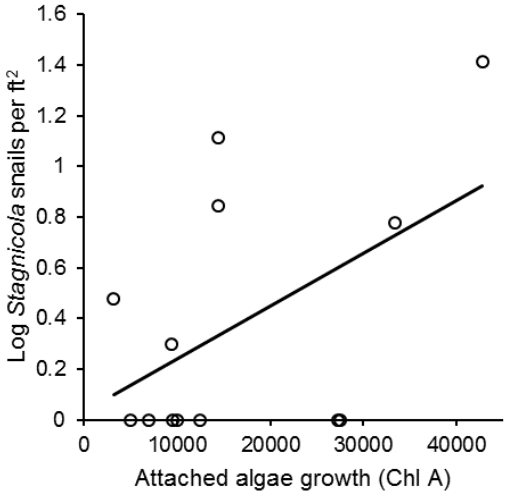
- **More urbanization** (within 1 mi of lake) → **More *Stagnicola* snails**

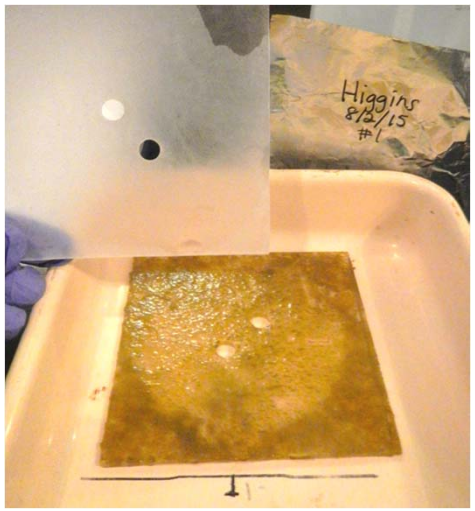
Urbanization:



Other correlates: Light intensity & attached algae growth



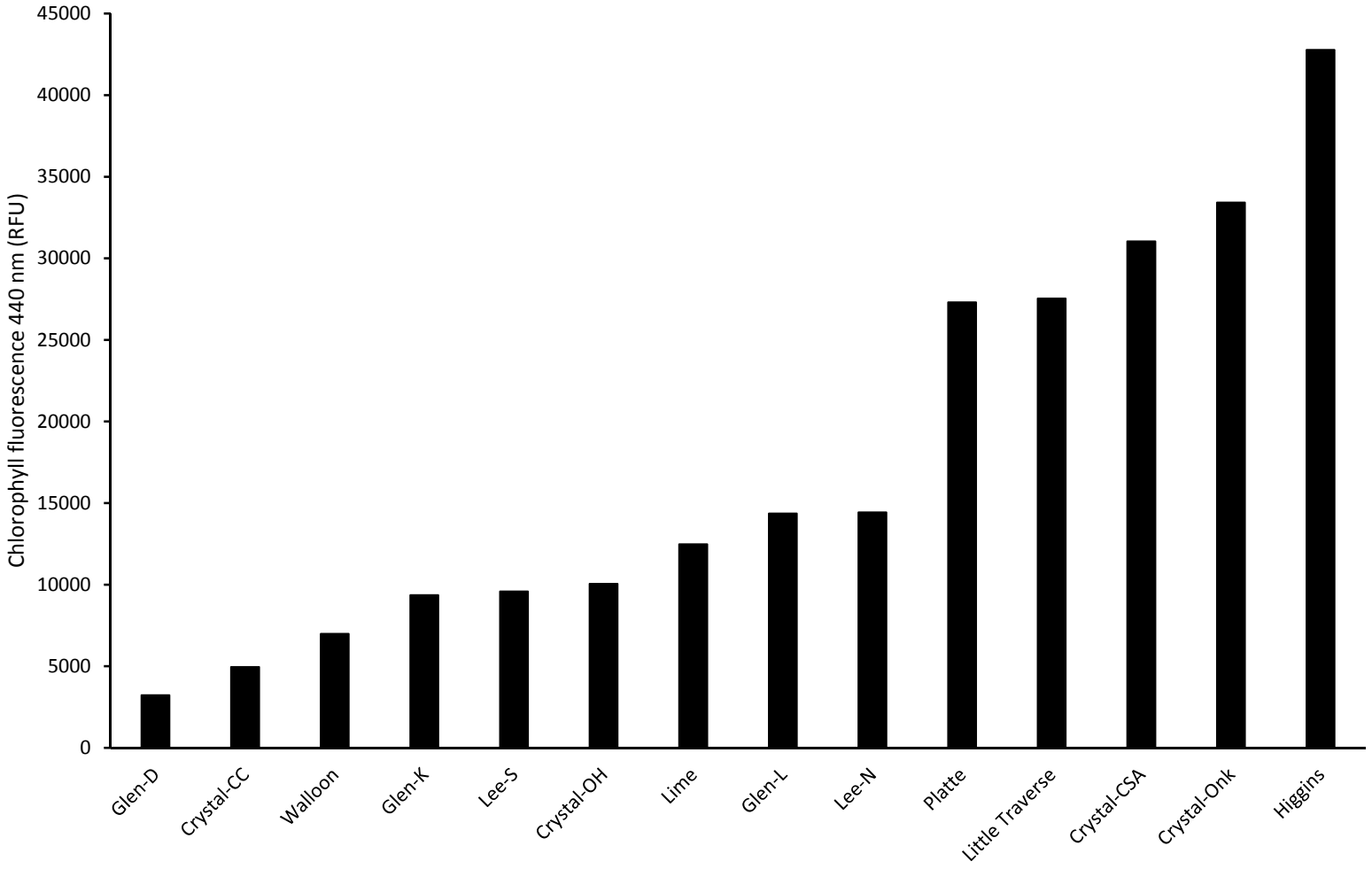




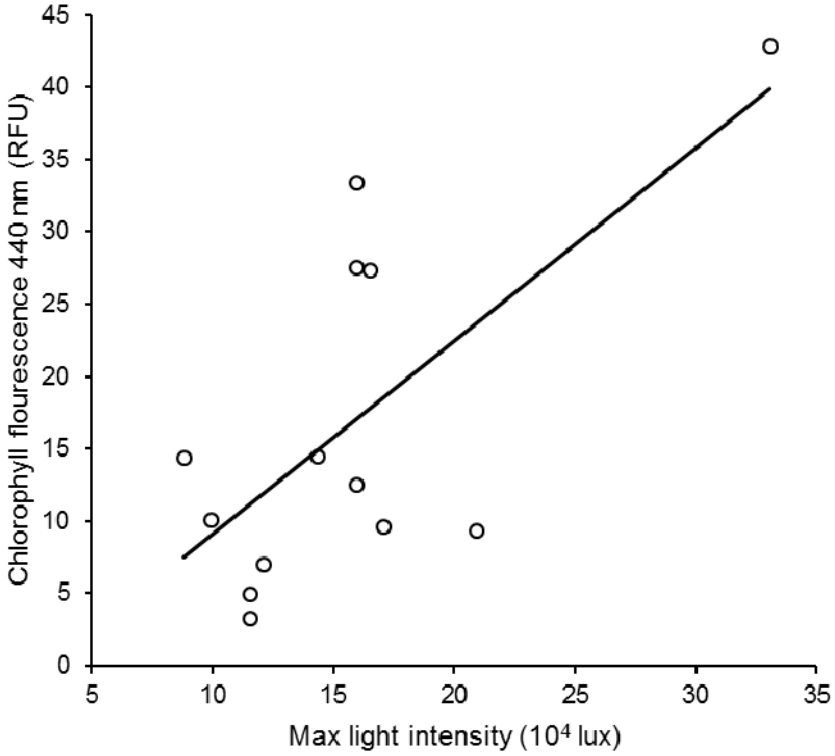
Preliminary Results: **periphyton**

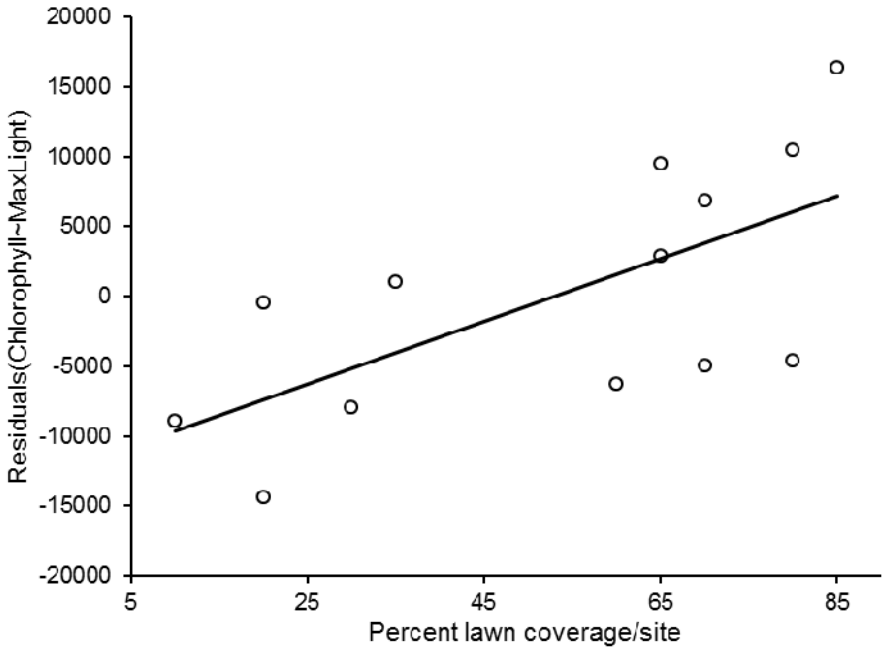
- **Primary food source for snails**
- Grows on lake bottom substrates
- Can be influenced by herbicide, nutrients, and sunlight
- Chlorophyll *a* extracted from filters and compared among sites

Preliminary Results: **periphyton**



Preliminary Results: **periphyton**

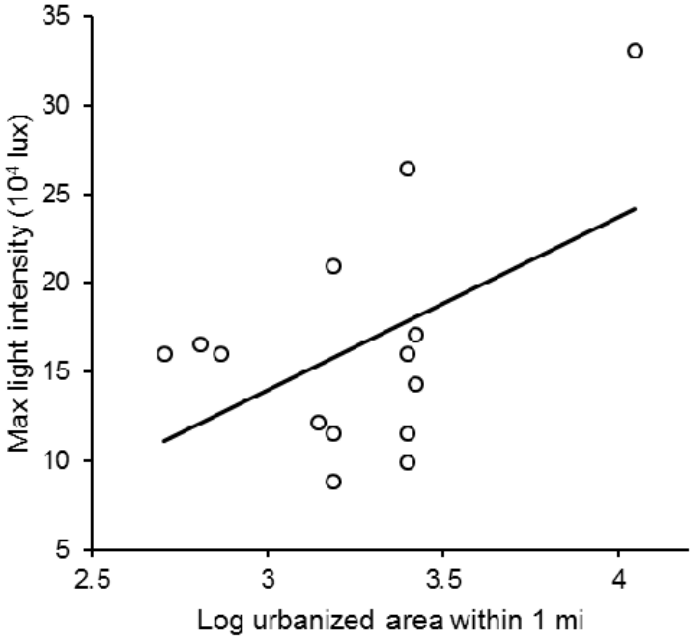




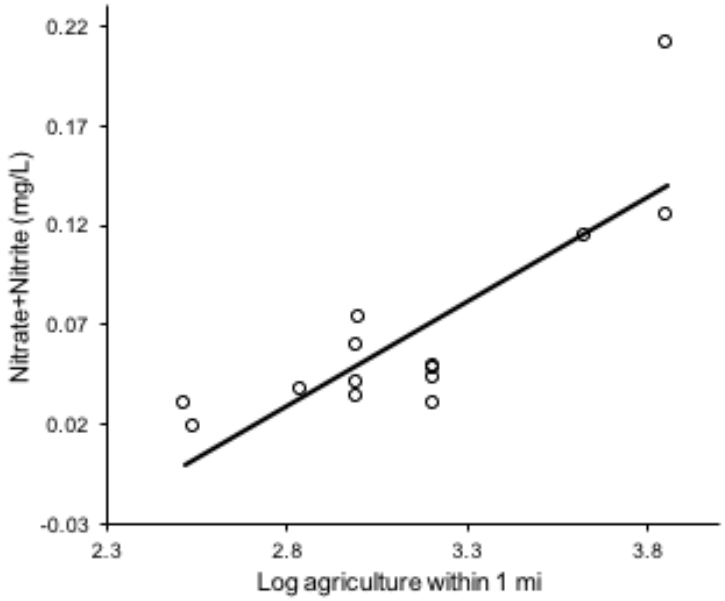
Response variable	Predictor variable(s)	p-value
Chlorophyll	Max light intensity (lx)	0.0033**
	Percent lawn coverage at site	0.0196*

Preliminary Results – other correlations from 2015

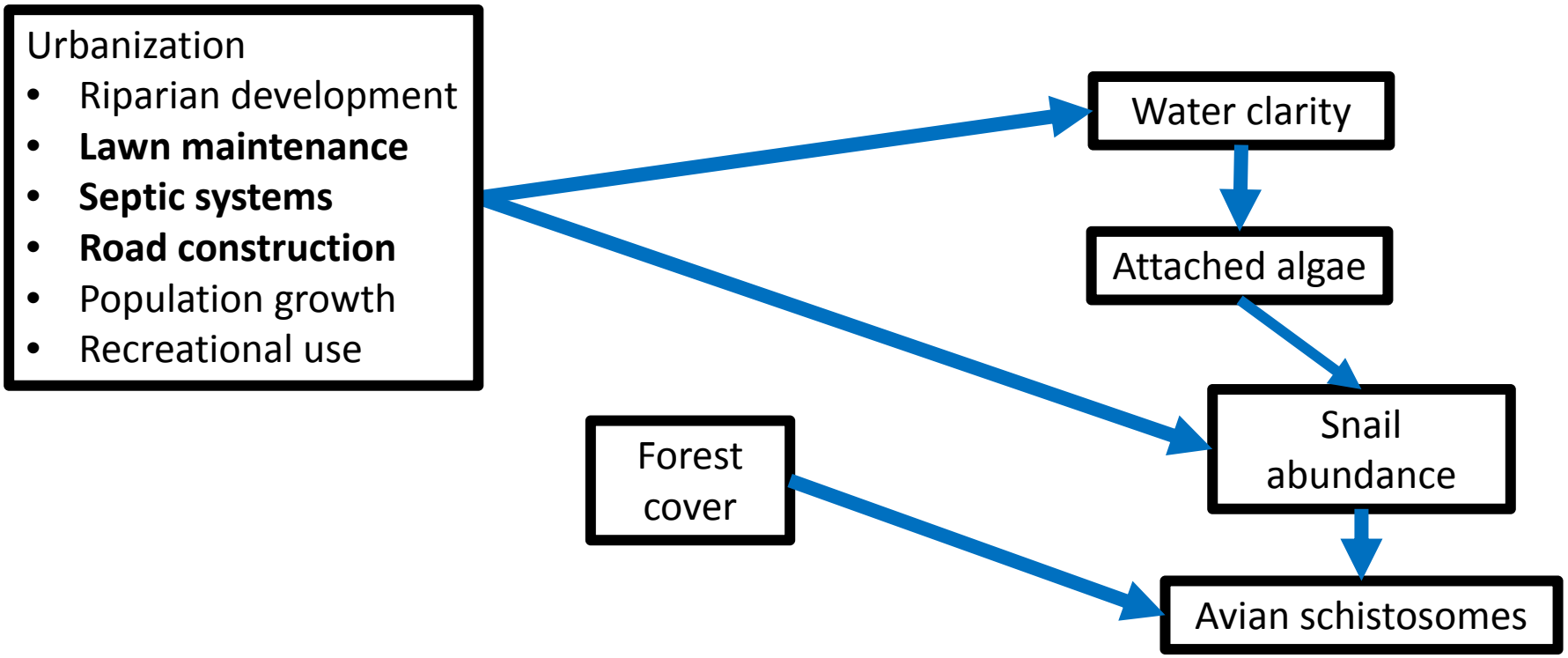
- **More urbanization** (within 1 mi of lake) **→ More light penetration (<u>water clarity</u>)**



- **More agricultural land → More nitrogen**

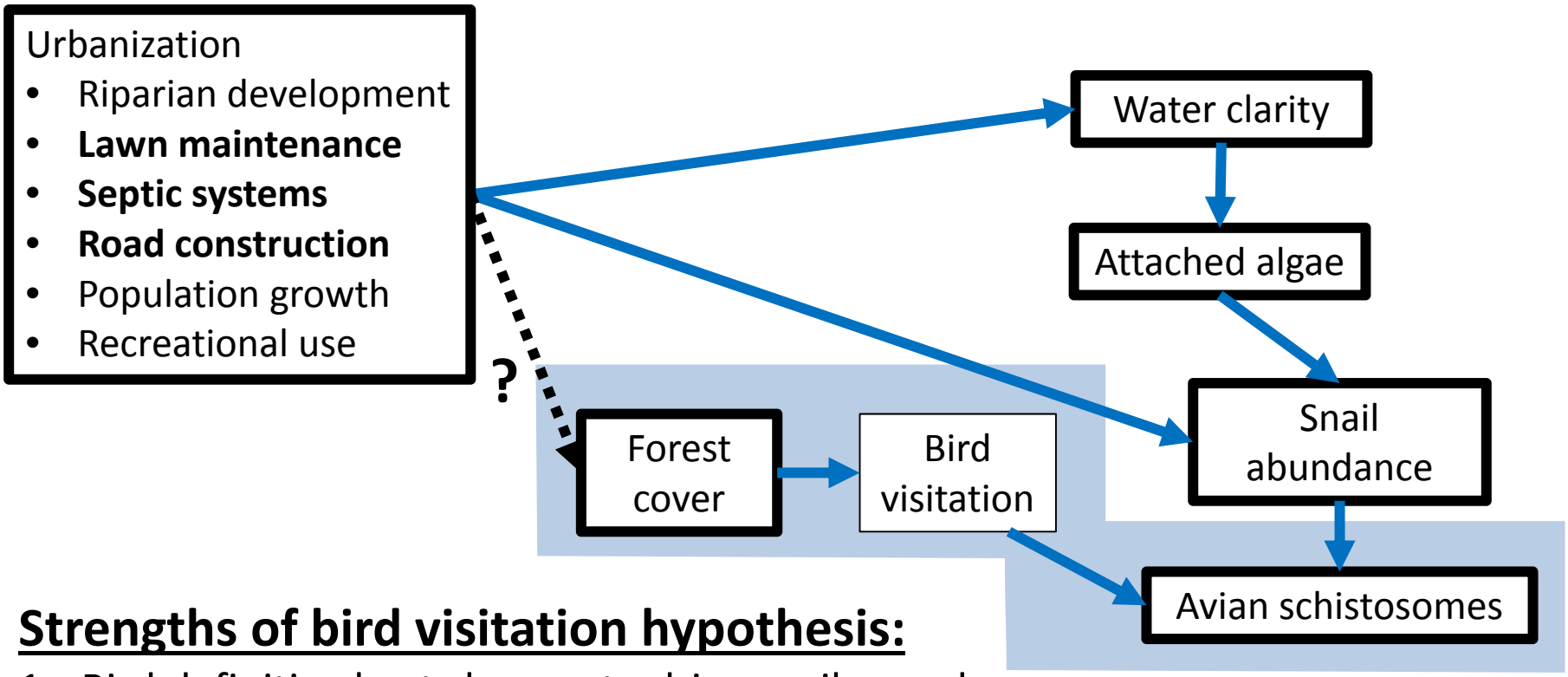


Preliminary Results – best predictors from 2015 (14 sites):



- **Ok, but what mechanisms could cause these effects?**

H1: Forest increases bird visitation → snail infection



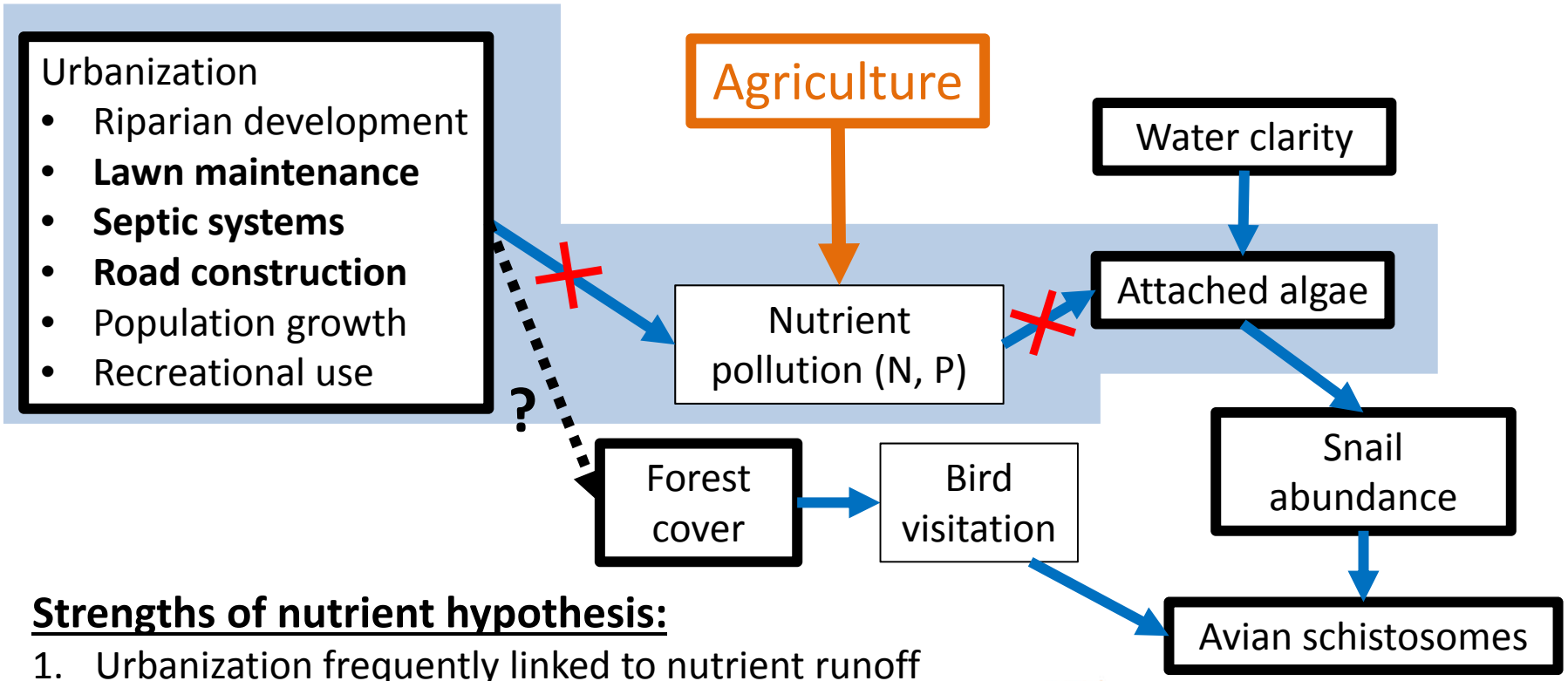
Strengths of bird visitation hypothesis:

1. Bird definitive hosts known to drive snail prevalence
2. Forest cover linked to bird visitation & trematode parasites in prior studies

Weaknesses:

1. Poor-quality bird data from 2015…

H2: Urbanization → Nutrient runoff → Eutrophication

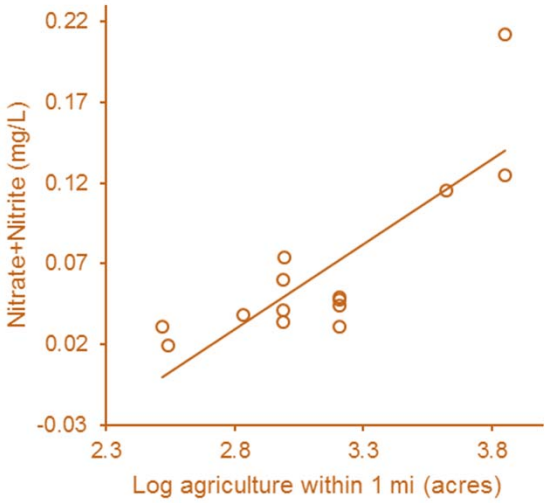


Strengths of nutrient hypothesis:

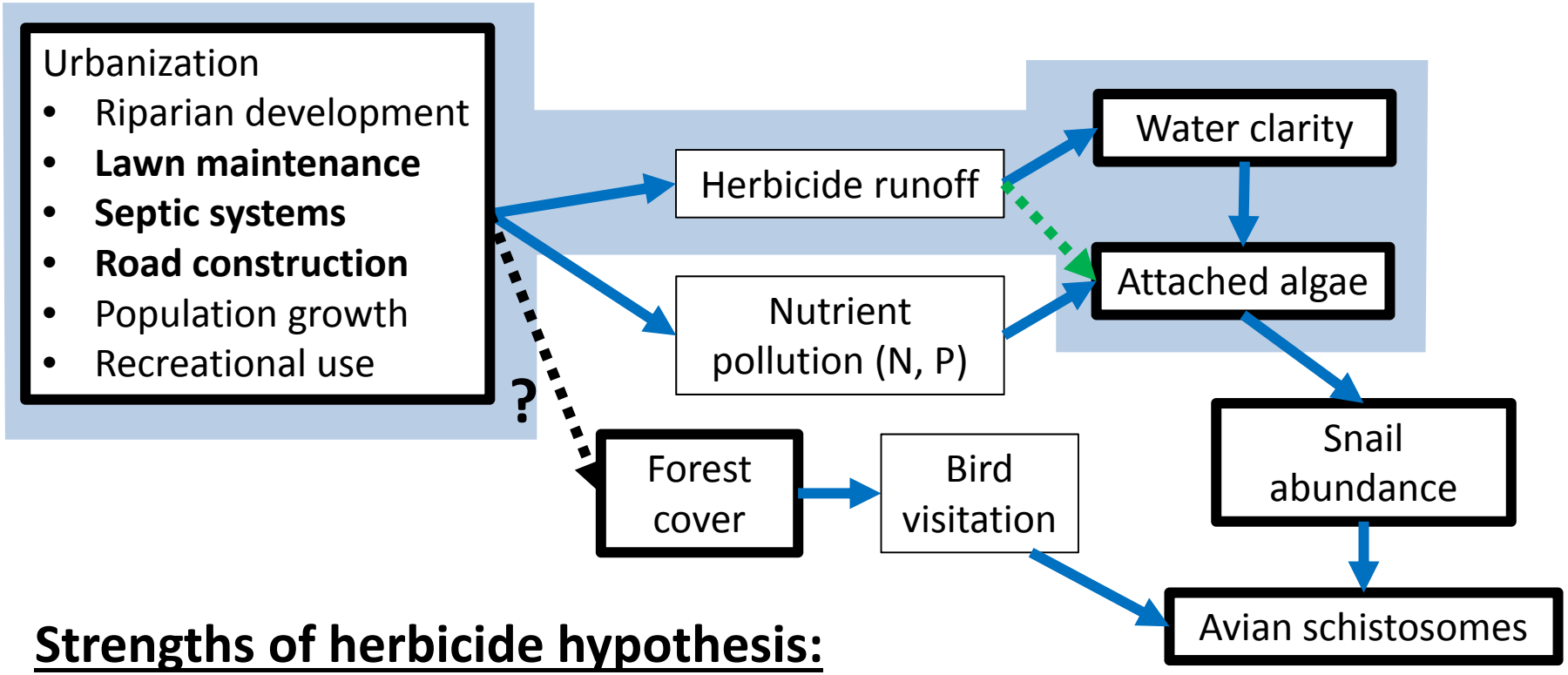
1. Urbanization frequently linked to nutrient runoff
2. Nutrient runoff frequently linked to algal blooms when nutrients are limiting

Weaknesses:

1. N & P poor predictors of attached algae, snails, & avian schistosomes in 2015
2. **N correlated with agriculture not urbanization in 2015 survey**



H3: Urbanization → Herbicide runoff → Water clarity

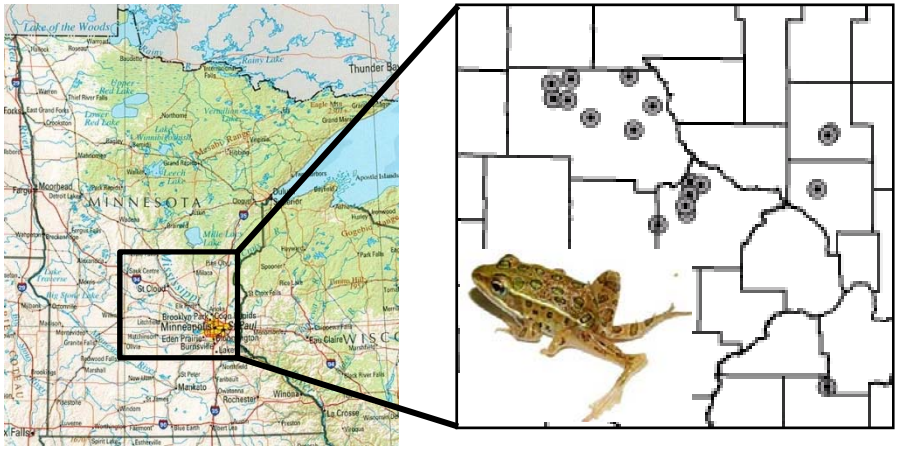


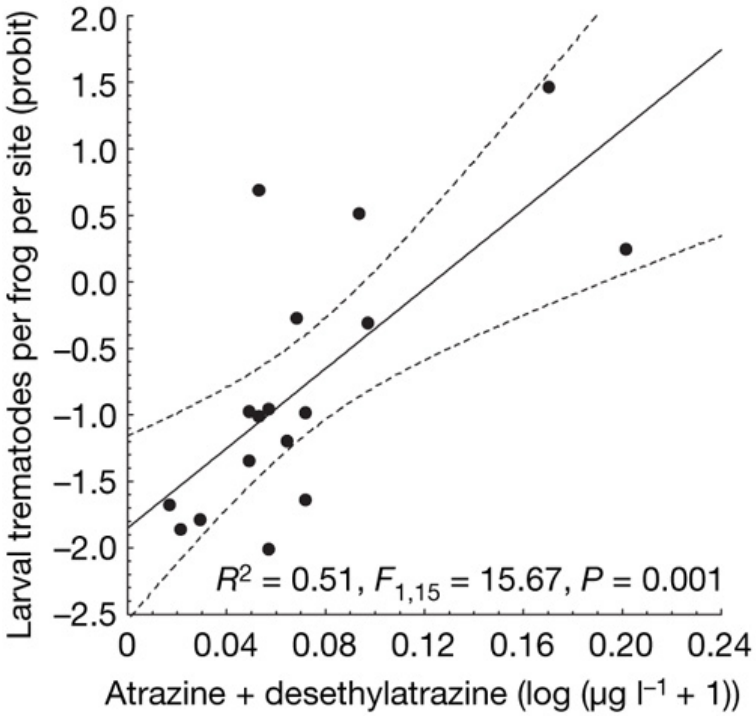
Strengths of herbicide hypothesis:

1. Atrazine best predictor of snails & trematodes in a prior large-scale survey (Rohr et al. 2008, Nature)
2. Large-scale experiments confirm that herbicides increase water clarity & light penetration, leading to more growth of attached algae and more snails
3. Urbanization associated with different herbicides from agriculture (e.g., 2,4-D)
4. **Herbicides can drive changes in attached-algae communities reported by many lake associations (more diatoms = "golden algae")**

Herbicides & trematodes:

(2008 Study with Jason Rohr Univ. S Florida)





Cattle tank experiment:

Herbicide

Fertilizer

Eutrophication

+Snails

+Cercariae

H4: Insecticides

Urbanization
- Riparian development
- **Lawn maintenance**
- **Septic systems**
- **Road construction**
- Population growth
- Recreational use

Insecticide runoff

Zebra mussels

Herbicide runoff

Nutrient pollution (N, P)

Attached algae

Forest cover

Bird visitation

Snail abundance

Avian schistosomes

Strengths of insecticide hypothesis:

1. Urbanization associated with insecticide applications
2. Large-scale experiments confirm that insecticides increase snail populations by killing their arthropod predators, including crayfish
3. Crayfish declines have been observed by local riparian owners
4. **Crayfish are also important predators of zebra mussels, which have major effects on water clarity (and therefore attached algae)**

2016 survey parameters:

Continuous/Daily monitoring:

- Cercaria density - daily filtered-water samples (volunteers + qPCR)
- Wind speed & direction (volunteers)
- Water temperature & light penetration (HOBO loggers)

Weekly surveys:

- Snail quadrat sampling & **collection** (identification, size distribution)
- **Turbidity***
- **Crayfish trapping**
- **Zooplankton sampling (density, composition)**
- **Bird camera traps***

Site-level measurements:

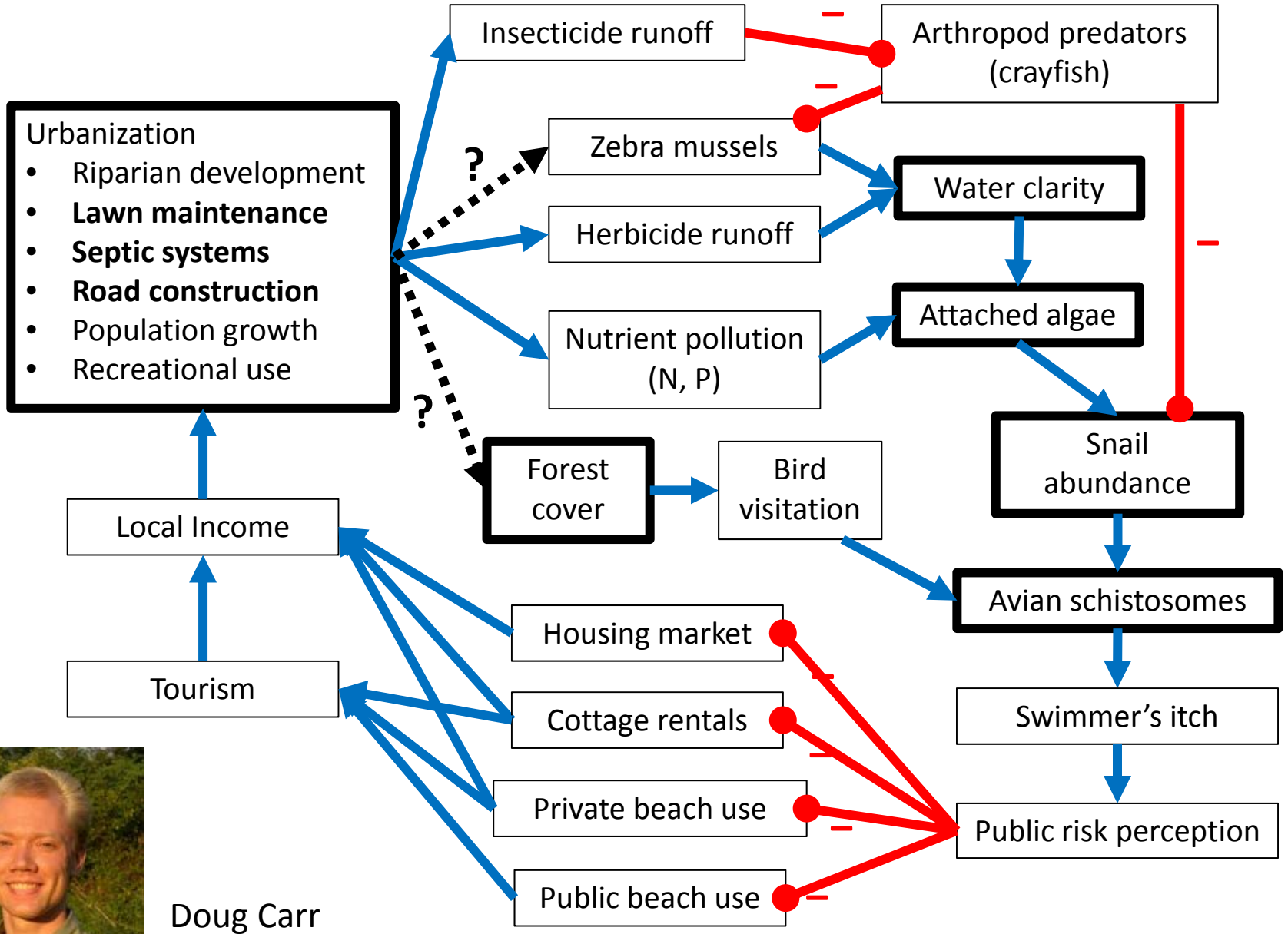
- Attached algae (periphyton) growth & **composition***
- **Zebra mussel sampling (settling rate)**
- **Water chemistry (nitrates+nitrites, organophosphate, ammonia)**
- **Nutrient limitation (bioassay)***
- **Pesticides (atrazine + products; 2,4-D; organophosphates + carbamates)**
- **Sediment cores (Copper*, Phosphorus, Organic carbon)**
- Substrate & shoreline characteristics; fetch; **slope**

Lake-level characteristics:

- Land use in watershed & near shore
- Lake size & depth

Future directions: ECONOMIC IMPACT STUDY

Doug Carr
Oakland University



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Thesis Committee:

Dr. Tom Raffel, chair
Dr. Keith Berven
Dr. Scott Tiegs

Raffel Lab Members

Karie Altman
Jason Sckrabulis
Jeff Stephens
Aaron Stoler

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John Kassarjian- Glen Lake
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Dave Hunter- Lake Leelanau
John Popa- Lake Leelanau
Wayne Swallow- Lake Leelanau
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Wilfred Swieki- Platte Lake
Len Allgaier- Little Traverse Lake
Dean Manikas- Lime Lake
Russ Kittleson- Walloon Lake
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