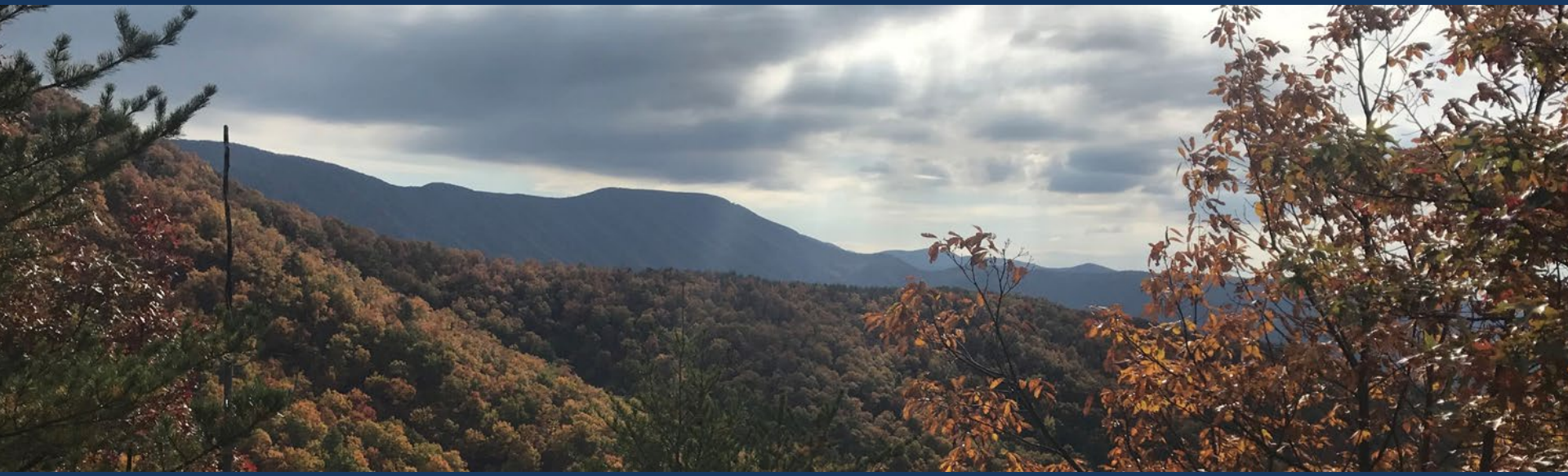
Riparian-Stream Connections Support Water Quality and Aquatic Biodiversity



Sally Entrekin
Entomology Department
Virginia Tech

Presentation topics

- What is a riparian area?
- How do riparian areas function?
- How are riparian forests “connected” to streams?
- Why are riparian-stream connections important for:
  - water quality
  - aquatic invertebrate biodiversity (and other organisms)
- How do we assess stream condition?

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Riparian Area Anatomy

https://www.nrcs.usda.gov/plantmaterials/wapmstn13160.pdf

Riparian zones, or areas, are lands that occur along the edges of rivers, streams, lakes, and wetlands. Examples include streambanks, riverbanks, and flood plains. They're different from the surrounding uplands because their soils and vegetation are shaped by the presence of water.

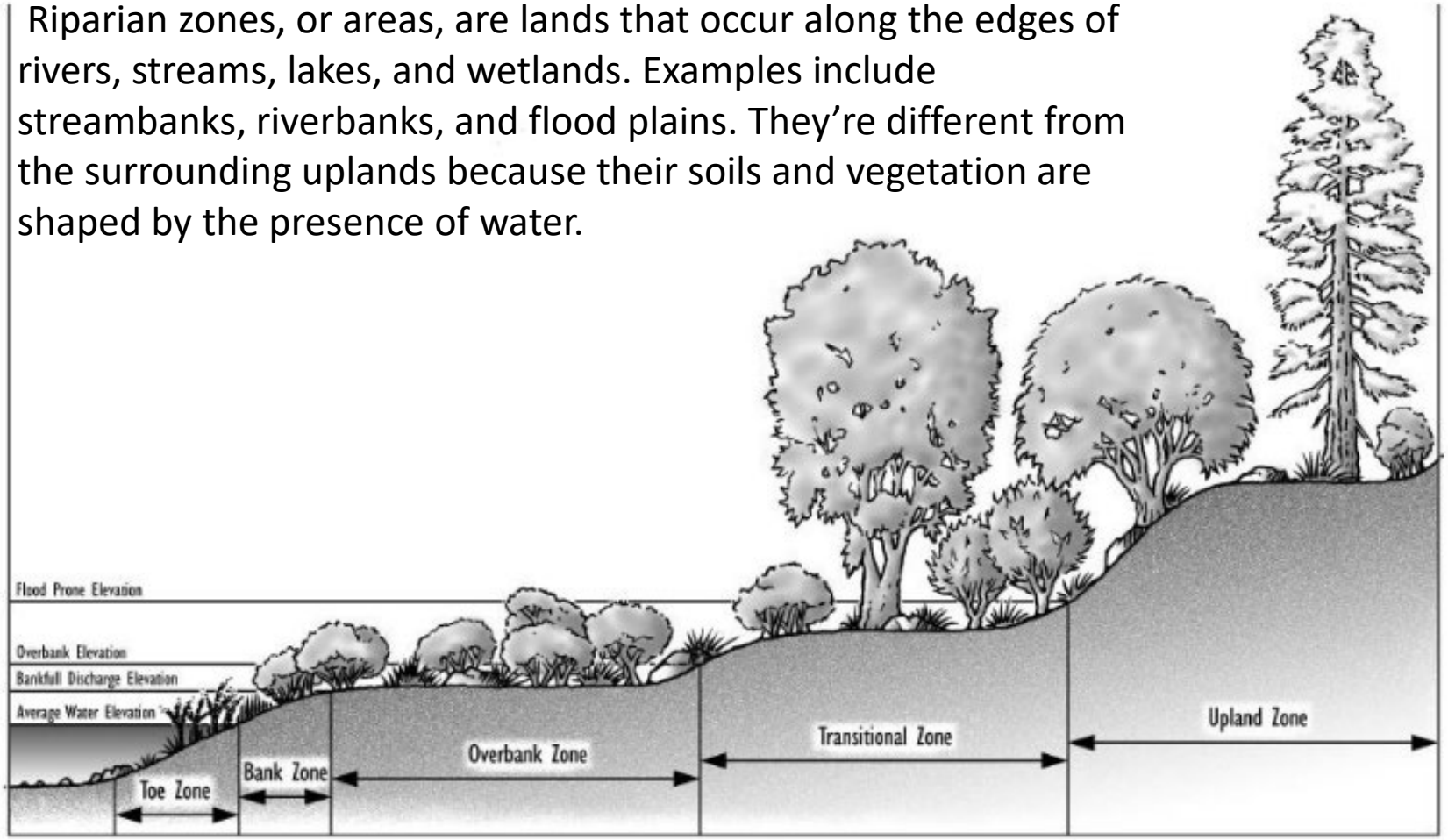

Figure1: Riparian Planting Zones can be used to determine where riparian species should be planted in relation to the waterline. This is a general depiction of a riparian zone. Not all streams look like this one. In the real world, some of these zones may be absent. (From Hoag 1999, Hoag and Landis 1999)

Riparian zones, or areas, are lands that occur along the edges of rivers, streams, lakes, and wetlands. Examples include streambanks, riverbanks, and flood plains. They're different from the surrounding uplands because their soils and vegetation are shaped by the presence of water.


Sycamore Creek
Image Landsat / Copernicus

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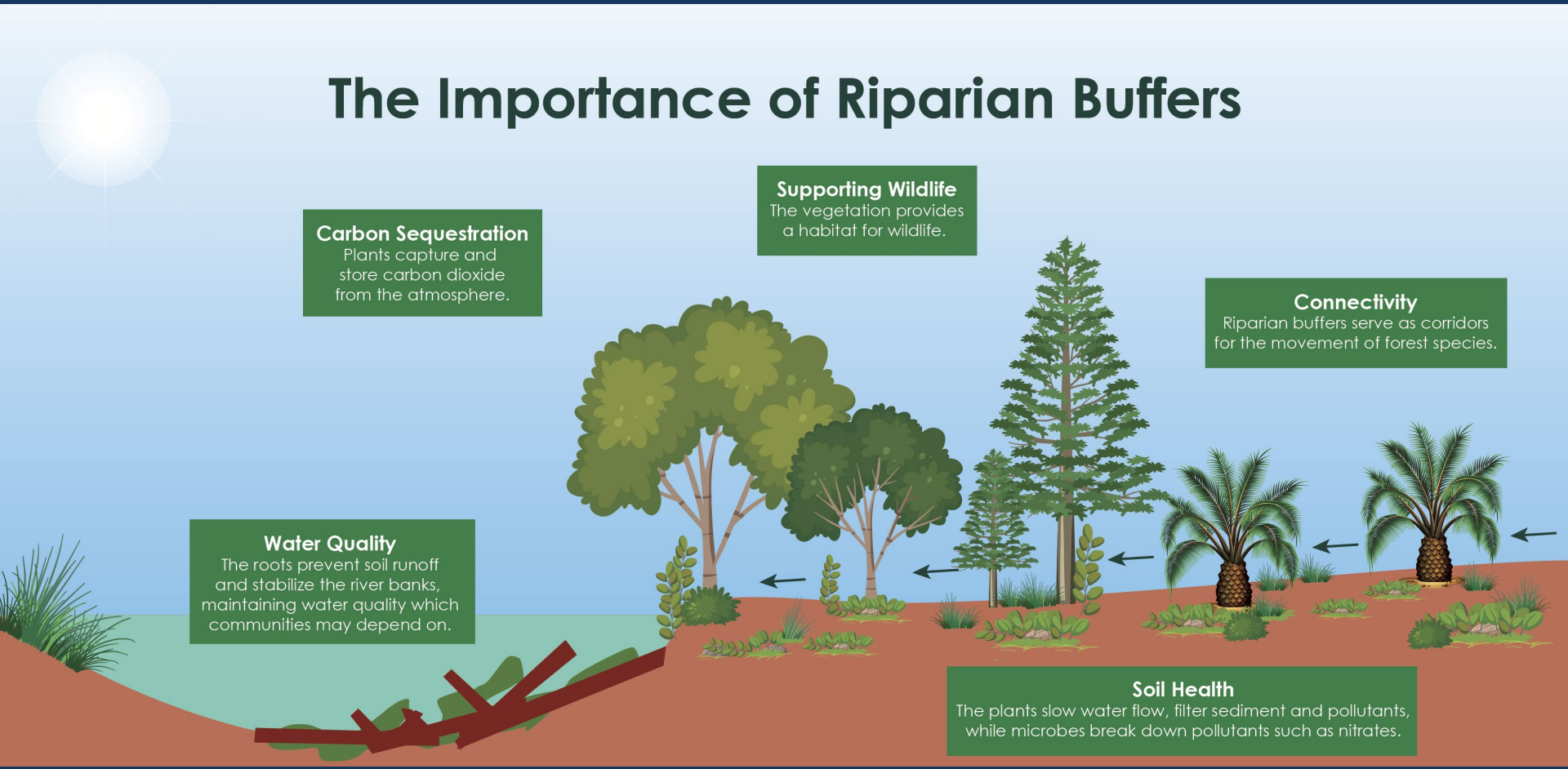
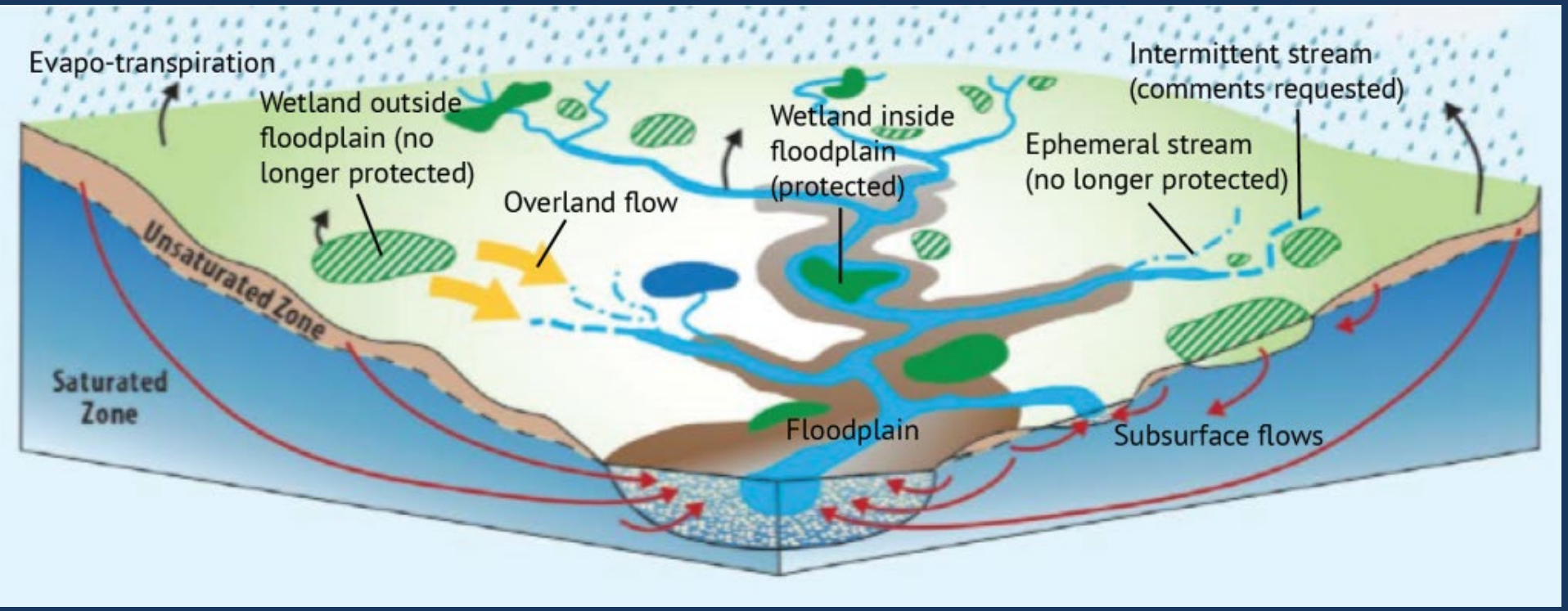
Riparian Area Functions = Ecosystem Services



https://www.musimmas.com/about-us/

The role of riparian areas in freshwater availability, access, interactions



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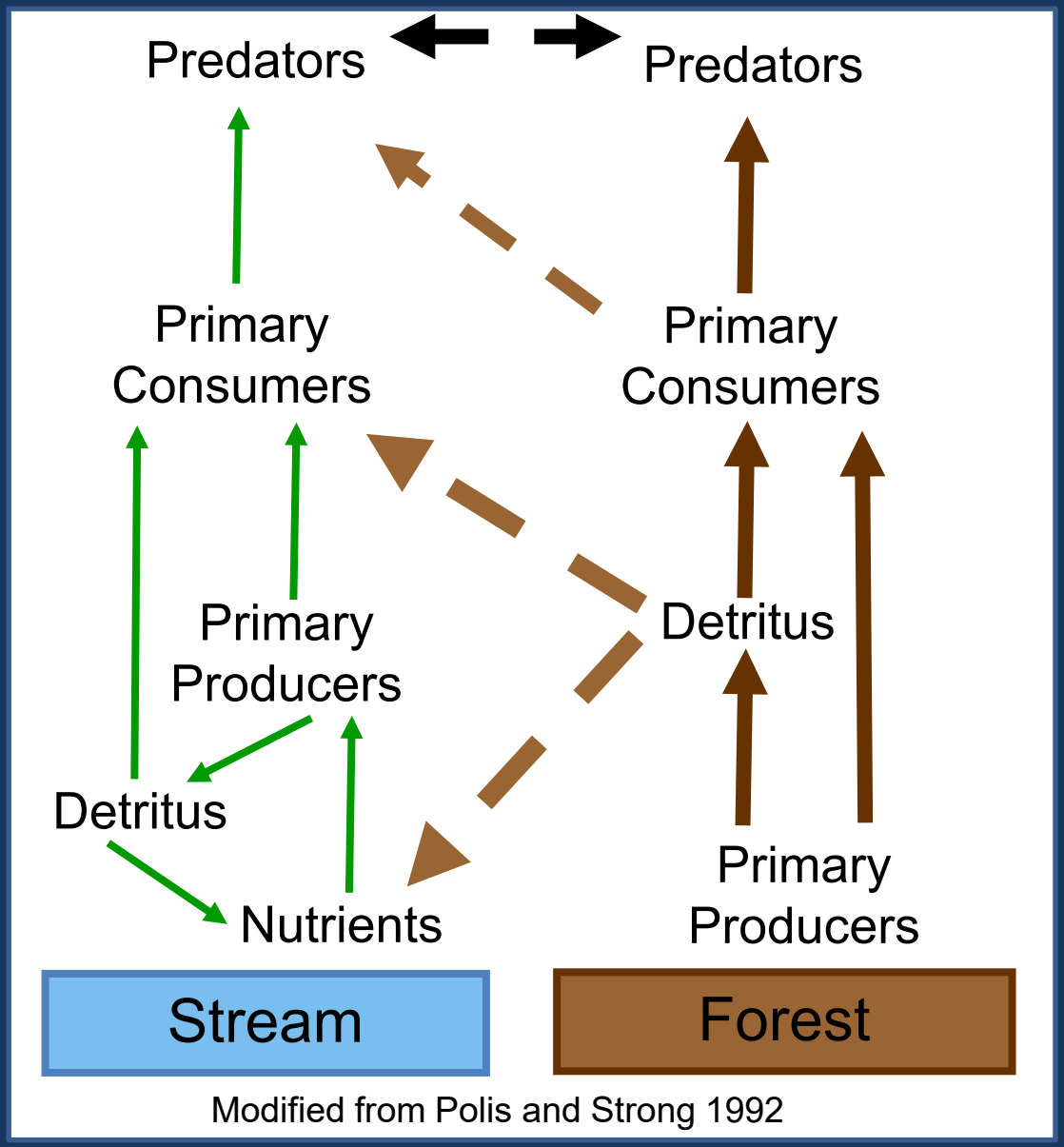
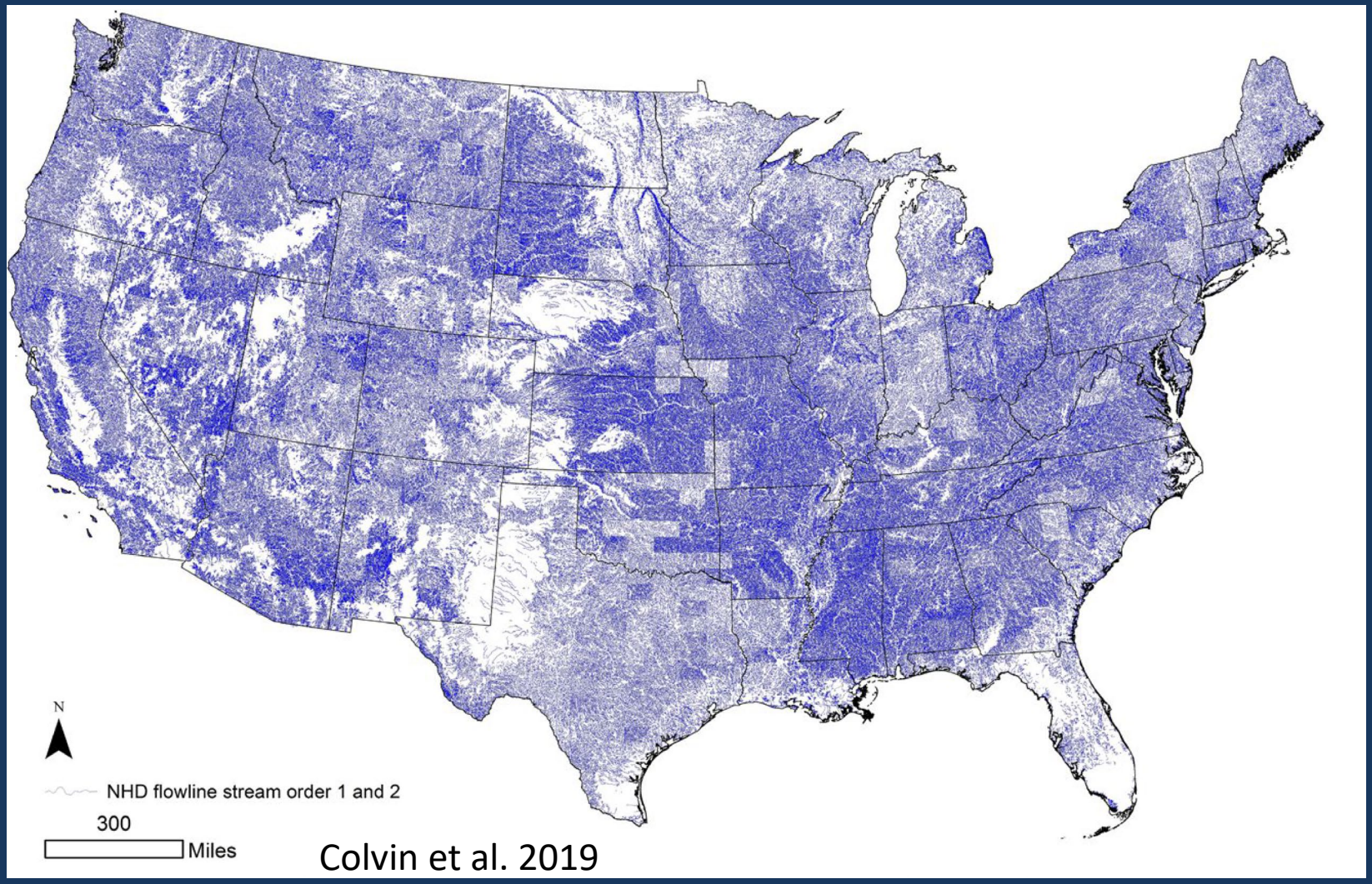
Small forested streams are donor-controlled food webs



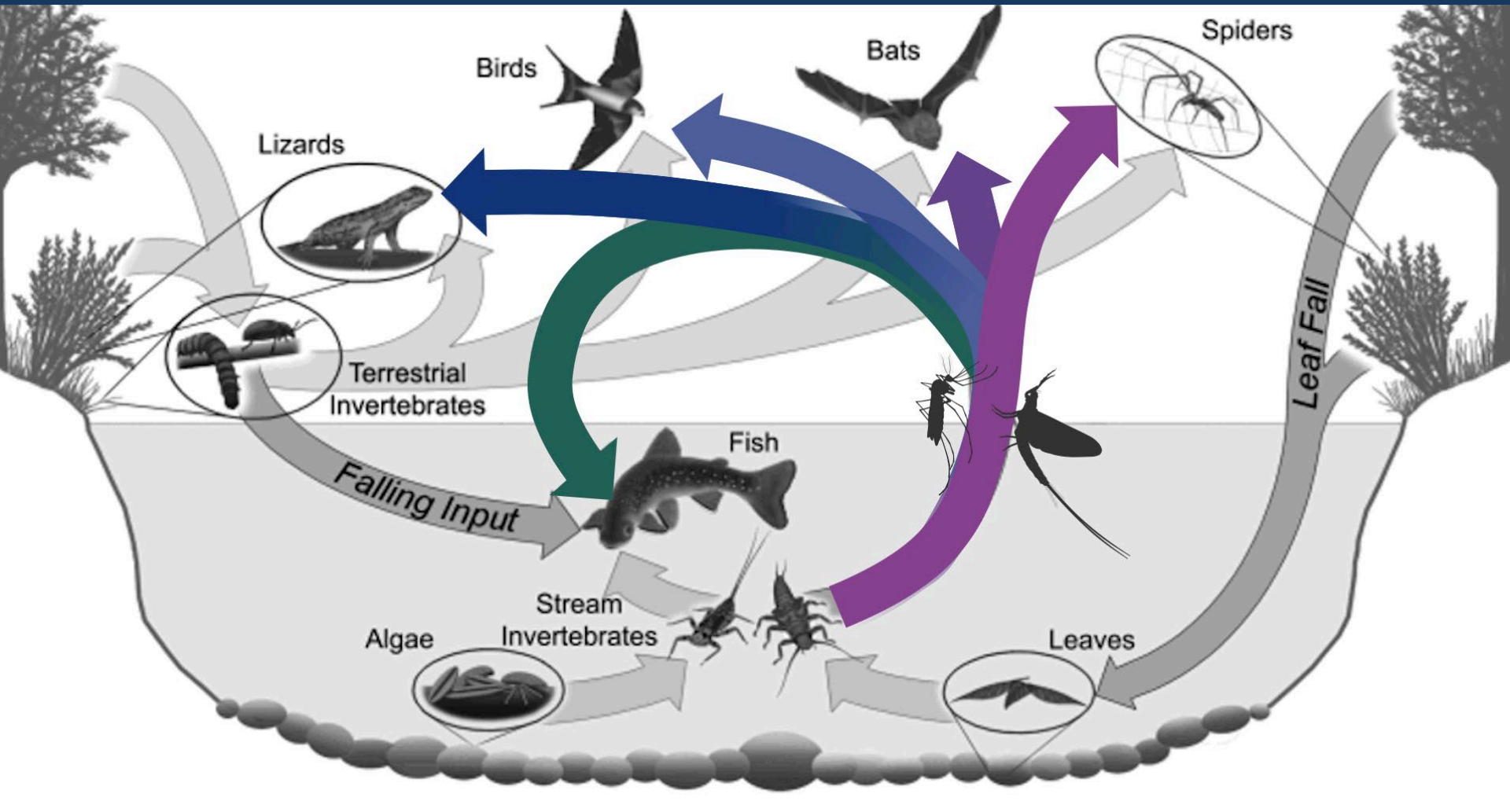
Modified from Polis and Strong 1992

Rivers are the gutters down which flow the ruins of continents
-Luna Leopold



Colvin et al. 2019

Aquatic insects connect streams to riparian areas



Baxter et al. 2005

Aquatic insects transform energy and matter

Coarse organic matter

Processing

Fine organic matter

Transport

Downstream food webs

Wallace, J.B. and Webster, J.R., 1996. The role of macroinvertebrates in stream ecosystem function. *Annual review of entomology*, *41*(1), pp.115-139.

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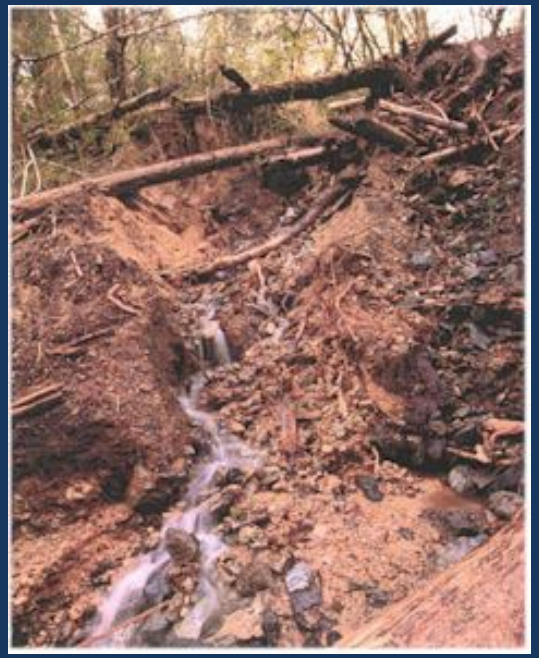
Land use change carbon amount and type



10% of global animal biodiversity is associated with habitats occupying <1% of the Earth's surf*D. Dudgeon. 2019*

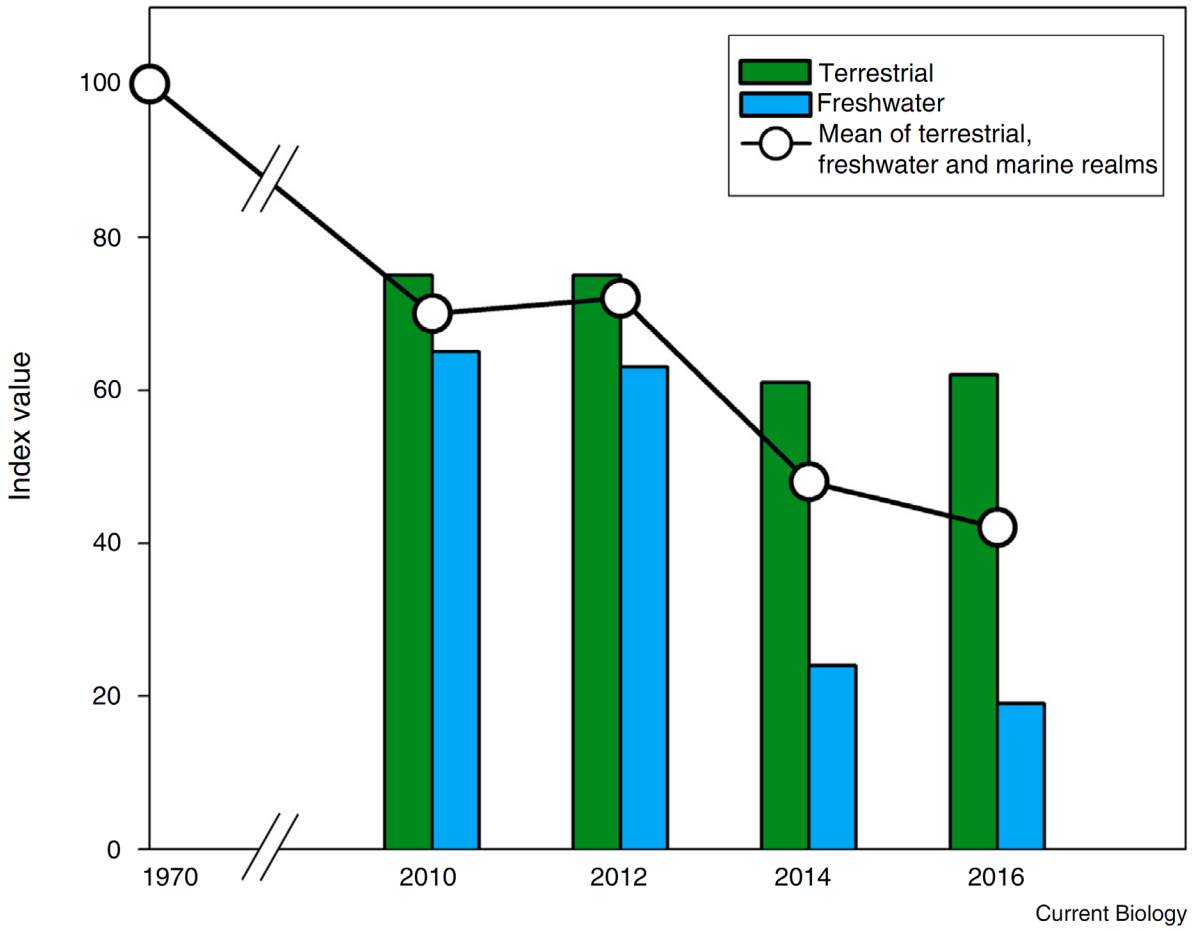


Figure 2. The WWF Living Planet Index [28] consists of population trend data for a collective 'basket' of vertebrates in the freshwater, marine and terrestrial realms.

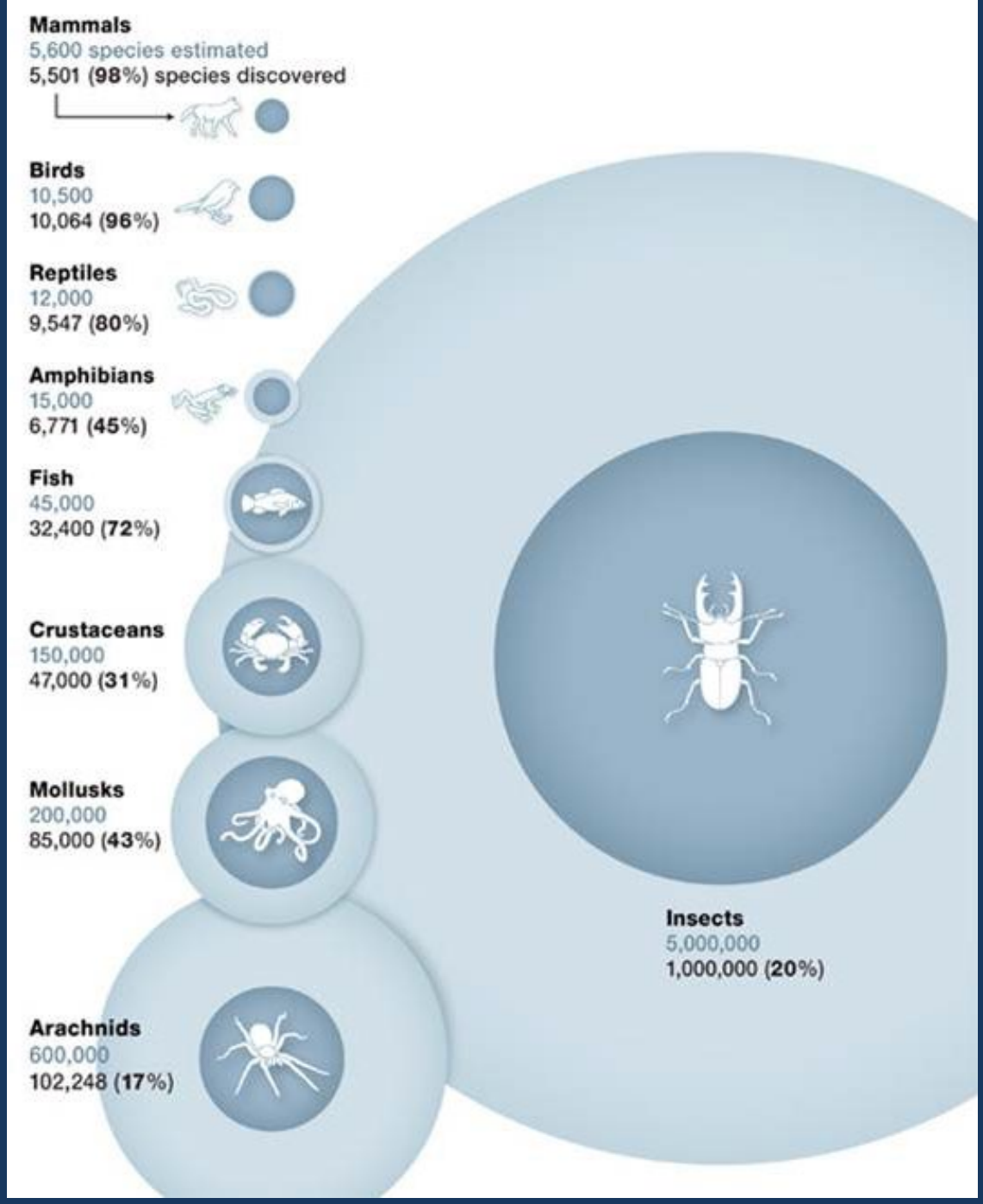
Diversity estimates:

Animal ≈ 1.4 million described species

Insect ≈ 1 million described species

Aquatic insect ≈ 100,000 - 300,000

Freshwater Biodiversity and Aquatic Insect Diversification. 2014. Annual Reviews



Biological Conservation 232 (2019) 8–27

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journal homepage: www.elsevier.com/locate/biocon

Review

Worldwide decline of the entomofauna: A review of its drivers

Francisco Sánchez-Bayo[a,*], Kris A.G. Wyckhuys[b,c,d]

[a] School of Life & Environmental Sciences, Sydney Institute of Agriculture, The University of Sydney, Eveleigh, NSW 2015, Australia
[b] School of Biological Sciences, University of Queensland, Brisbane, Australia
[c] Chrysalis, Hanoi, Viet Nam
[d] Institute of Plant Protection, China Academy of Agricultural Sciences, Beijing, China

A focus on insects

- Greatest # of studies
- Insect orders with most survey data

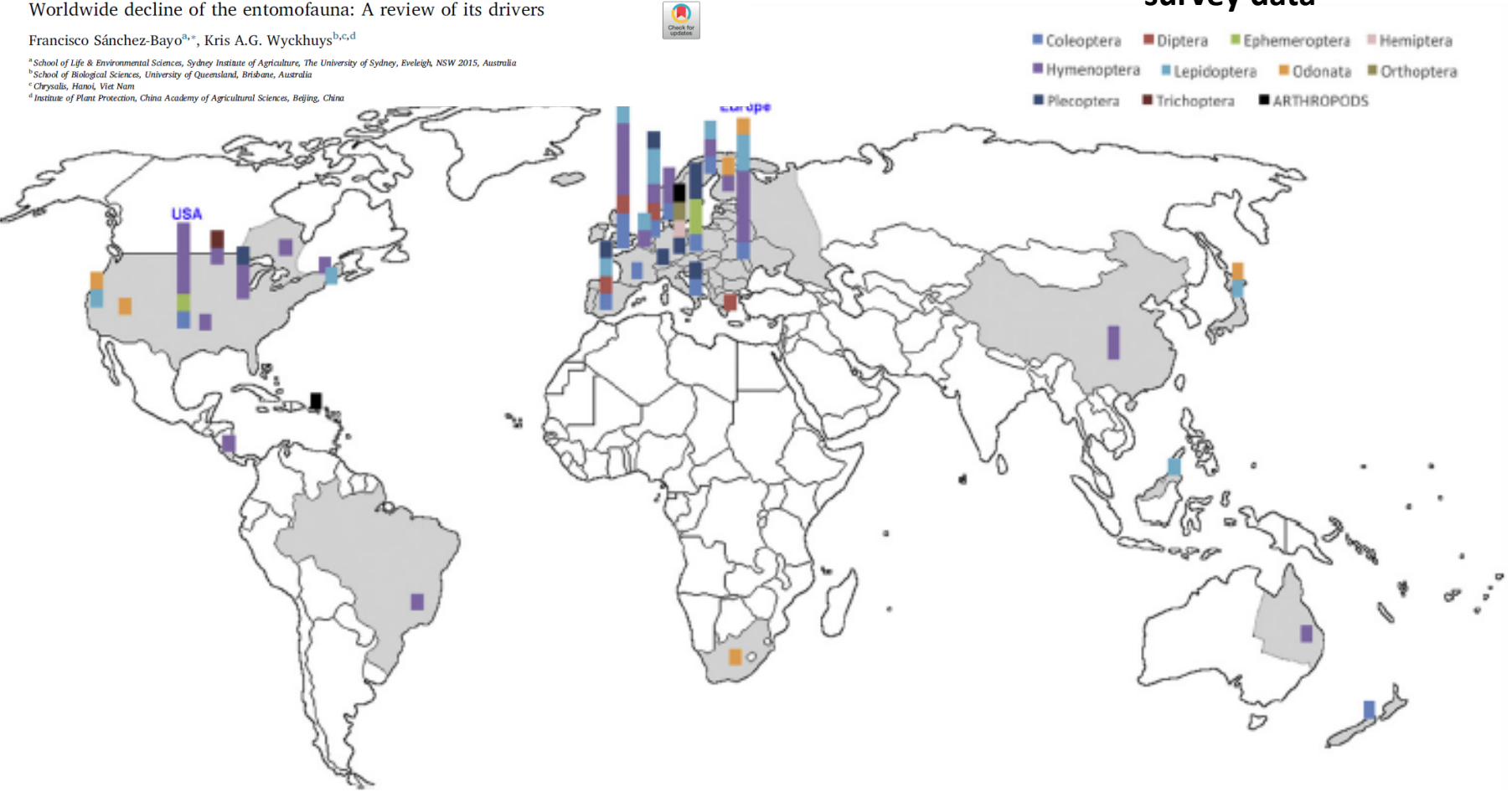


Fig. 1. Geographic location of the 73 reports studied on the world map. Columns show the relative proportion of surveys for each taxa as indicated by different colours in the legend. Data for China and Queensland (Australia) refer to managed honey bees only. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Summary of insect decline scientific papers:
https://en.wikipedia.org/wiki/Decline_in_insect_populations

Highlights

- Over 40% of insect species are threatened with extinction.
- Lepidoptera, Hymenoptera and dung beetles (Coleoptera) are the taxa most affected.
- Four aquatic taxa are imperiled and have already lost a large proportion of species.
- Habitat loss by conversion to intensive agriculture is the main driver of the declines.
- Agro-chemical pollutants, invasive species and climate change are additional causes.

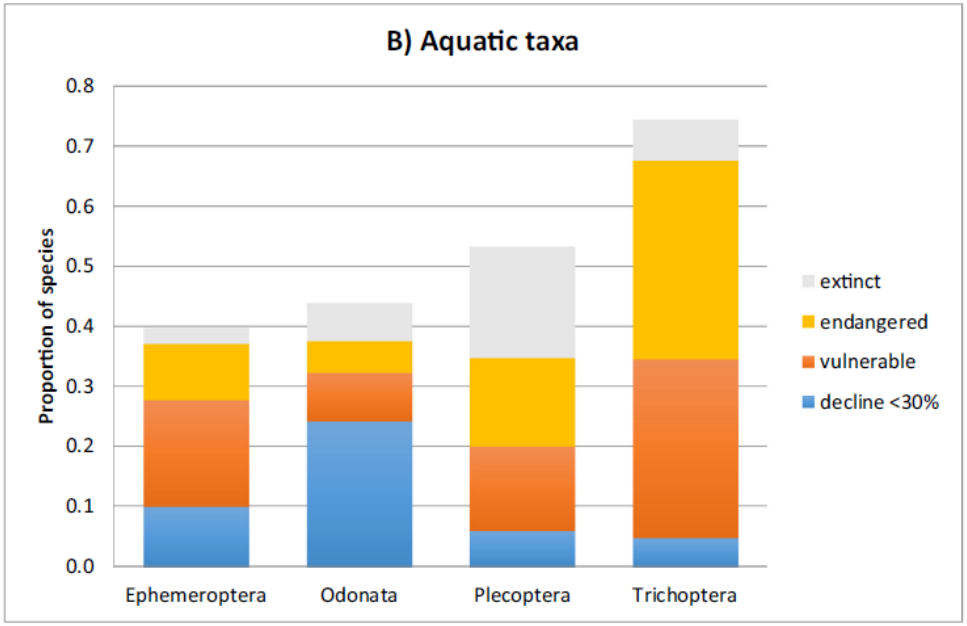
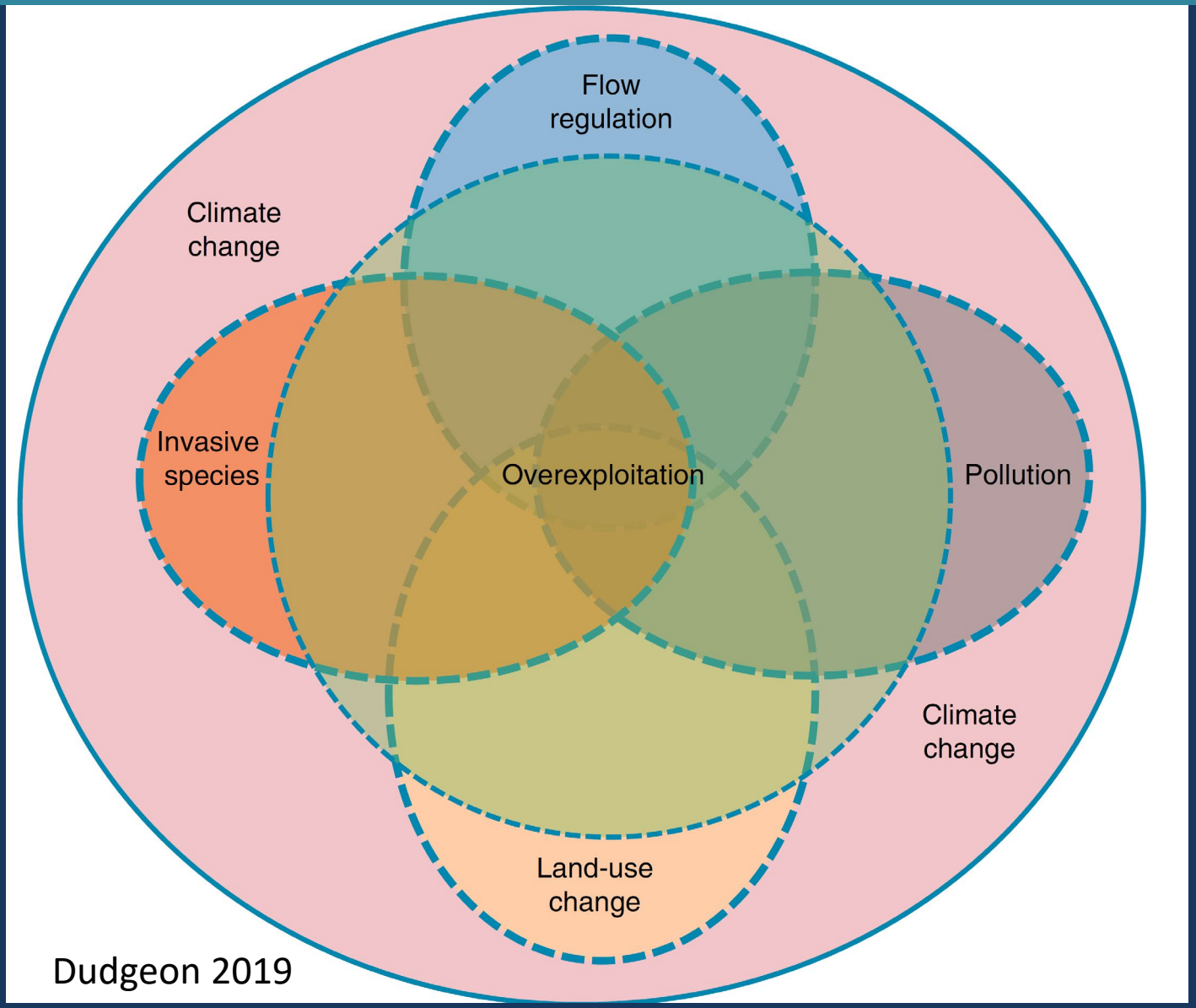


Fig. 3. Proportion of insect species in decline or locally extinct according to the IUCN criteria: vulnerable species (> 30% decline), endangered species (> 50% decline) and extinct (not recorded for>50 years). A) terrestrial taxa; B) aquatic taxa.

Sánchez-Bayo, F., & Wyckhuys, K. A. (2019). Worldwide decline of the entomofauna: A review of its drivers. *Biological conservation*, *232*, 8-27.

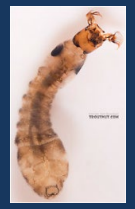
Causes of declines



Trophic simplification

Fine organic matter & algae

Processing



Fine organic matter

Transport

Downstream
food webs

Rahel, F.J., 2002. Homogenization of freshwater faunas. *Annual Review of Ecology and Systematics*, *33*(1), pp.291-315.

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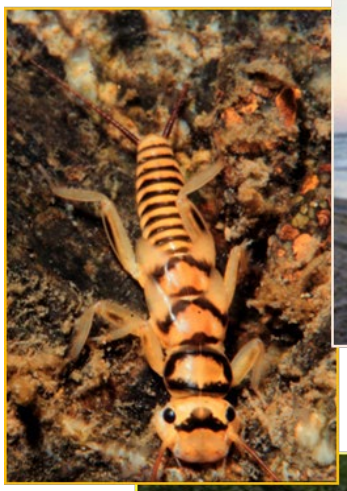
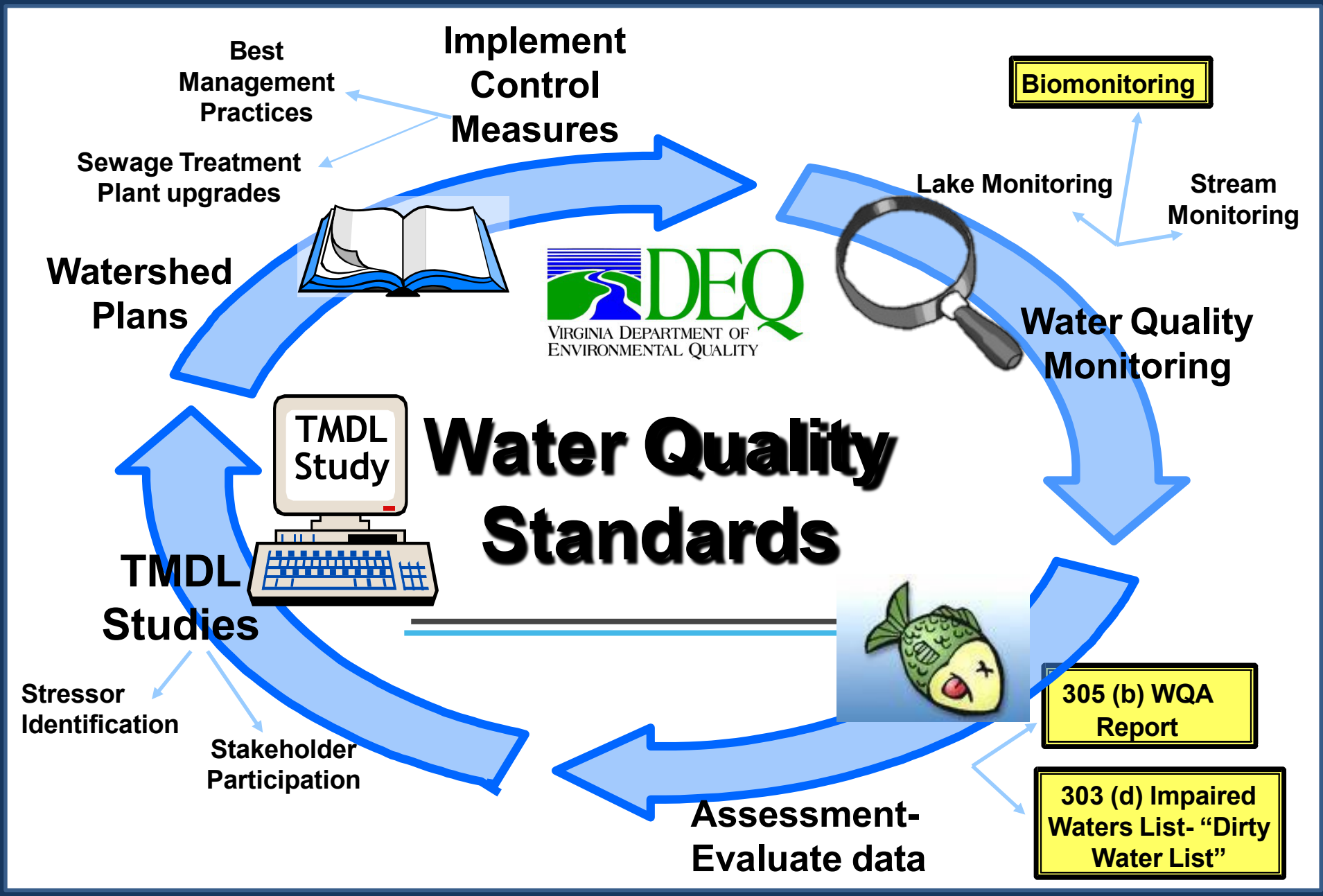
Water Quality Monitoring
Collect data about water quality
Assessments
Study and analyze data from water samples
Reporting
Issue a biennial report on water quality and identify impaired waters
Cleanup Studies
Plans for restoring impaired waters (TMDL or watershed plan)
Cleanup Implementation Plans
Plans for actions needed to restore water quality
Implementing Control Measures
Permits, Best Management Practices (BMPs), grants, cleanup actions
Clean Water
Virginia's Water Quality Standards

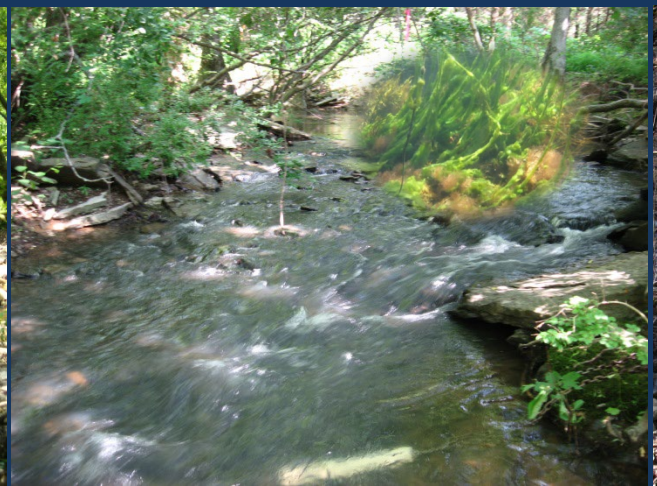
Virginia's Water Quality Standards

- WQS protects the 6 designated uses:
  - **aquatic life**
  - wildlife
  - fishing
  - shellfish
  - swimming
  - drinking water

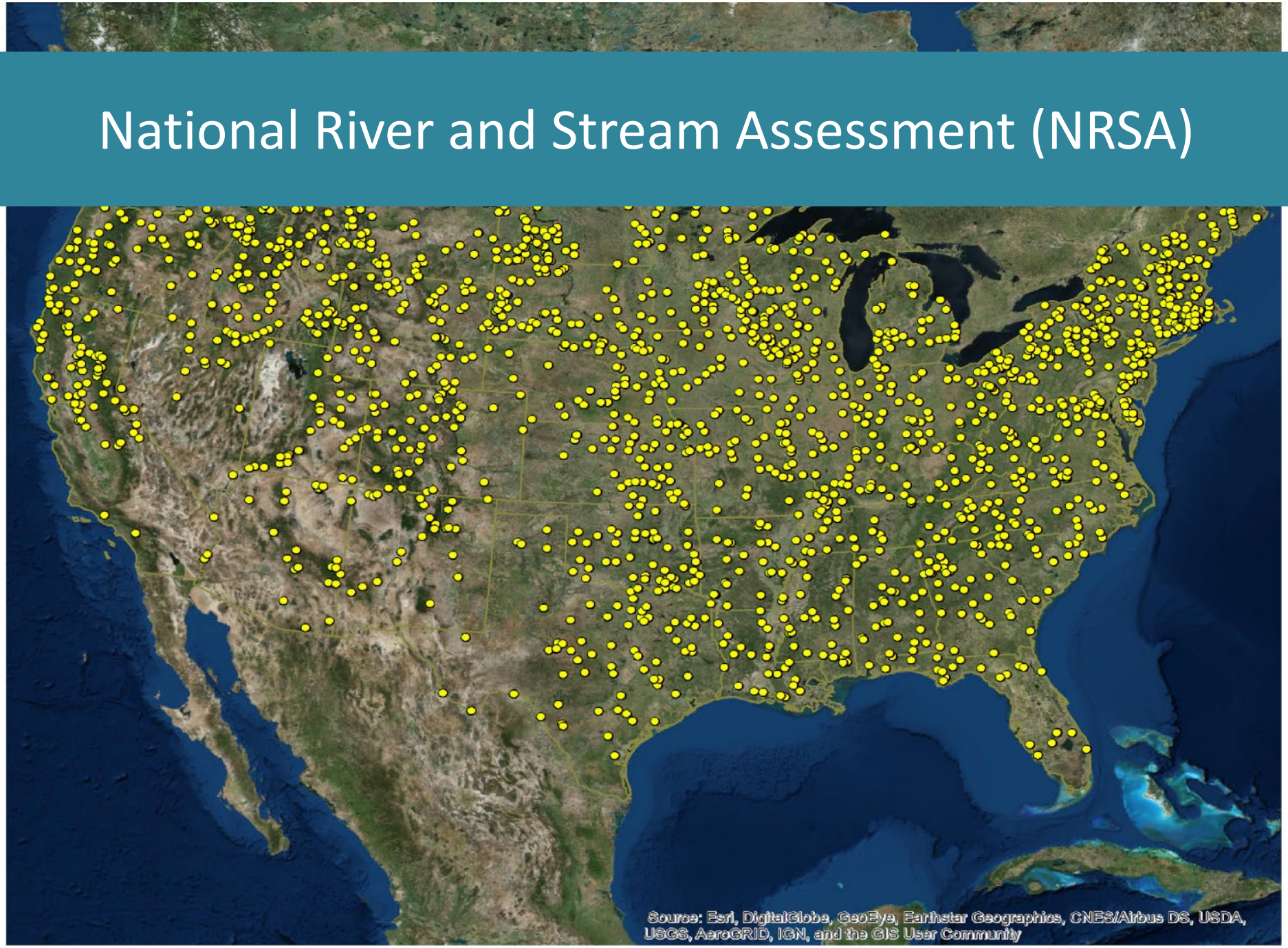



Best Management Practices
Implement Control Measures
Sewage Treatment Plant upgrades
Biomonitoring
Lake Monitoring
Stream Monitoring
Watershed Plans
DEQ
Virginia Department of Environmental Quality
Water Quality Monitoring
TMDL Study
Water Quality Standards
TMDL Studies
Stressor Identification
Stakeholder Participation
305 (b) WQA Report
303 (d) Impaired Waters List- "Dirty Water List"
Assessment- Evaluate data

Freshwater Biota



National River and Stream Assessment (NRSA)



How are we assessing our streams?

Sensitive **Tolerant** **Resistant**

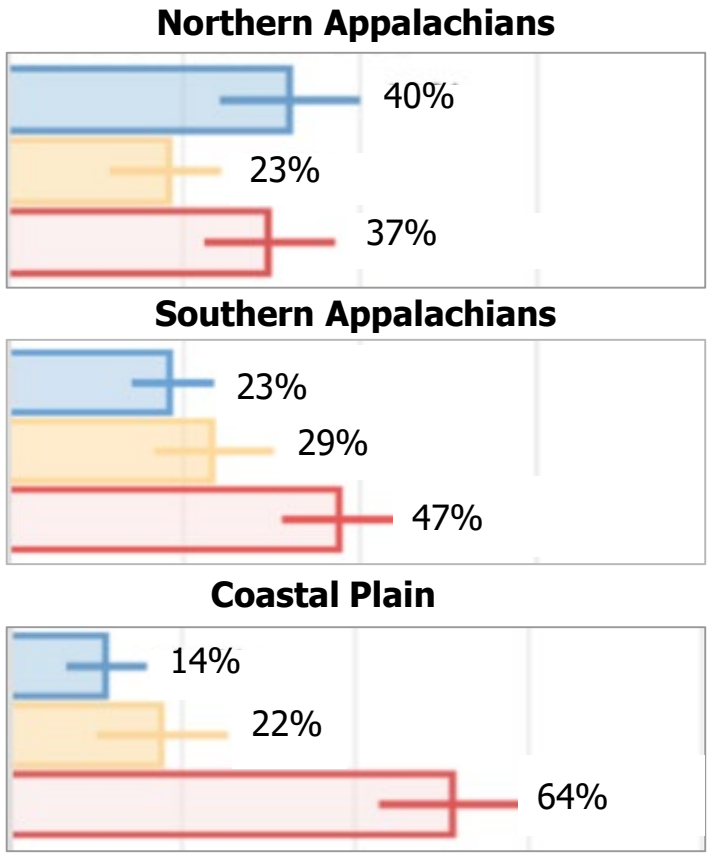
Environmental Conditions gradient

Pictures from macroinvertebrates.org

Concept from Ligiero et al. 2014

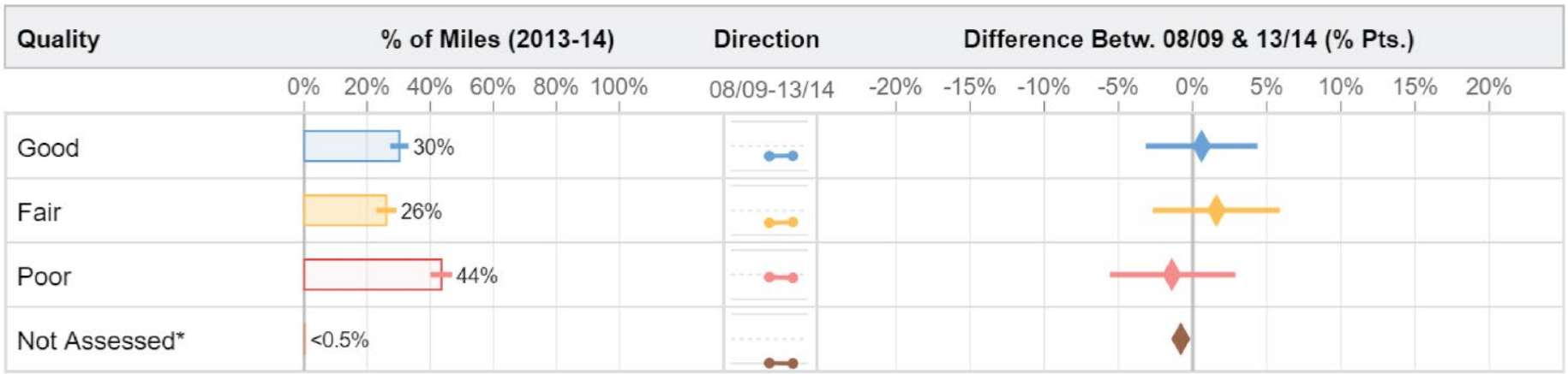
Macroinvertebrate-focused stream bioassessments: % miles assessed

National Rivers and Streams Assessment (NRSA) 2014



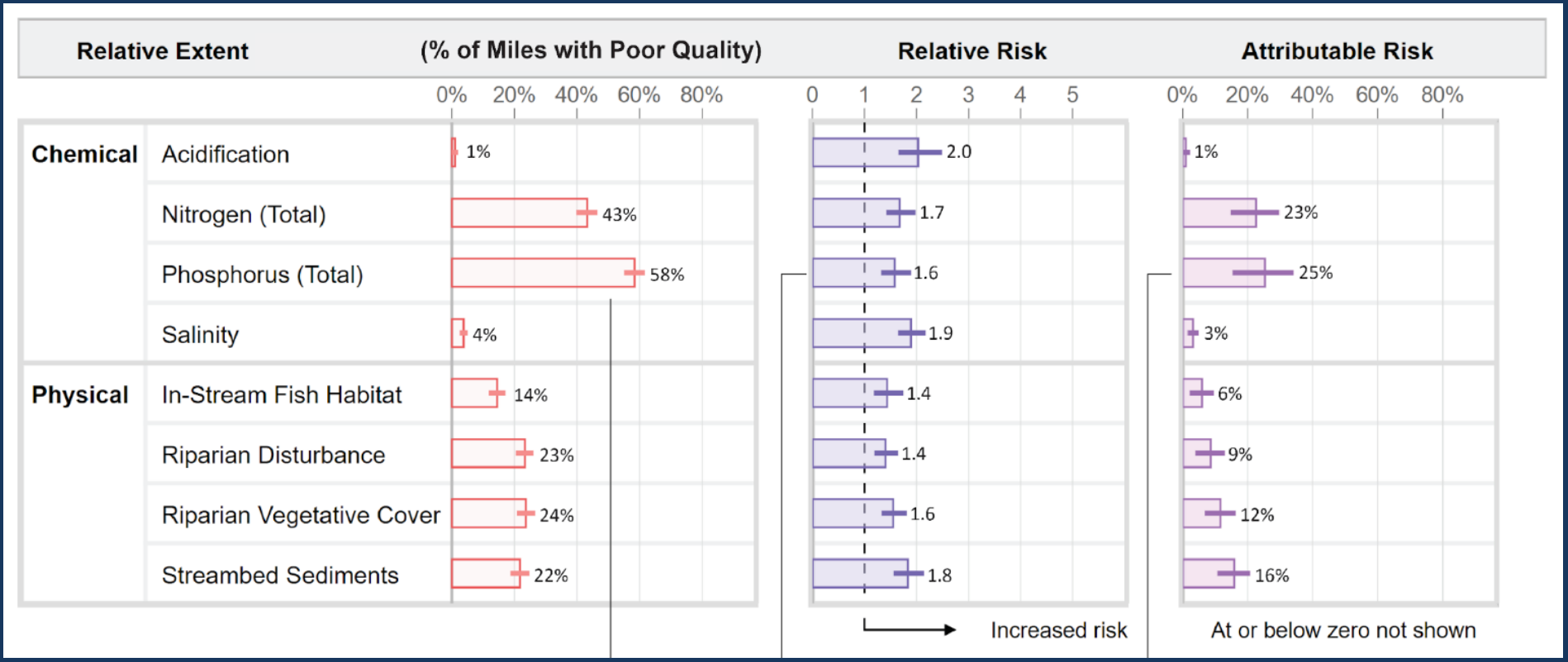
Macroinvertebrate-focused stream bioassessments: % miles assessed

Figure 3.2 Macroinvertebrates: NRSA 2013–14 National Results



*Reflects a statistically significant change between 2008–09 and 2013–14 (95% confidence).

Relative extent, relative risk, and attributable risk to macroinvertebrates: NRSA 2013-2014



Relative extent: % of miles affected by each stressor

Relative risk: the likelihood of having poor biological quality when a particular stressor is rated poor

Attributable risk: % of miles rated poor for a biological indicator that could be improved if a stressor were removed

Identifying stressors that affect aquatic life

Candidate Stressors

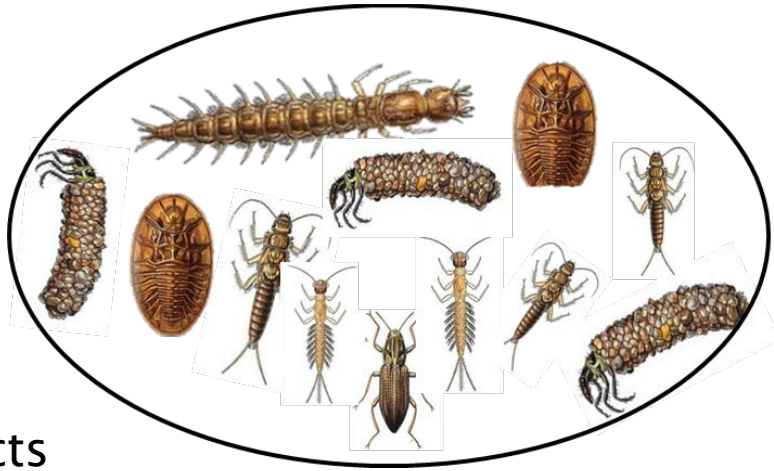
Sediment proxies:
TSS
Total Habitat scores
LRBS

Indirect Effects

Habitat

Ph
DO
Dissolved Metals
Temperature
Toxins
Conductivity

Direct Effects



Total Phosphorus
Total Nitrogen
Organic Matter

Indirect Effects

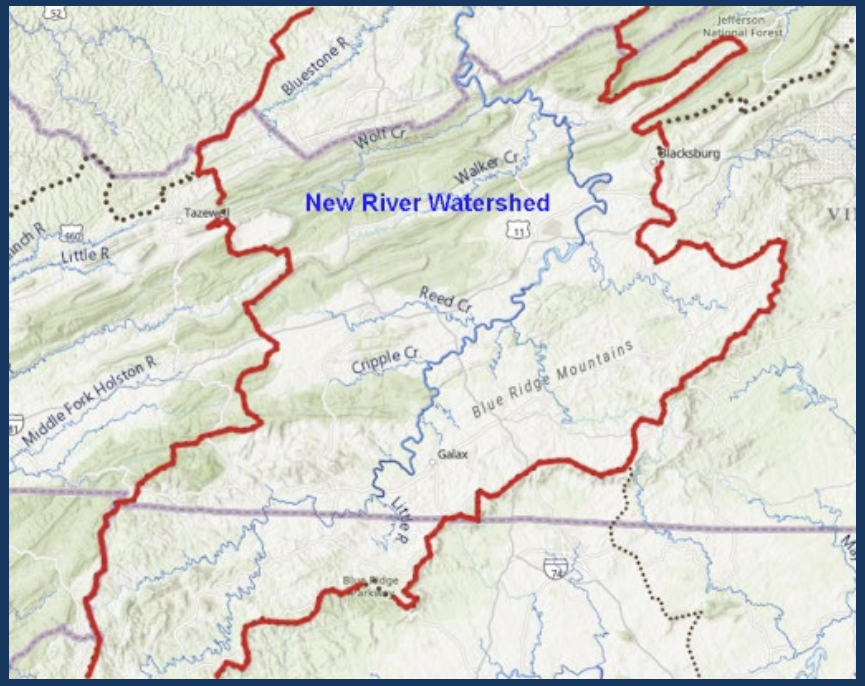
Food Resources

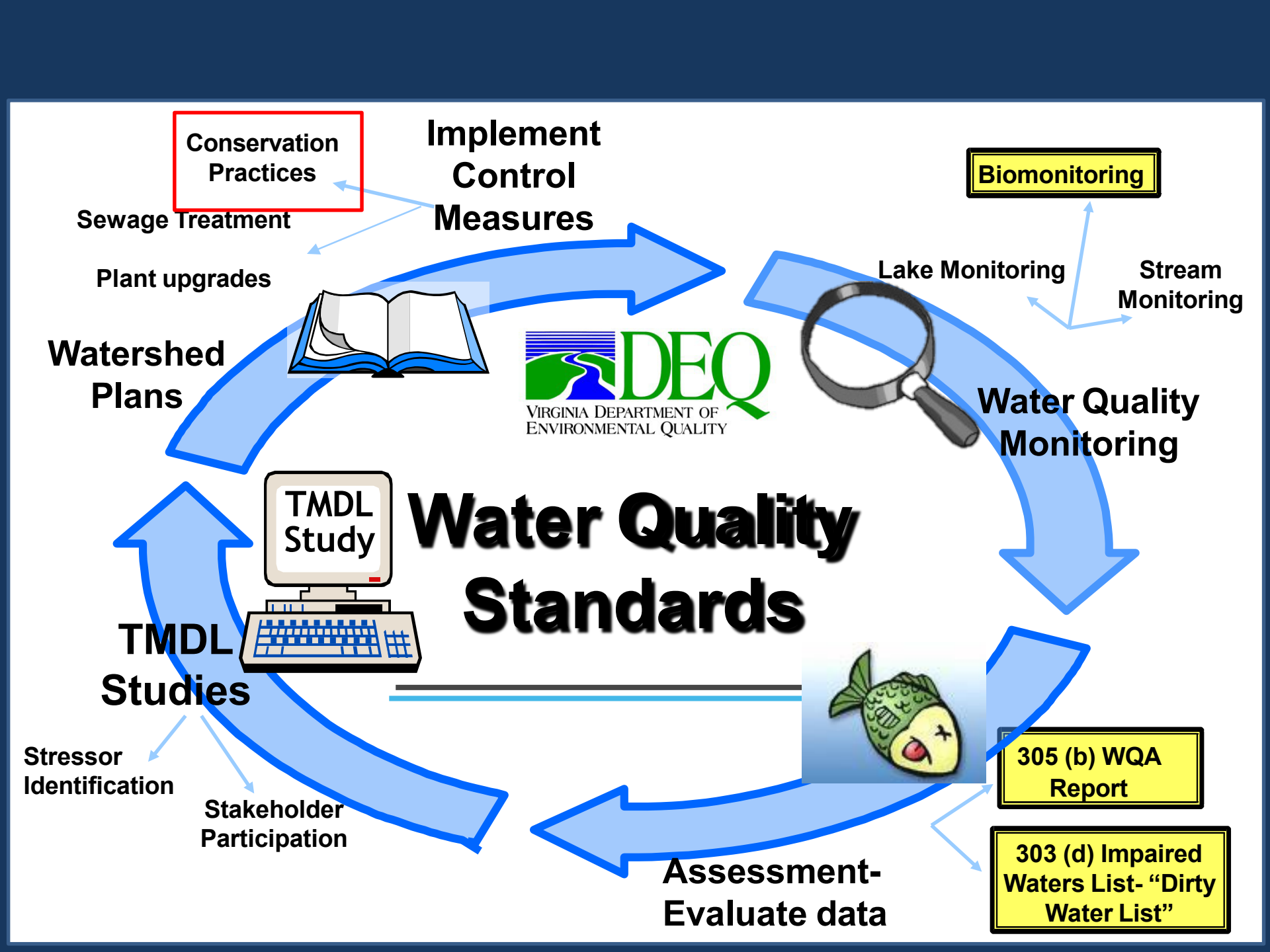
How to reduce or eliminate identified stressors?

Conservation Practices

Student project:

- Sergio Sabat-Bonilla
- Abigail Belvin




Conservation Practices
Implement Control Measures
Sewage Treatment
Plant upgrades
Biomonitoring
Lake Monitoring
Stream Monitoring
Watershed Plans
DEQ
Virginia Department of Environmental Quality
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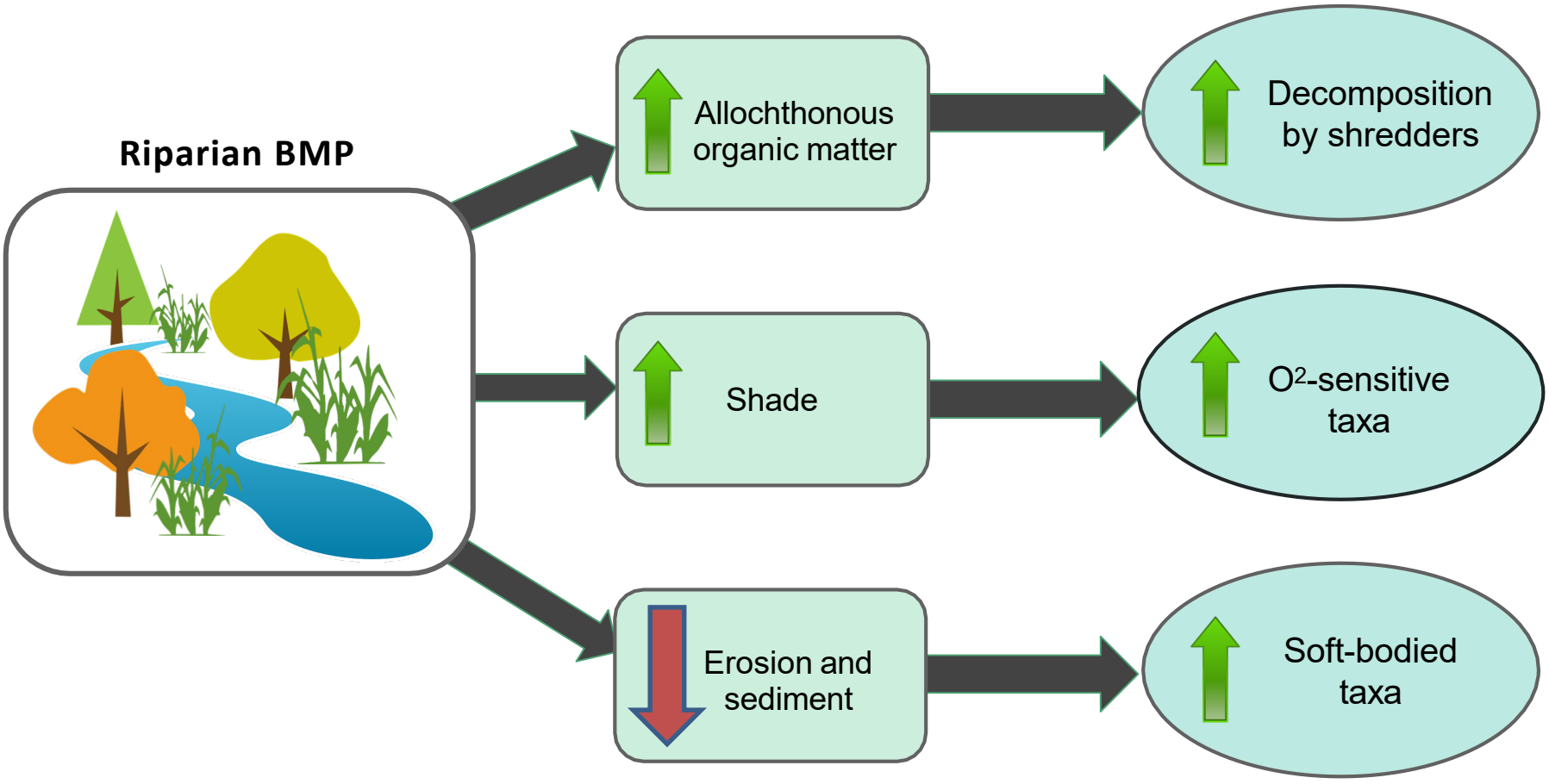
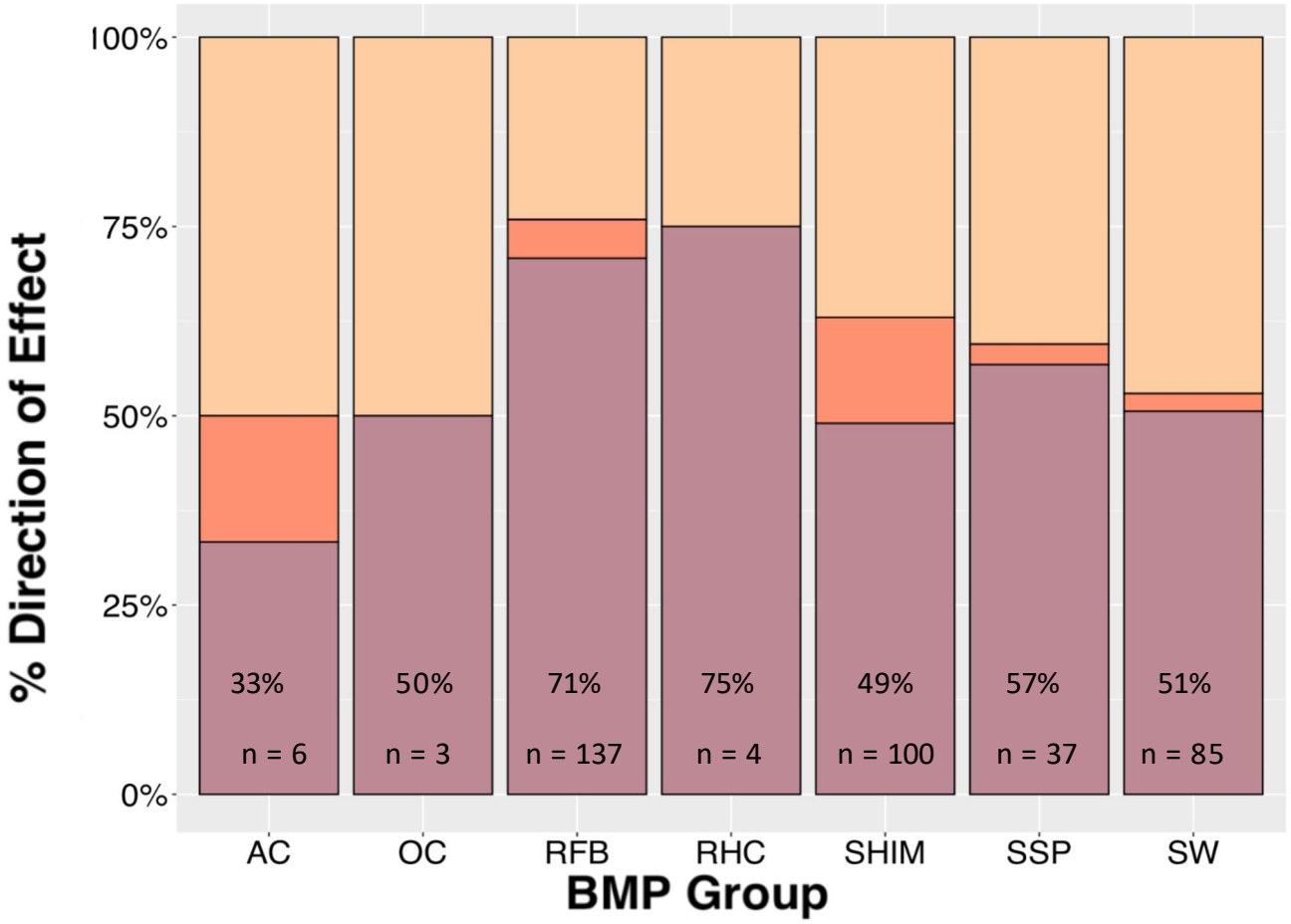
Water Quality Standards
TMDL Studies
Stressor Identification
Stakeholder Participation
305 (b) WQA Report
303 (d) Impaired Waters List- "Dirty Water List"
Assessment- Evaluate data

How do we manage for stressor reduction?



Direction of effects of BMP groups on macroinvertebrate metrics

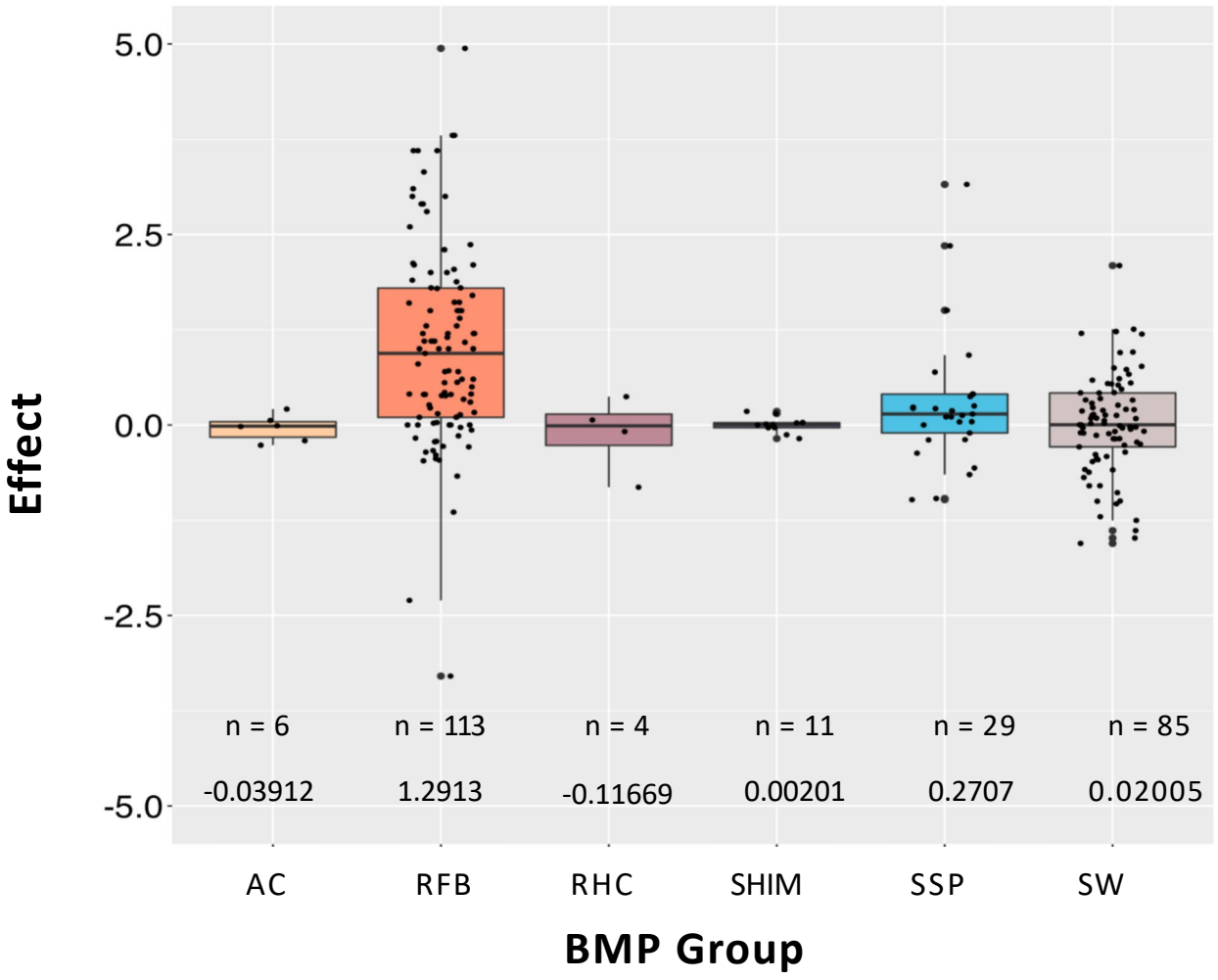


Total n = 374

- Negative
- No Effect
- Positive

AC	Access Control
OC	Open Channel
RFB	Riparian Forest Buffer
RHC	Riparian Herbaceous Cover
SHIM	Stream Habitat Improvement and Management
SSP	Streambank and Shoreline Protection
SW	Structures for Wildlife

Effects of agricultural BMPs on macroinvertebrate responses

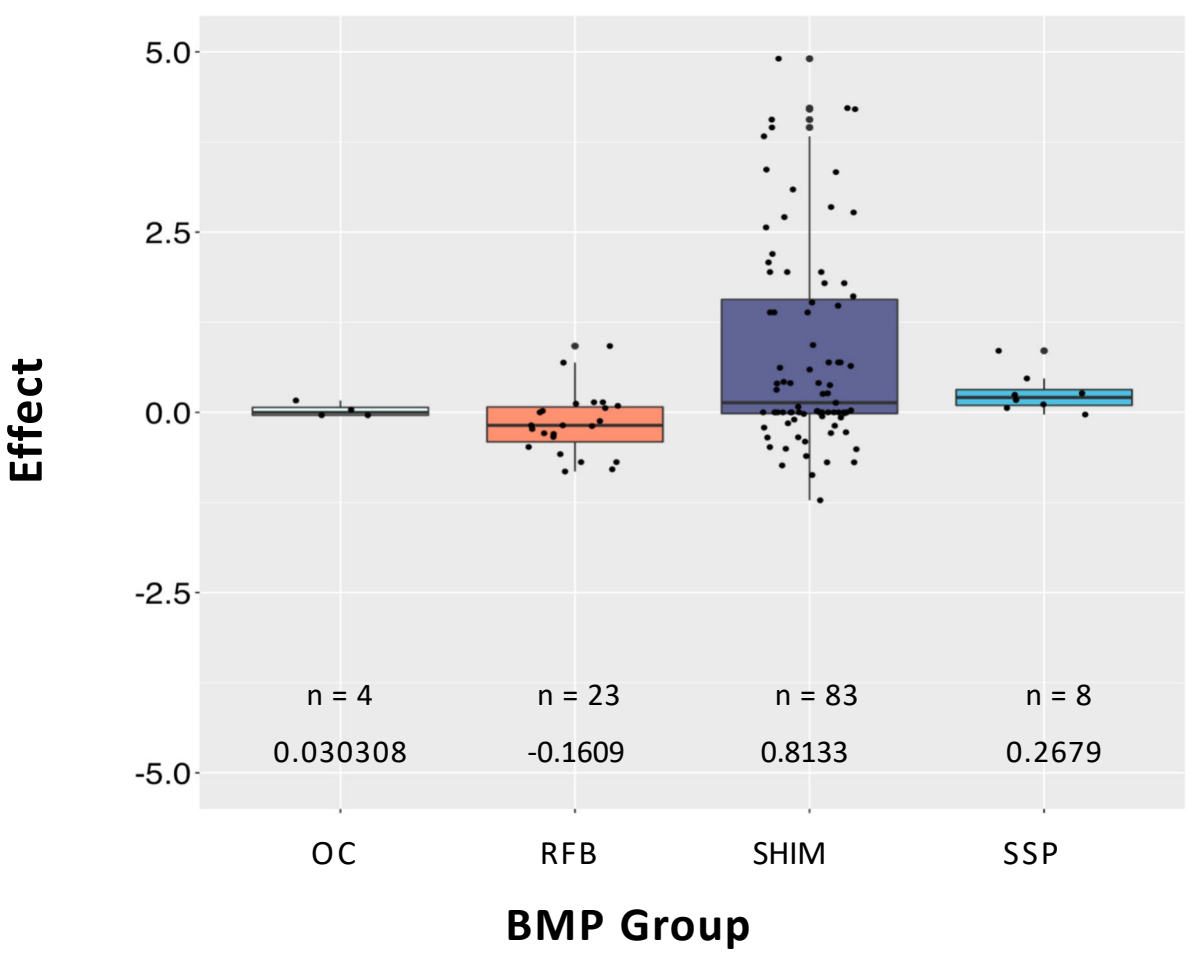


Average effect size: 0.2380

BMP Groups

- (AC) Access Control
- (RFB) Riparian Forest Buffer
- (RHC) Riparian Herbaceous Cover
- (SHIM) Stream Habitat Improvement and Management
- (SSP) Streambank and Shoreline protection
- (SW) Structures for wildlife

Effects of urban BMPs on macroinvertebrate responses



Average Effect Size: 0.2377

BMP Groups

- (OC) Open Channel
- (RFB) Riparian Forest Buffer
- (SHIM) Stream Habitat Improvement and Management
- (SSP) Streambank and Shoreline protection

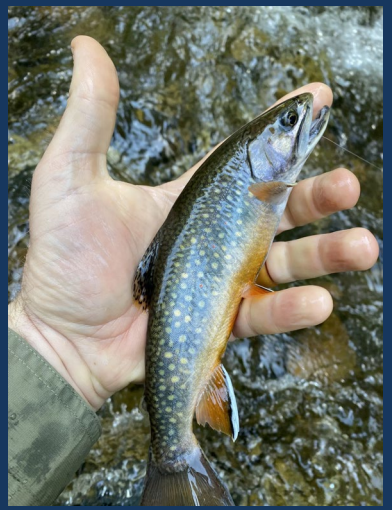
Are 30 meter riparian buffers enough?

Reduce food resources alter aquatic food webs (England and Rosemond 2007)

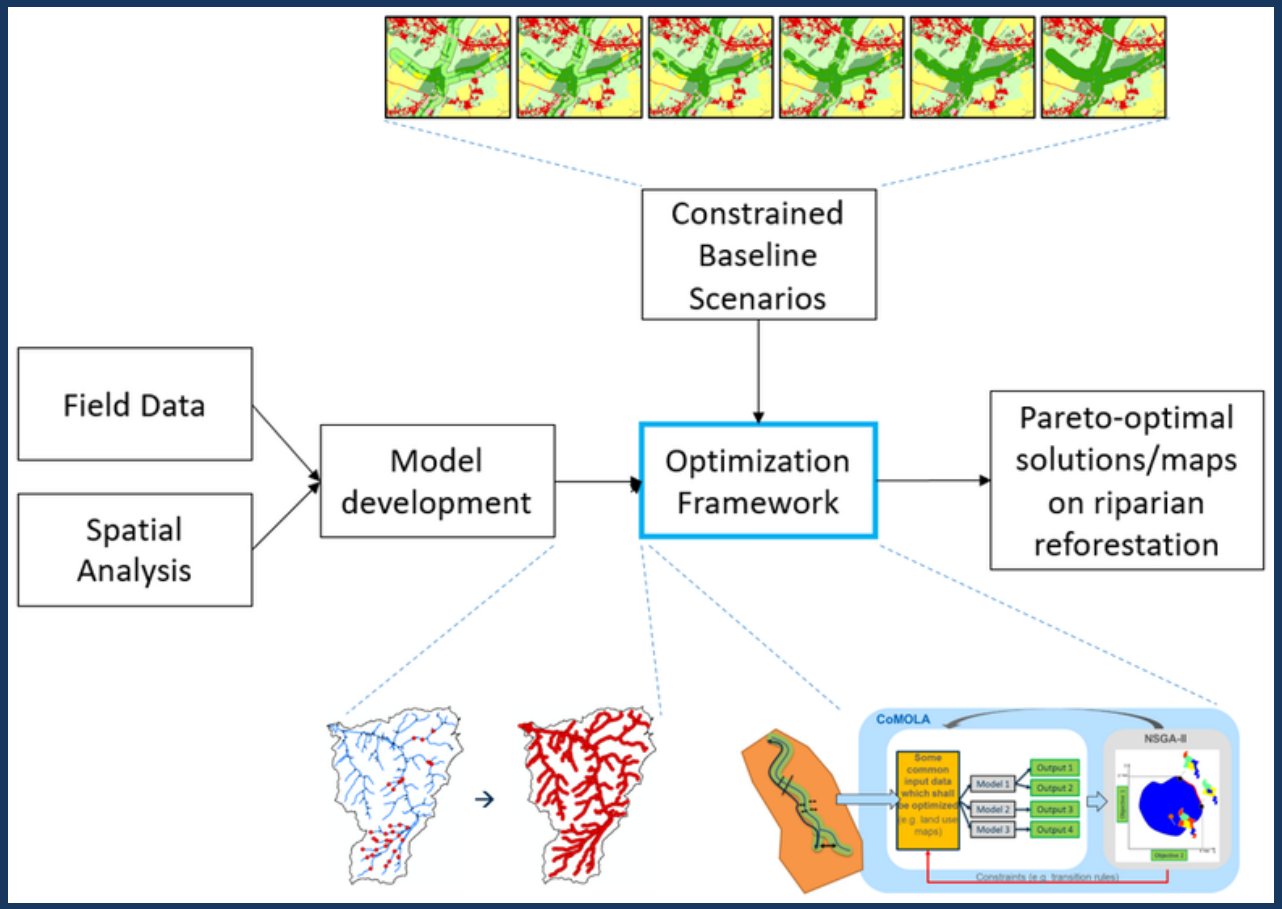
- watershed forest cover range: 82-96%

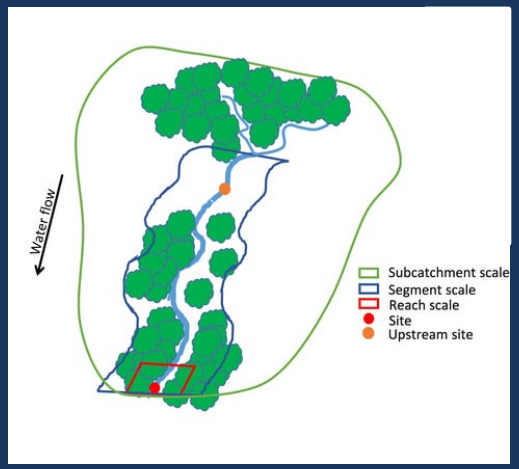
Population declines of thermally sensitive species:

- brook trout (Andrew et al. 2022)
- giant stoneflies (Kowalski & Richer 2020)
- giant salamander patterns of recruitment that can lead to nest failure (Jachowski & Hopkins 2018 , Hopkins et al. 2023)
  - catchment-wide extent of riparian area range: 54%-68%.



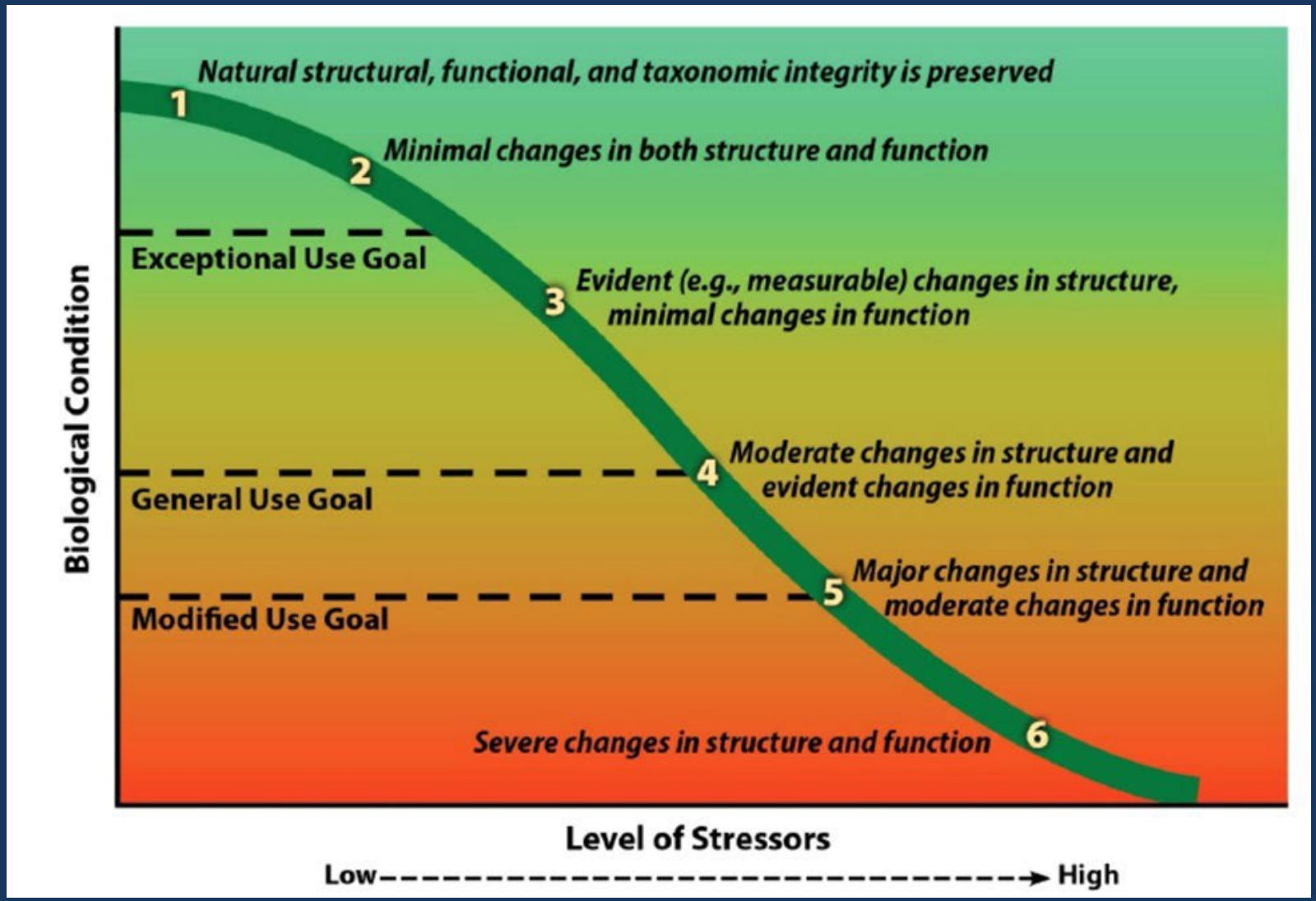
Optimizing the placement or conservation of riparian buffers





https://www.riparianbuffers.com/optimization.html

Biological Condition Gradient



Davies and Jackson, 2006

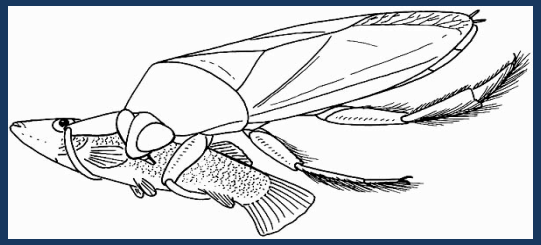
Macroinvertebrates: streams, wetlands, rivers

Major freshwater ecosystems: lakes

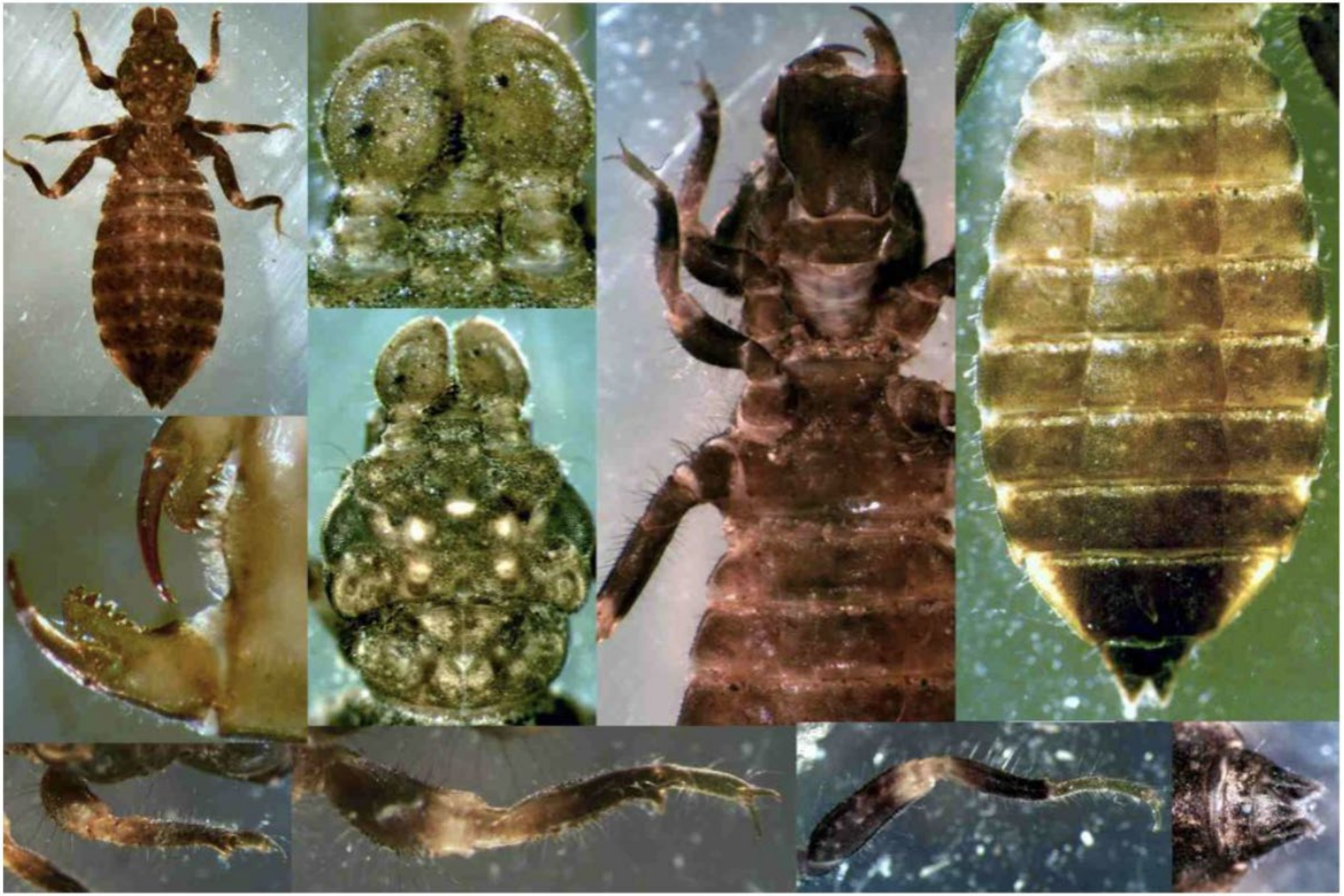
Adaptations for acquiring food: predator (engulfers)

Hellgramites/Alderflies
Megaloptera
Corydalidae

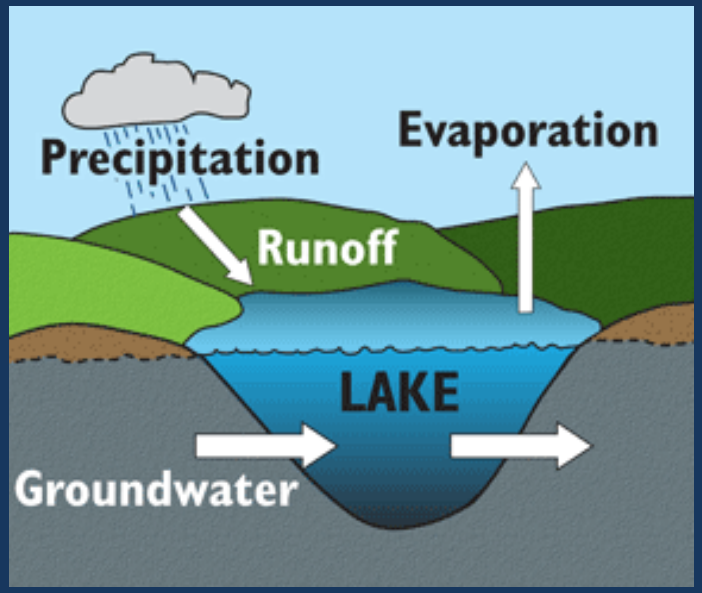
Adaptations for acquiring food: predators (piercers)

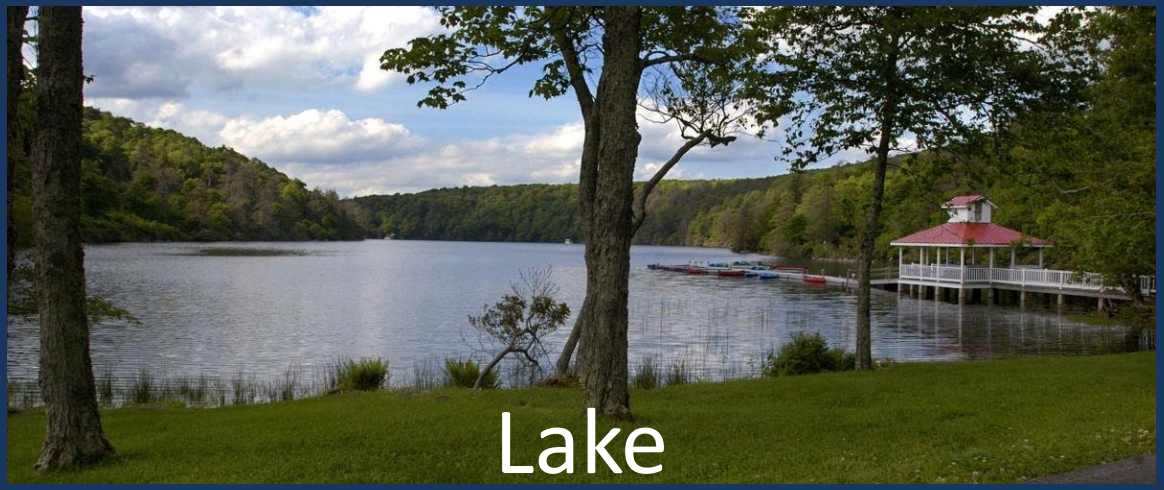


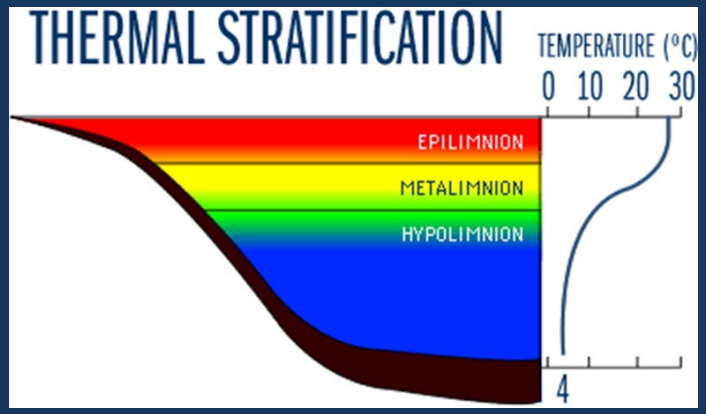
True Water Bugs
Hemiptera
Belostomatidae



Major freshwater ecosystems: lakes

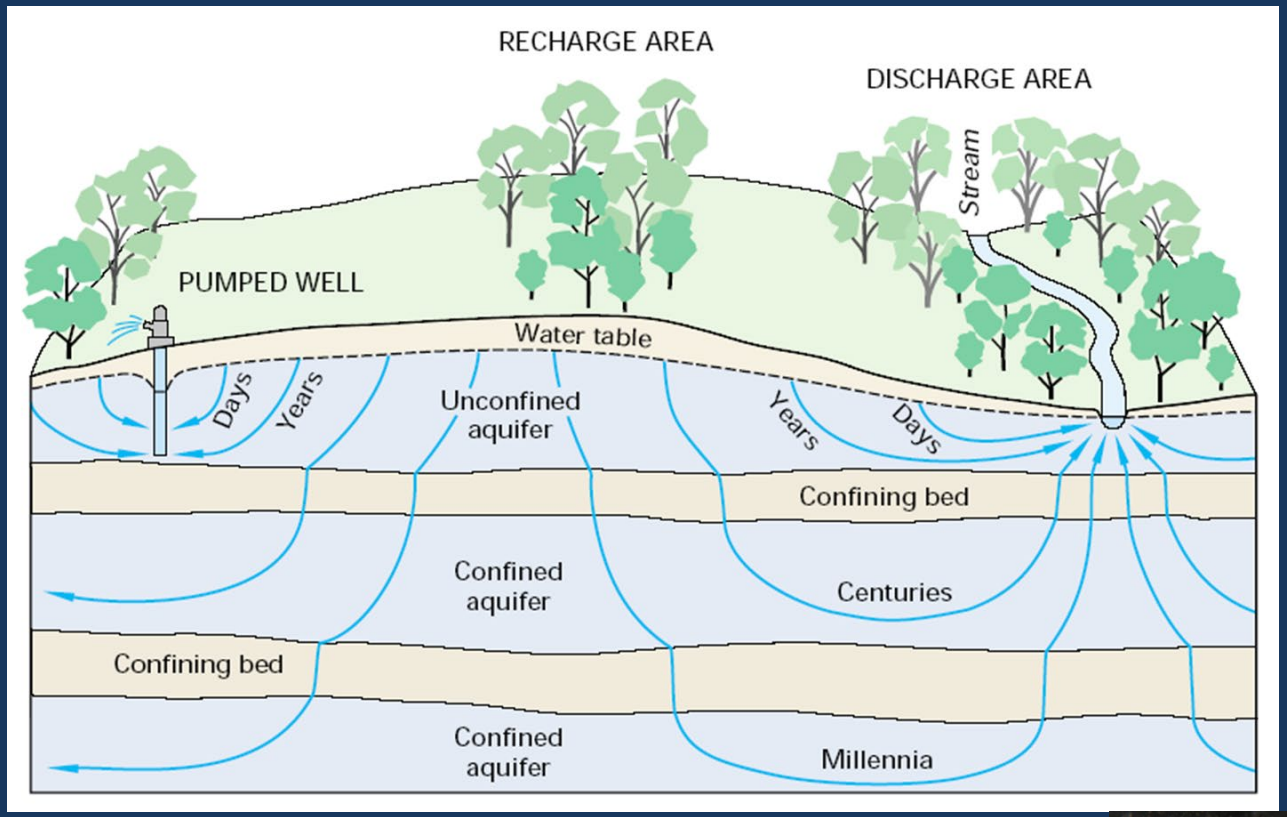




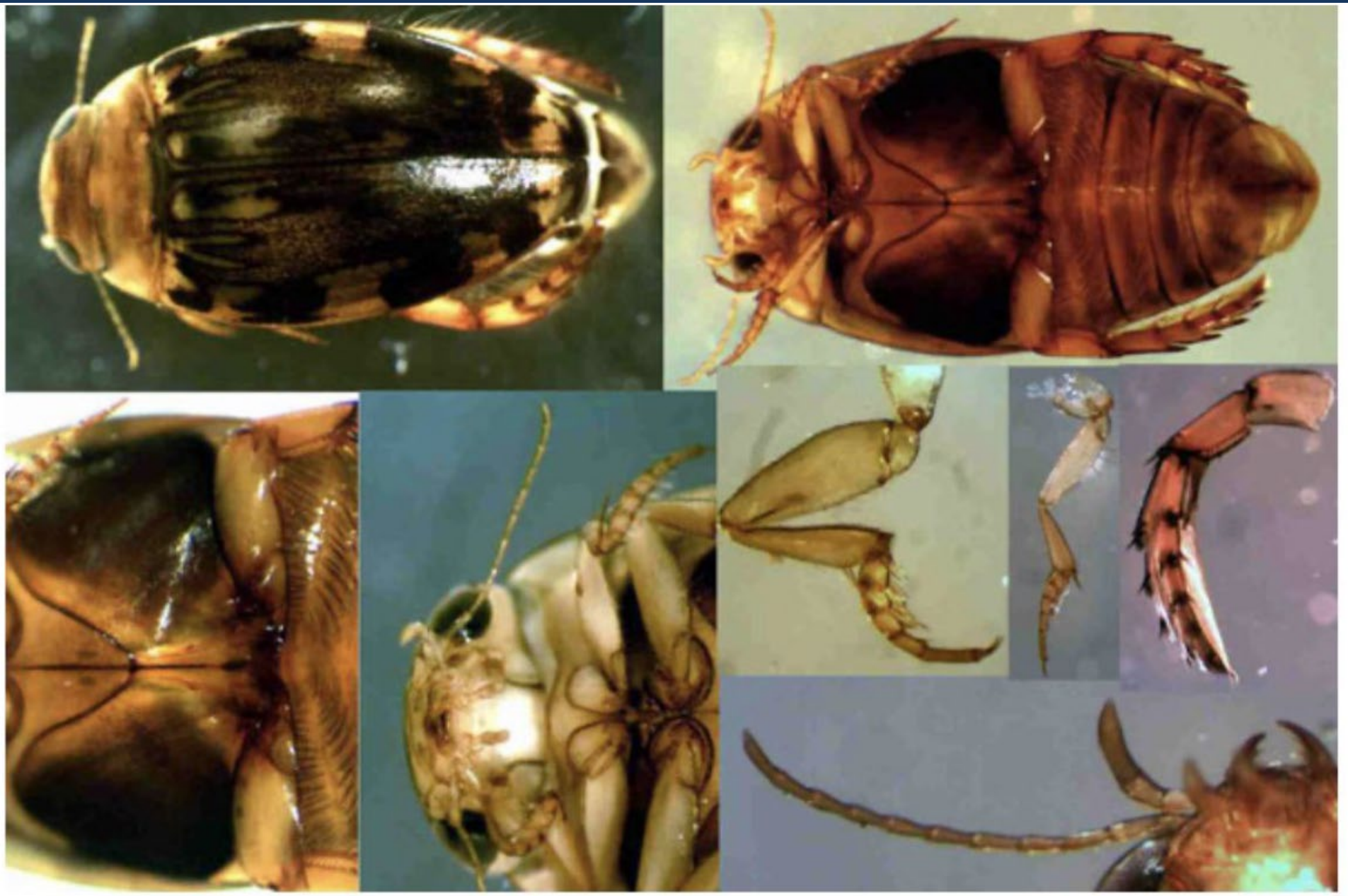


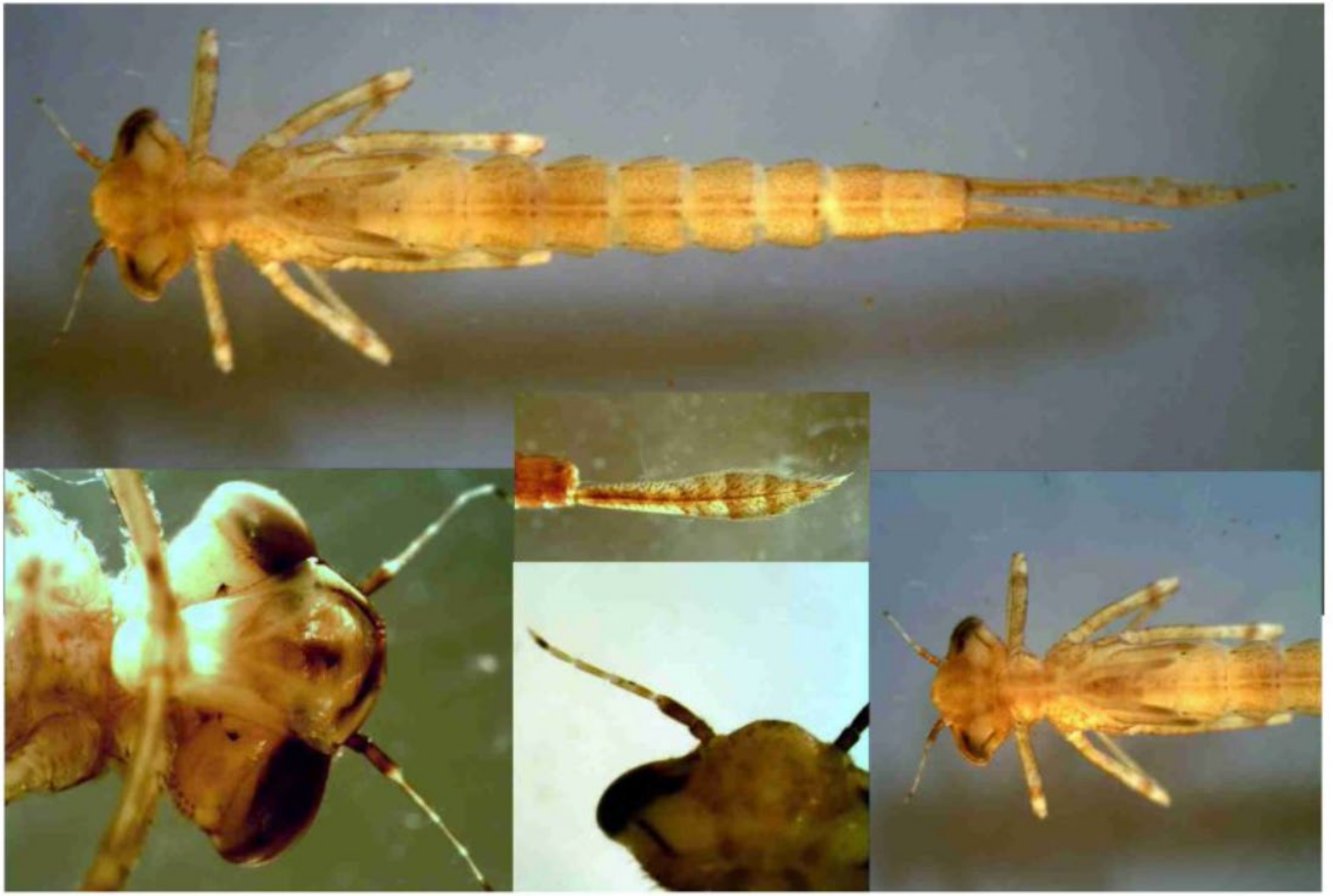
Lentic - lotic

Major freshwater ecosystems: groundwater



Hyporheic

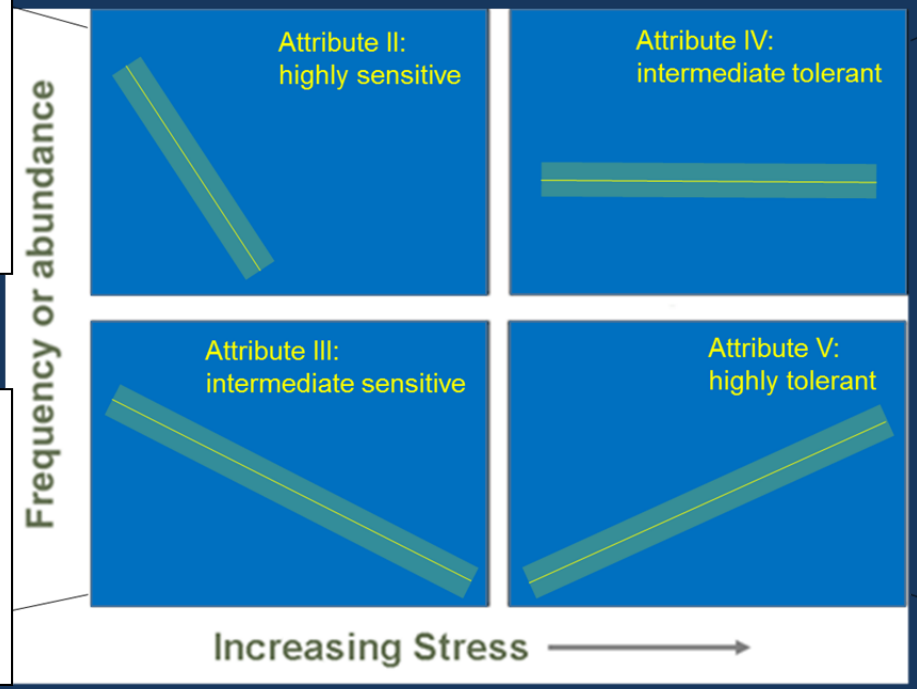




Attribute individual taxa

II Highly Sensitive: Higher relative abundance and occurrence in minimally disturbed sites, but can occur in low numbers. Might be specialists.

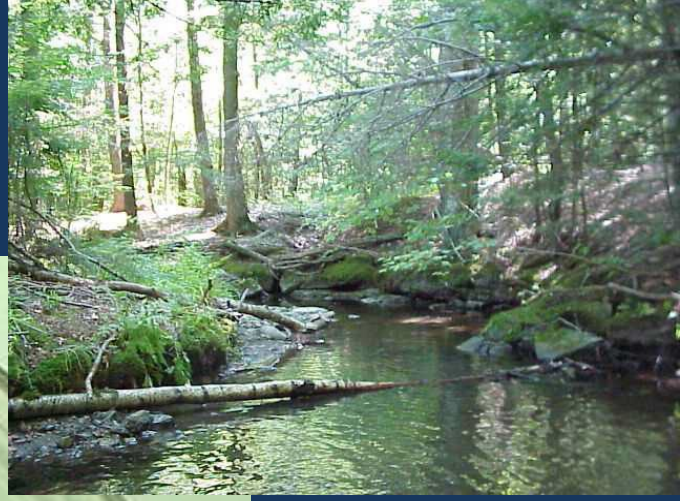
III Sensitive: Occur throughout the stressor gradient, but with higher probability in sites with less disturbance.

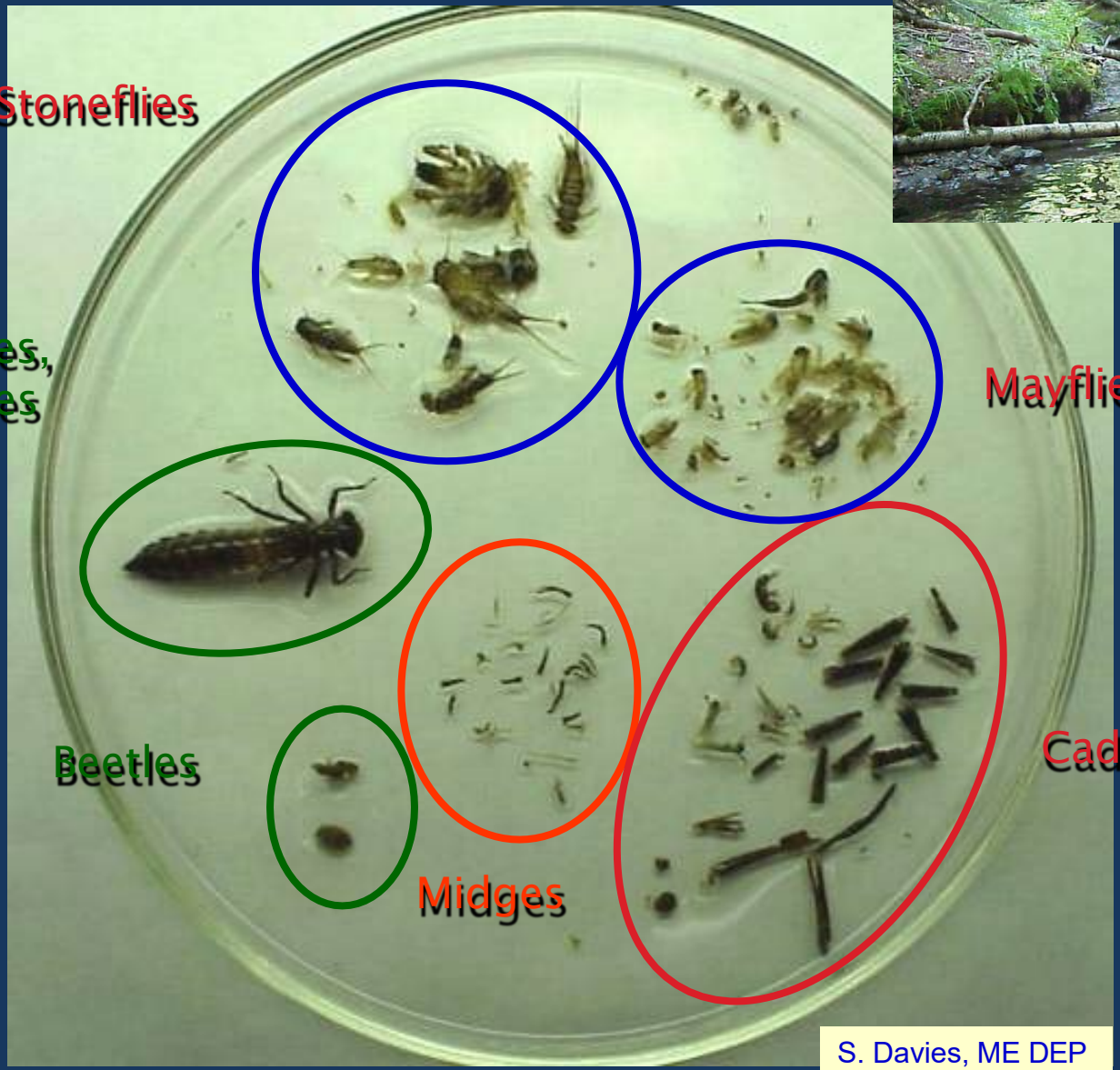


IV Intermediate Tolerant: Occur throughout the stressor gradient and with equal probability throughout, or with a central peak.

V Highly Tolerant: Occur throughout the stressor gradient, but with higher probability of occurrence and greater abundance in disturbed sites.

A Reference Community



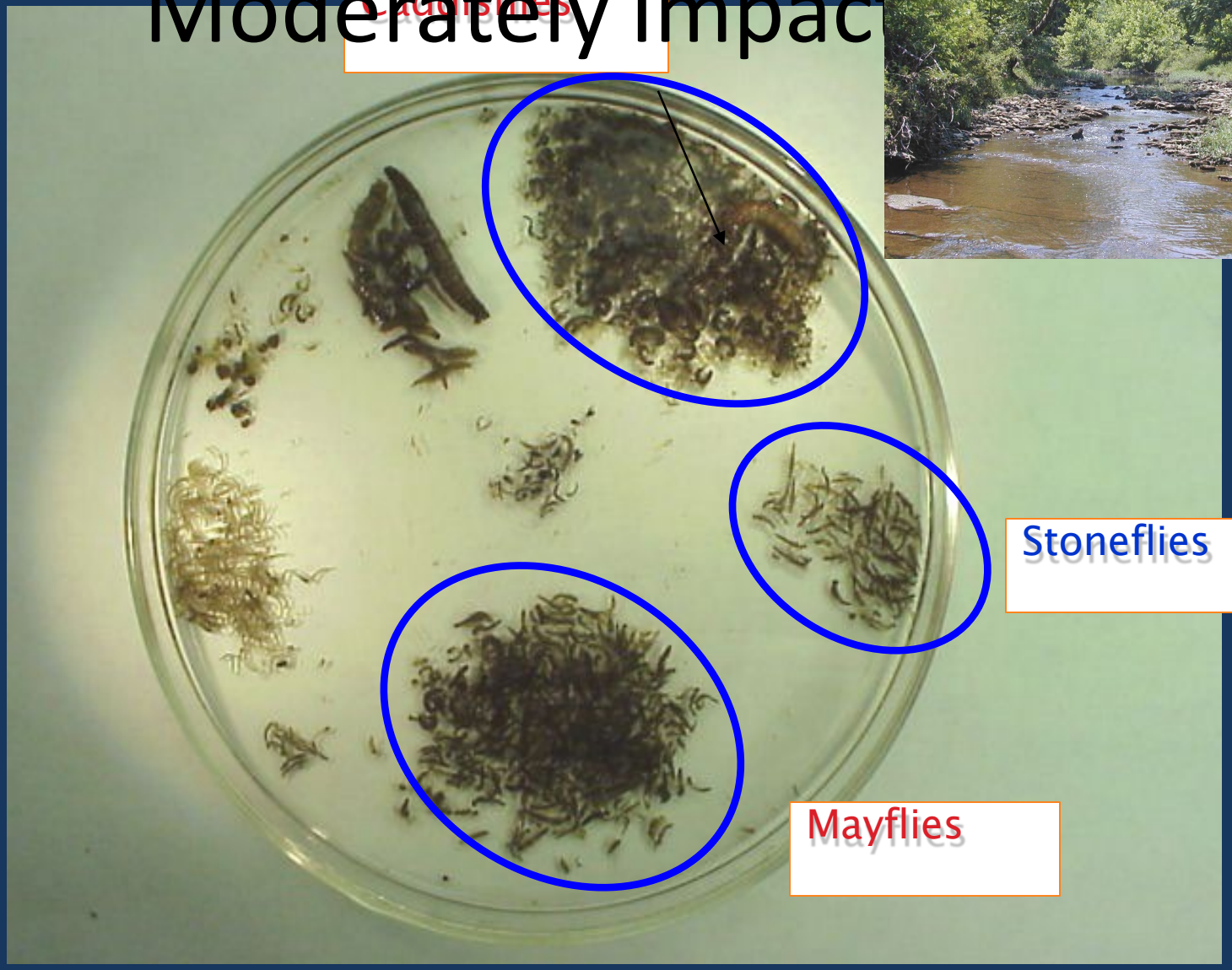


Moderately Impact

1 inch

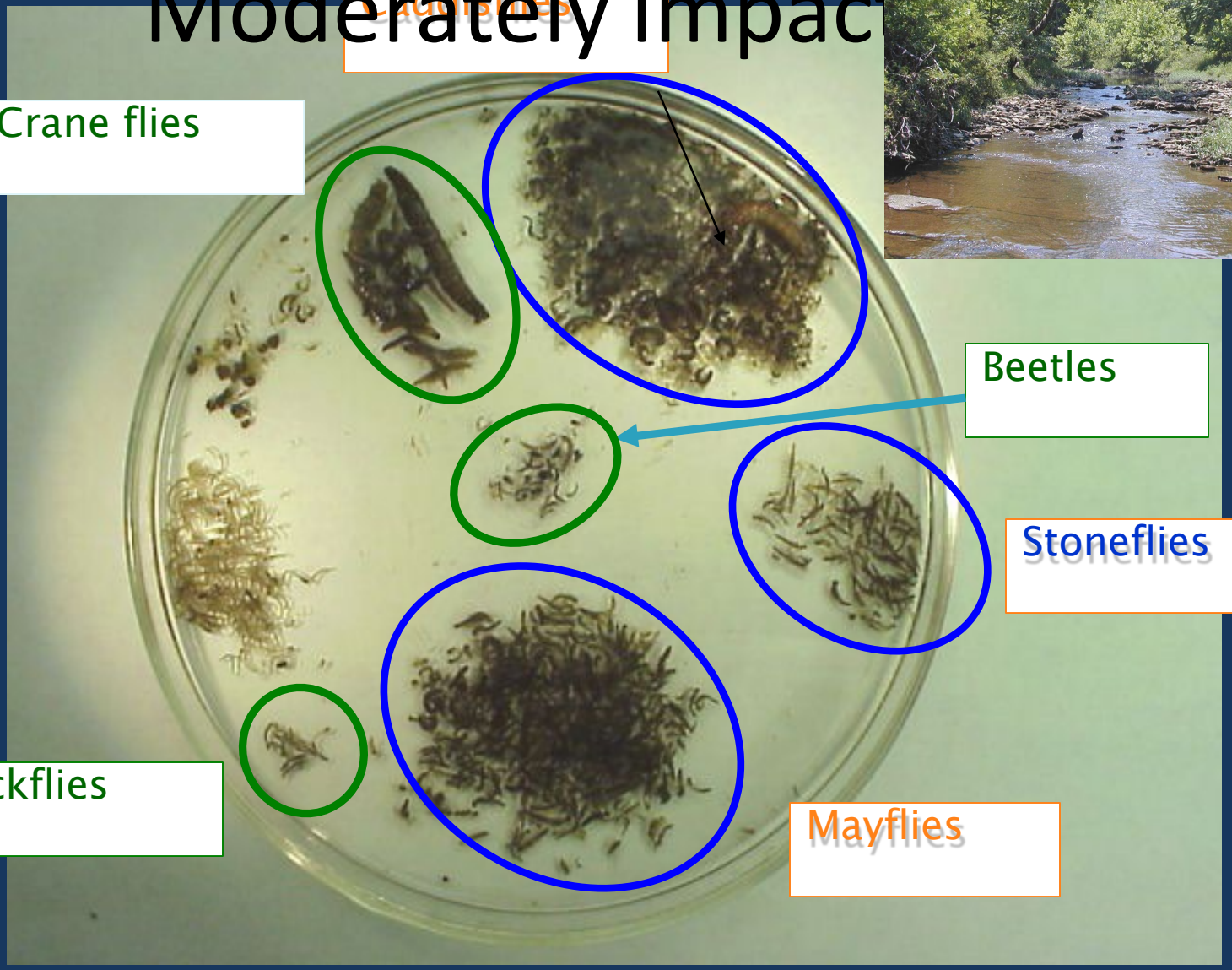
S. Davies, ME DEP

Moderately Impact



S. Davies, ME DEP

Moderately Impact



S. Davies, ME DEP

Moderately Impact

Caddisflies

Crane flies

Non-insects

Beetles

Midges

Stoneflies

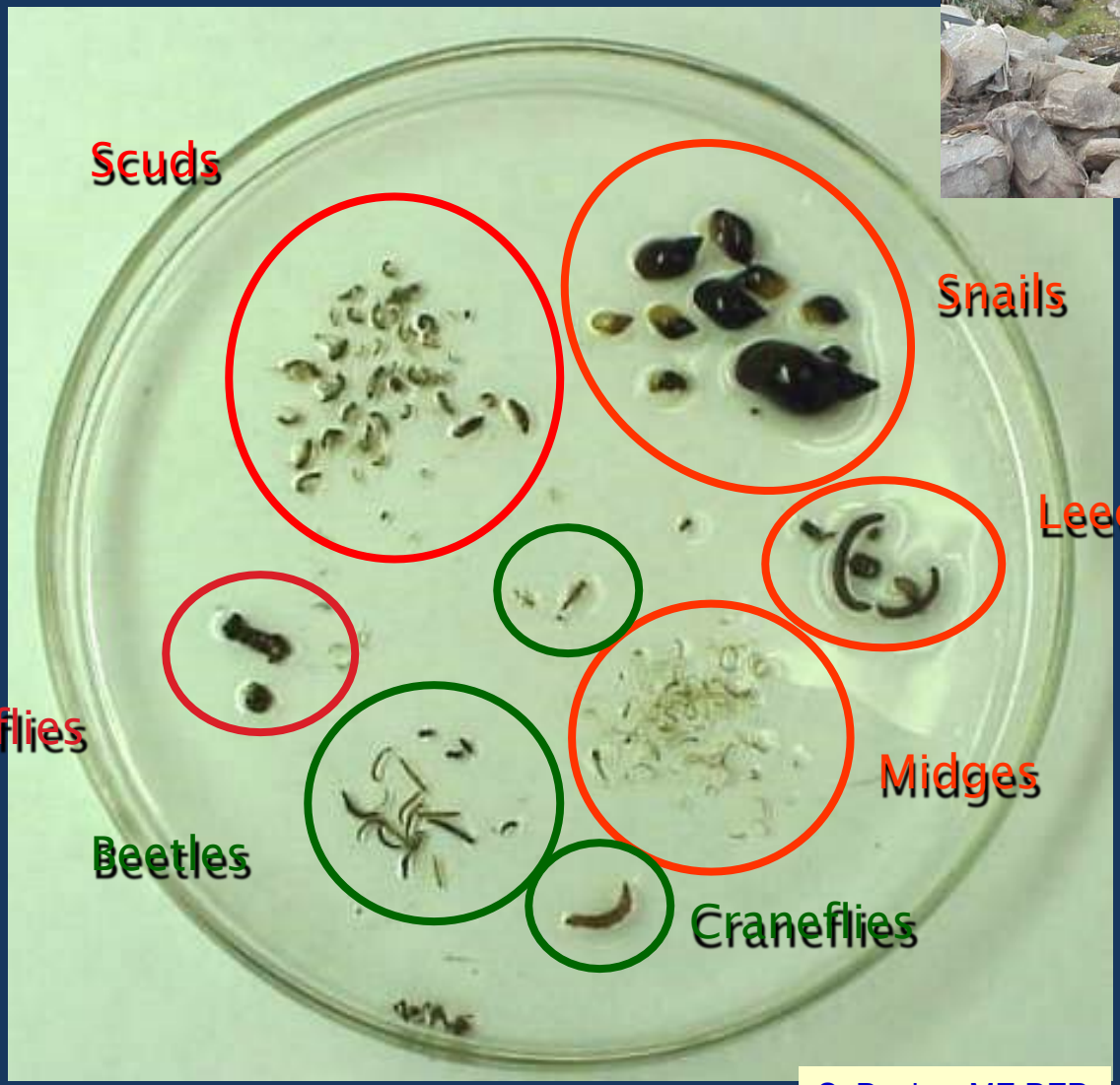
Blackflies

Mayflies

1 inch

S. Davies, ME DEP

Reference, Moderately impacted or Severely impacted?



S. Davies, ME DEP