Community and ecosystem responses to artificial night lighting across aquatic-terrestrial boundaries

Scioto River, Columbus, OH

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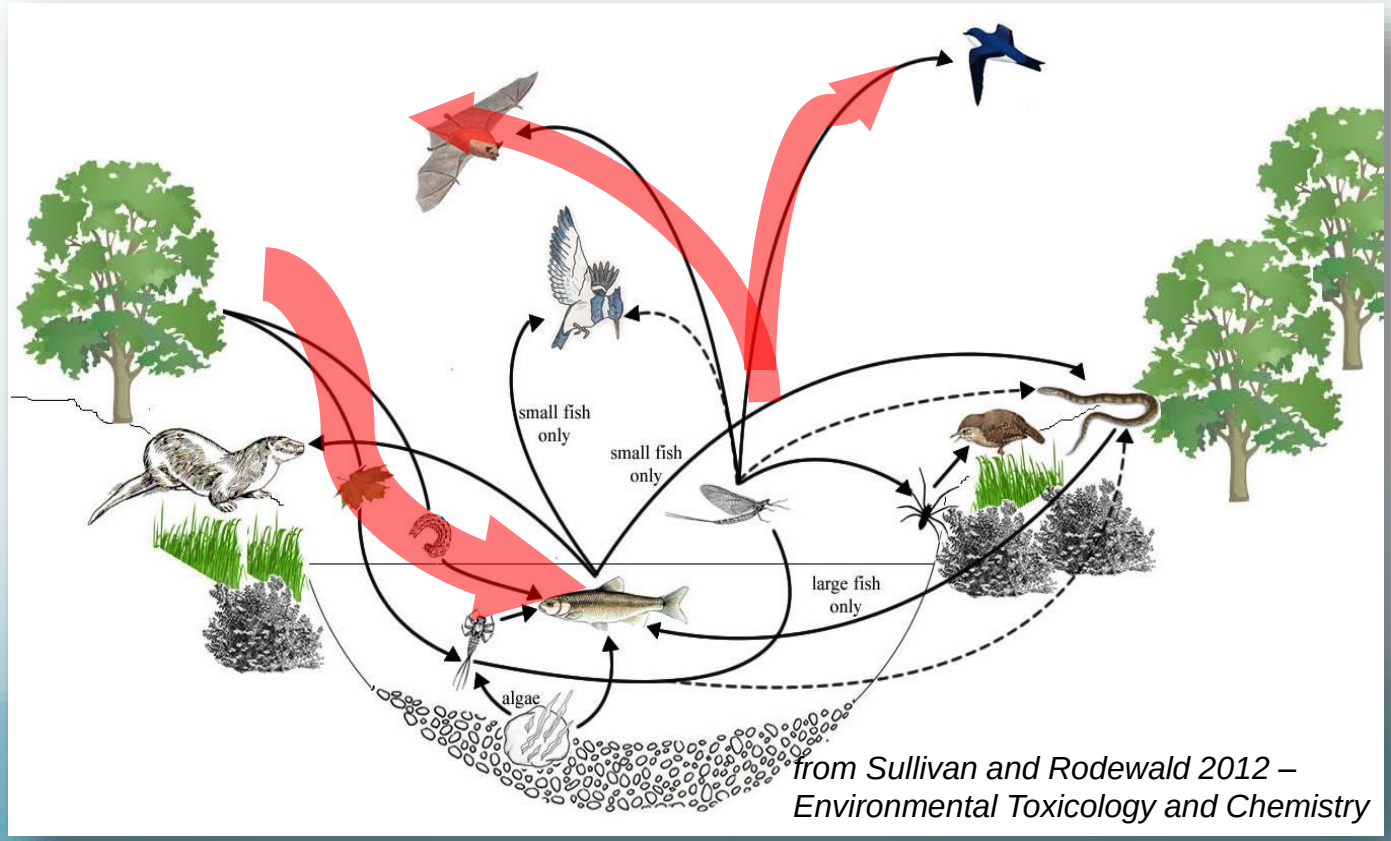
Aquatic-Riparian Food Webs

- Current paradigm remains largely unidirectional
  - nutrients and matter are transported downslope from the surrounding watershed
  - bidirectional/reciprocal nutritional subsidies, including aquatic to terrestrial



from Sullivan and Rodewald 2012 – Environmental Toxicology and Chemistry

Influences of ELP

- Light plays a fundamental role in organismal biology (i.e., as both an energy source and a source of information)
- Impacts from individuals to species (reviewed in Gaston et al. 2012).
  - animal movements, interspecific interactions, communication, foraging, reproduction, and mortality (Longcore and Rich 2004, Rich and Longcore 2006, Bruce-White and Shardlow 2011)
- For invertebrates, ELP strongly affects both terrestrial and aquatic taxa (Longcore and Rich 2004).
  - artificial night lighting can attract post-emergent aquatic insects, thereby disrupting their dispersal patterns, and in some cases serving as ecological traps leading to direct mortality (Horvath et al. 2009).
- ELP has also been shown to disrupt plant phenology
  - exposure of woody and non-woody plants to street lighting can delay or advance flowering (depending on the species), delay leaf abscission, and promote shoot growth (Matzke 1936, Kramer 1937, Cathey and Campbell 1975).

Populus balsamifera


Pluvialis squatarola


Pipistrellus kuhlii


Araneida

Community and Ecosystem Responses

- Davies et al. 2012
  - Increased relative abundance of predators and scavengers in ground-dwelling invertebrate communities under stream lights
- Becker et al. 2013
  - Altered fish communities within urban estuarine systems implicating unnatural predation

Port Alfred, SA

Study System

- Columbus, Ohio
  - City: 835,000 (15th largest in US)
  - Metro Area: 2,300,000

Streams

Lab

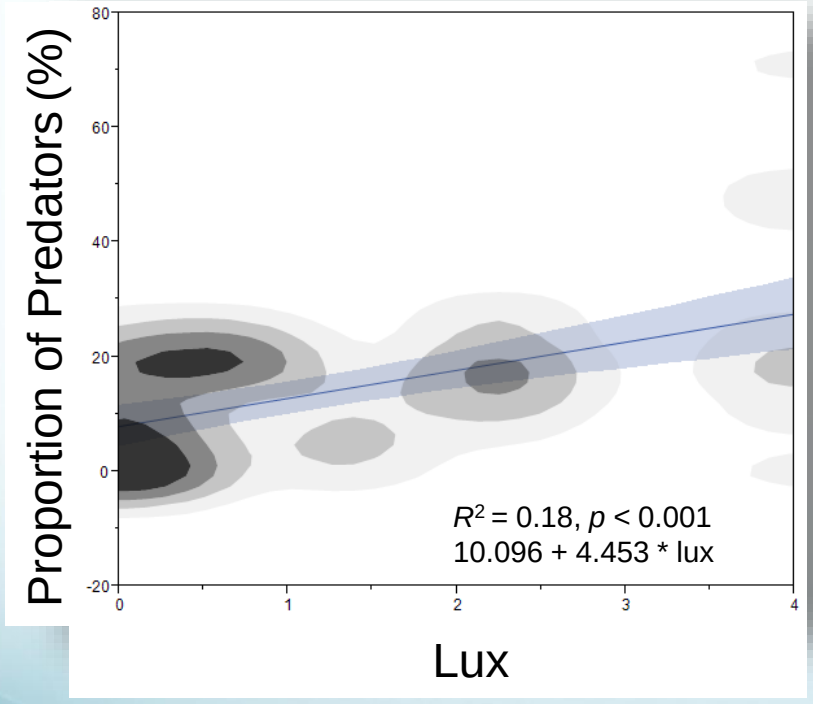
Wetland

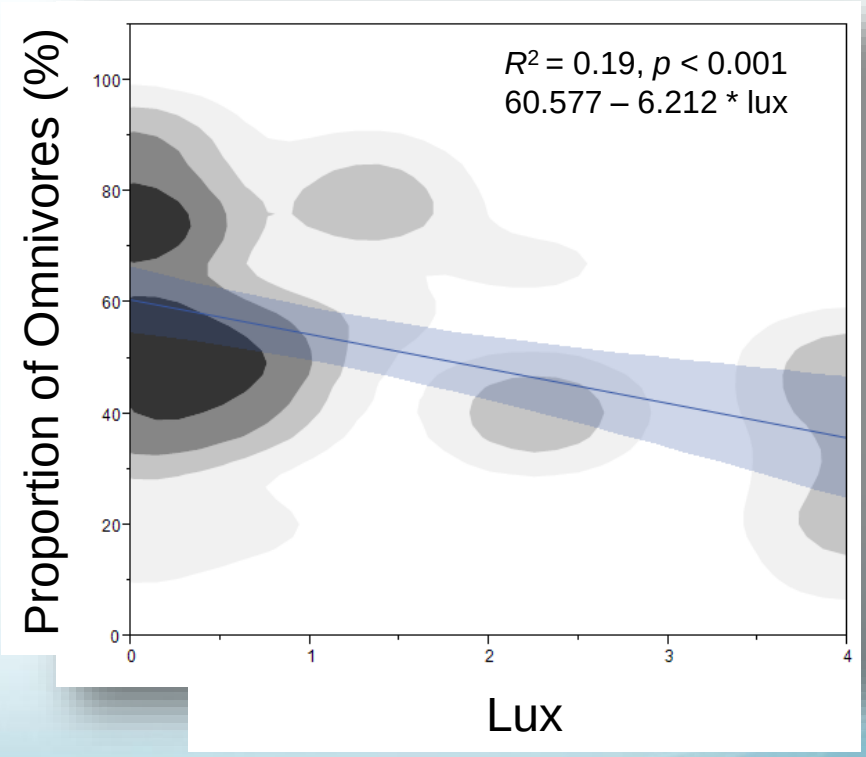
Stream-Riparian Methods

- Characterized 15 stream reaches (2011-2012) along an ELP gradient of 0.1 – 4.0 lx (riparian arthropods)
- Characterized light into three levels commonly found in area at 9 stream reaches (2010-2011) (cross-boundary fluxes)
  - Low: 0.01- 0.5 lx
  - Moderate: 0.6 – 2.0 lx
  - High: 2.1 – 4.0 lx
  - Experimentally added lighting in following year – 10-12 lx

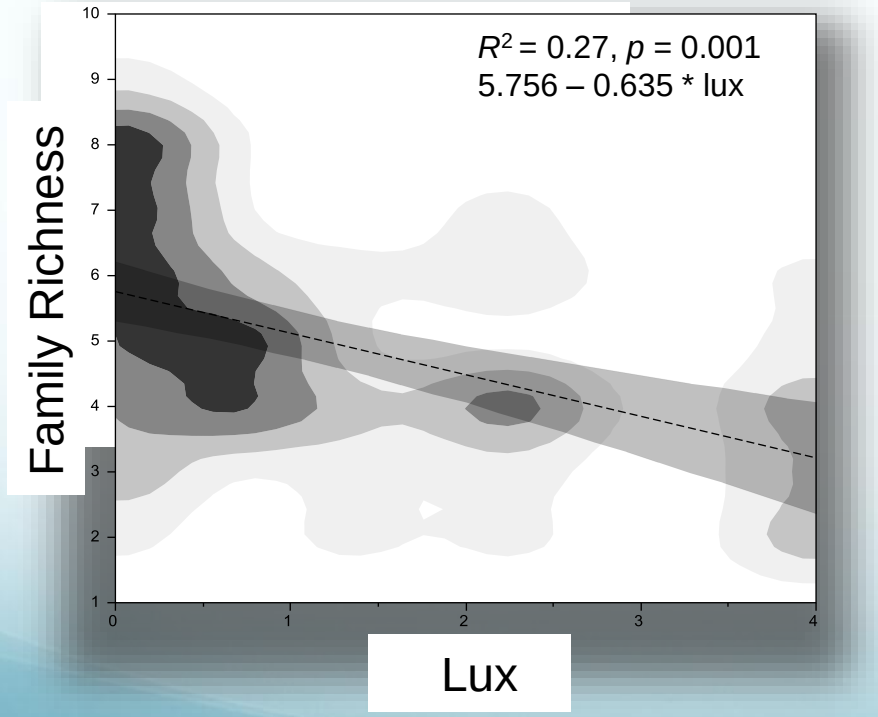
- 30-m stream reaches
  - in subwatershed of the Scioto River
  - comparable geomorphology, riparian buffers, and chemical water quality
- Maturing description of lighting environment
  - ILT1700 Photometer
  - **0.027 lx** difference
- Used ranges of lux in our study, the purpose being to compare ecological responses across **relative** low, med, and high light levels in our system.

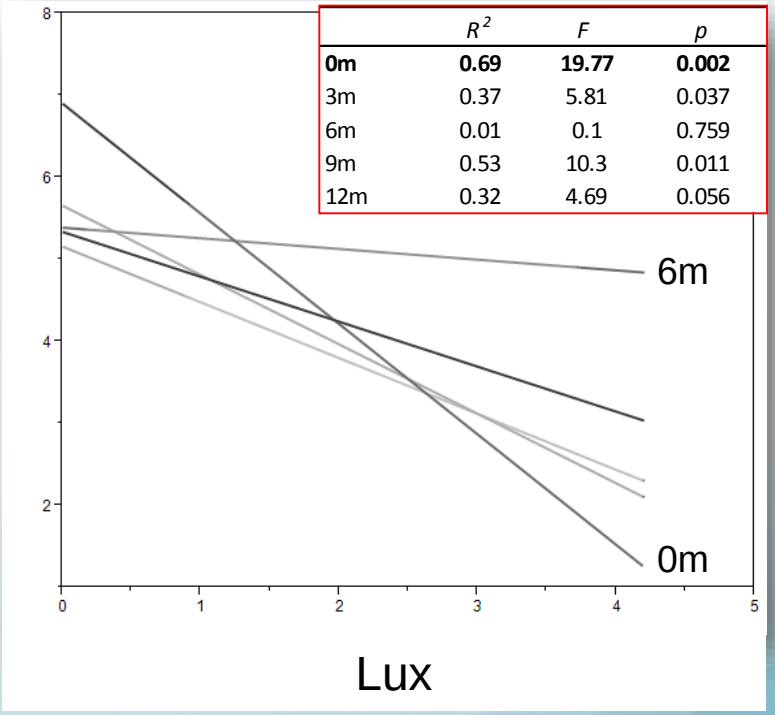
Community Responses – riparian arthropods





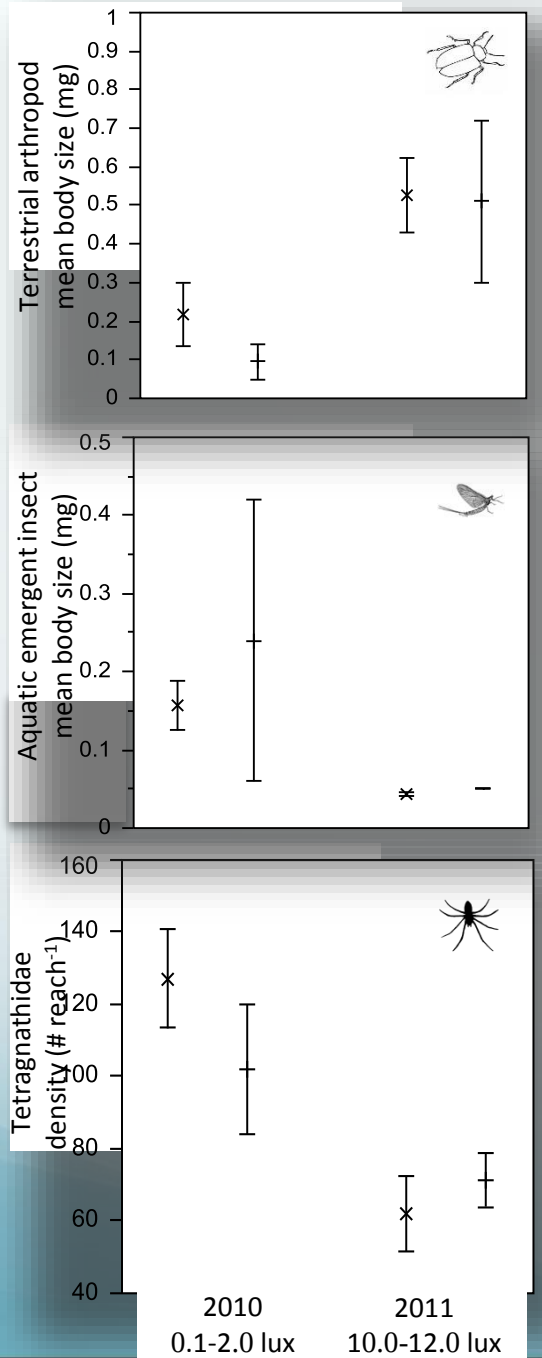
Community Responses – riparian arthropods (cont'd)



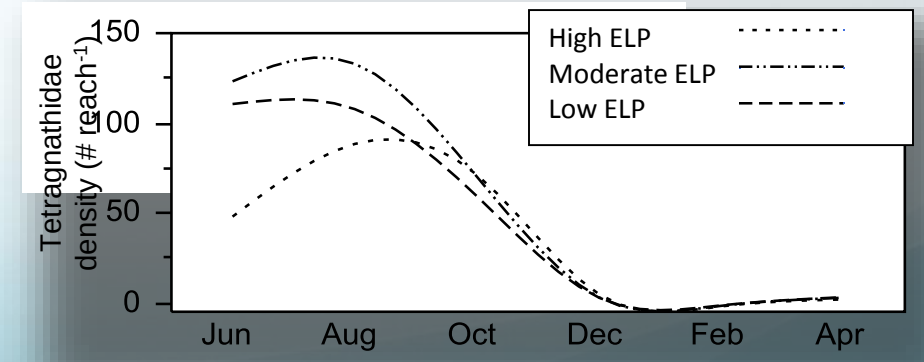


	R^2	F	p
0m	**0.69**	**19.77**	**0.002**
3m	0.37	5.81	0.037
6m	0.01	0.1	0.759
9m	0.53	10.3	0.011
12m	0.32	4.69	0.056

Community Responses – cross-boundary



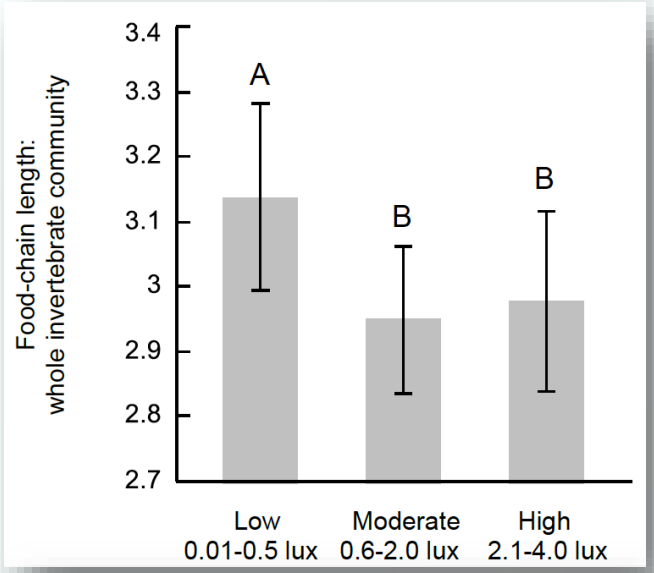
- Higher ELP levels associated with increase in the density, diversity, and body size (p = 0.015, 309%) of terrestrial arthropods entering the stream (accidentally)
- Reduction in emergent aquatic insect body size (p = 0.022, 76%) and community diversity (p = 0.040, 16%)
- Reductions in terrestrial predator density (spiders of the family Tetragnathidae; (p = 0.035, 44%)

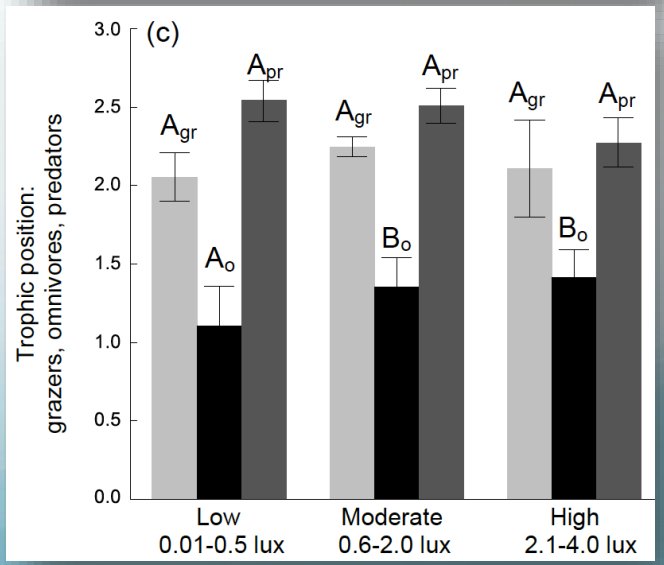


Meyer and Sullivan, Ecological Applications, 2013

Trophic Responses

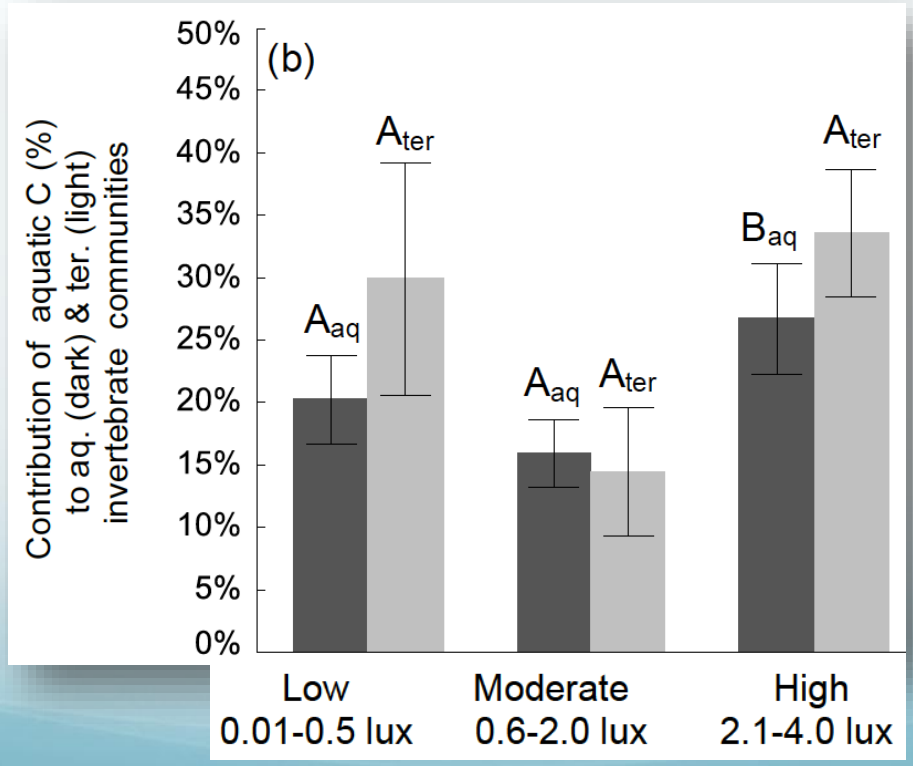
- Food-chain length
  - Central property of ecological communities that can influence structure, function, and stability
  - Tightly-linked to energy exchanges
- Increase ELP associated with reductions in FCL of entire aquatic-terrestrial invertebrate community, and increased TP of omnivores and ground-dwellers





Trophic Responses (cont'd)

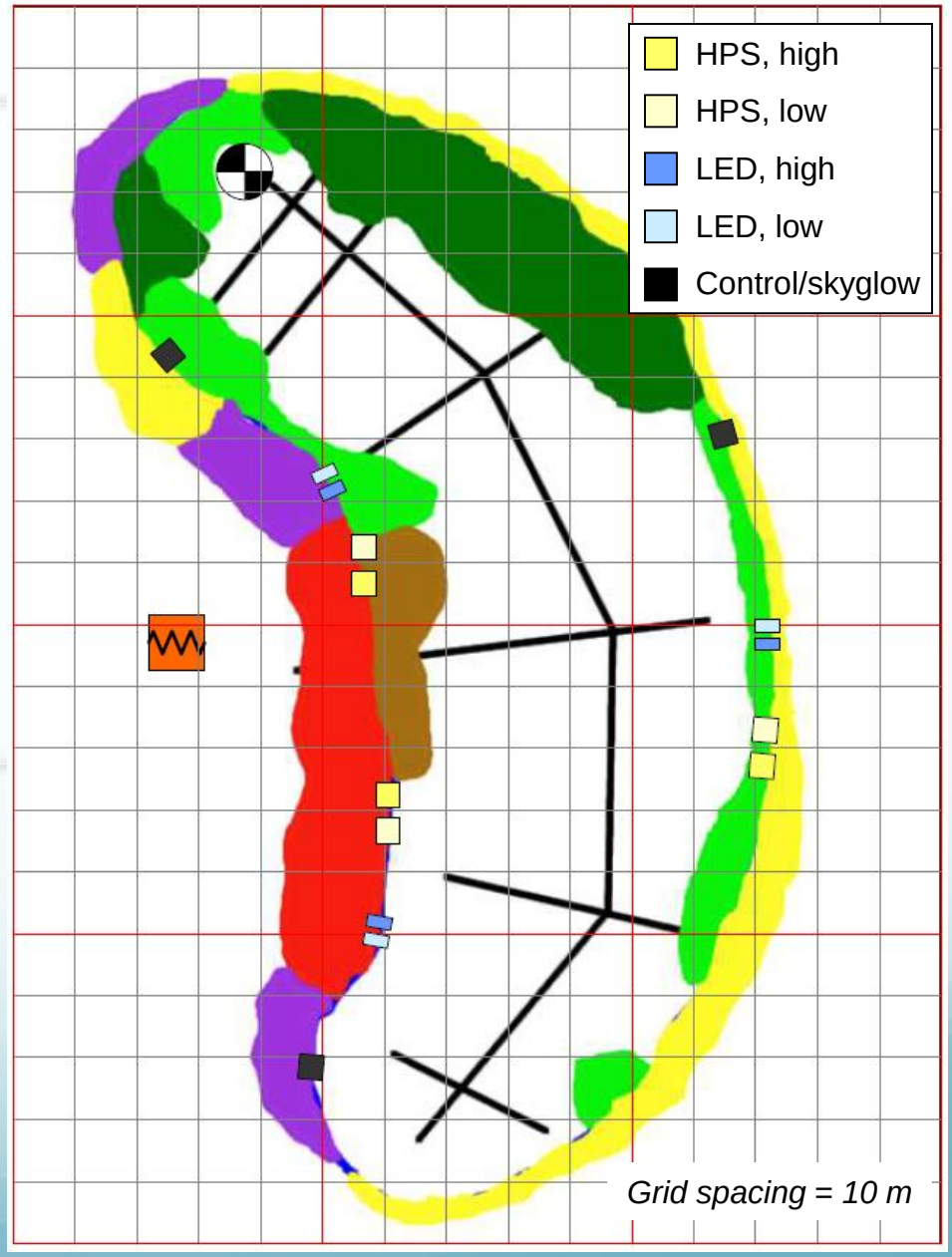
- Reliance on aquatic primary production
  - For aquatic invertebrates, increased reliance on aquatic nutritional subsidies at high light sites



Meyer and Sullivan, In prep

Olentangy River Wetland Design

- 2012-2013
- 5 lighting treatments × 3 replicates each = 15 stations
- 2 Lighting types
  - HPS, LED
- 3 Illuminance levels
  - High (~ 10 lx to 20 lx)
  - Low (~ 1 lx to 5 lx)
  - Skyglow (~ 0.1 lx)
- Lighting installed ~1 month prior to sampling
- Leaf litter collected per week over 8 weeks (Sep-Oct)
- Spider web counts weekly over 4 weeks (Sep)

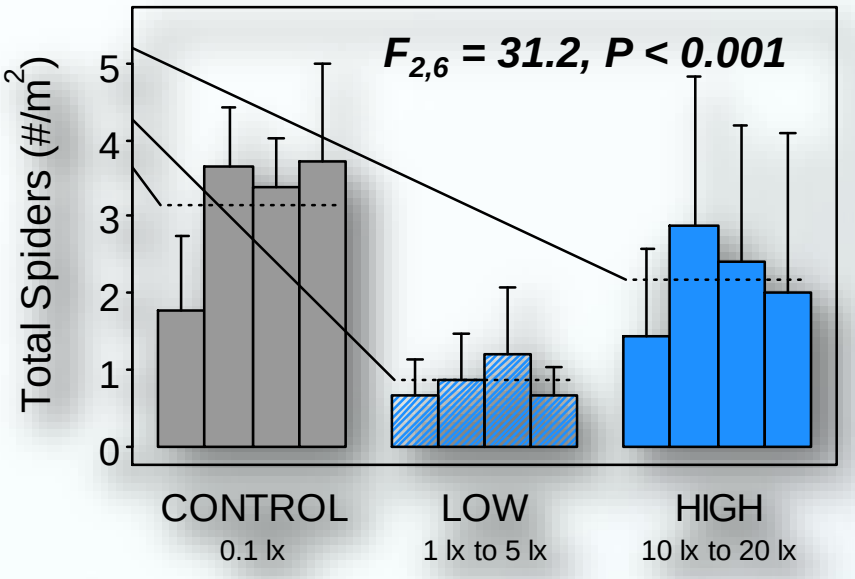


Sullivan et al, In prep

Community Responses

- Riparian spider web counts
  - 3 m transect (2 m wide × 2 m high)
  - Tetragnathidae (horizontal)
  - Araneidae (vertical)

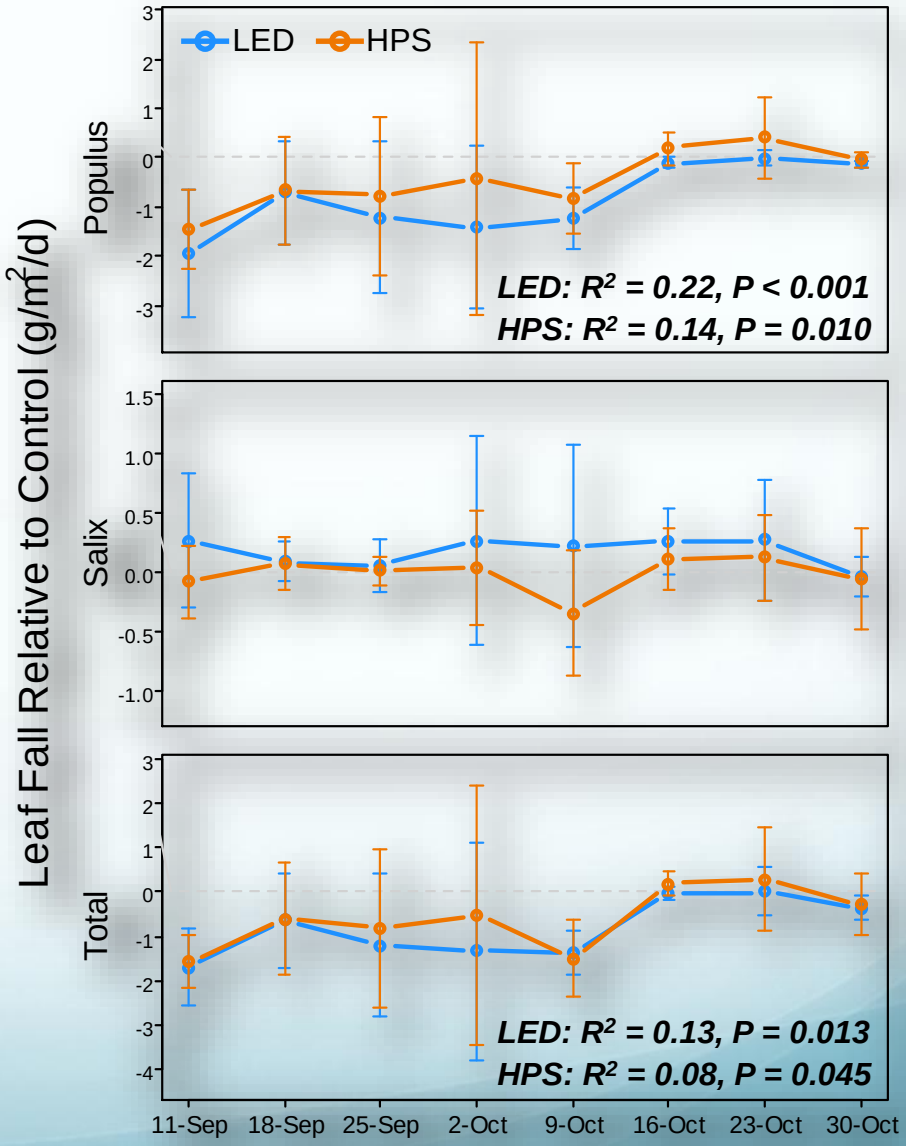
- Decrease in spider density with night lighting
  - esp. at low night light intensities
  - start to see increase at higher night lighting intensities
  - no difference in lighting type (LED vs. HPS)
  - similar responses in Araneidae and Tetragnathidae



Leaf Litter

- Leaf litter traps
  - 1.0 m × 0.7 m
  - Sorted: *Populus deltoides*, *Salix* spp., other

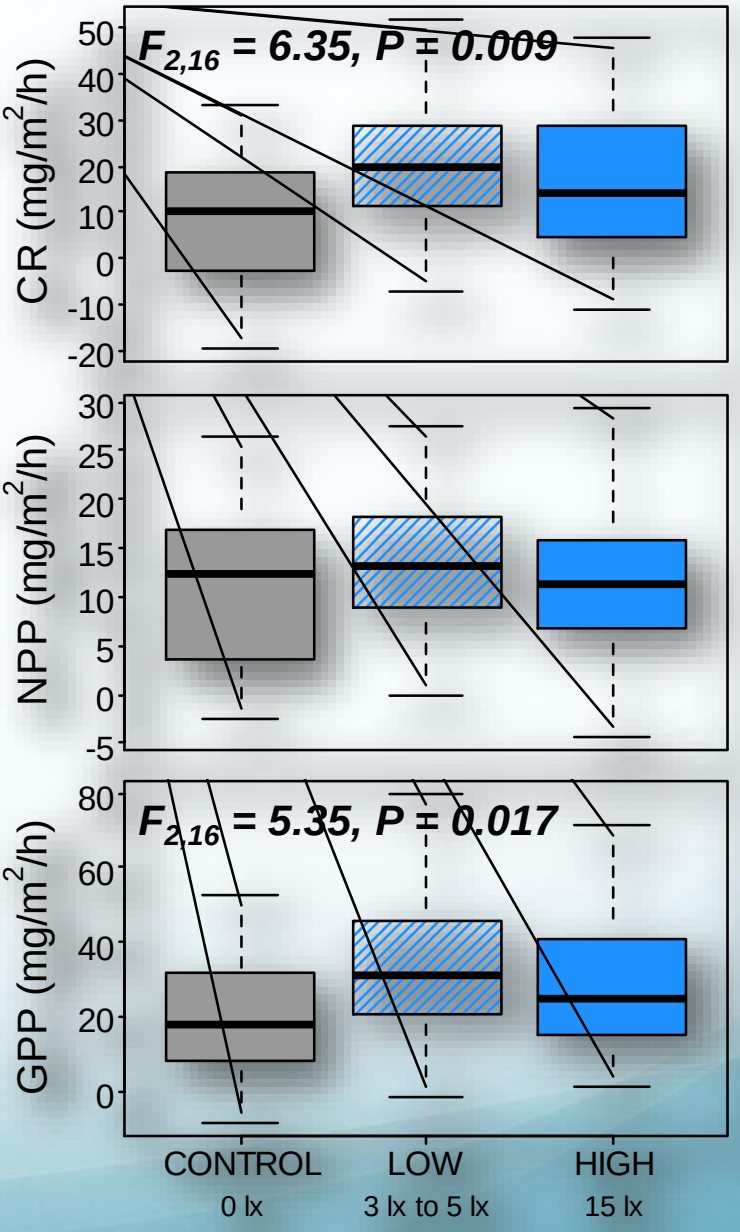
- Delay in leaf fall with night lighting
  - even at low night light intensities (no response difference for low vs. high intensity)
  - some species more sensitive (e.g., *P. deltoides*)
  - response may be stronger with LED (vs. HPS)



Laboratory Experiment – Primary Productivity

- 2014-2105
- 12 aquaria: 3 light treatments × 4 reps
  - control = 0 lx; low = 3-5 lx; high = 15 lx
  - common river diatom (*Navicula pelliculosa*)
  - 3 week establishment
- Measure productivity using DO method
  - twice weekly over 4 weeks

➢ Significant effect at low night light intensity
  - ➢ increase in CR (community respiration)
  - ➢ increase in GPP (gross primary productivity)



Implications

- ELP may act as environmental disturbance that alters food webs in linked aquatic-riparian ecosystems
  - Reduced density of riparian spiders but elevated relative abundance of other riparian invertebrate consumers
  - Shifts in trophic position and reliance on aquatic primary production
  - Reductions in emerging insect density, diversity, and body size -> changes in nutrient fluxes
  - Delayed leaf senescence and potential changes in aquatic primary productivity

- Research priorities
  - Organisms vary widely in their sensitivities to multiple properties of light including wavelength of the light relative to the spectral sensitivity of pigments and/or visual receptors of organisms, light intensity, and the orientation of light (Land and Nilsson 2002, Gaston et al. 2012).
  - Types of lighting (HPS, Metal Halide, LED, Hg vapor)
  - Target and test mechanisms

- Increased work understanding if patterns scale up

- Conservation/management
  - Policy makers should consider ways to minimize the duration, intensity, and extent of ELP in riparian areas
  - Informing the public
  - Assess lighting needs
  - Mitigation
    - Shielding
    - Timed
    - Riparian buffer zone
    - Limiting growth light installation

Acknowledgements

We extend our thanks to members of the Stream and River Ecology Laboratory.

This research was funded by The Ohio State University and MacIntyre-Stennis funds.

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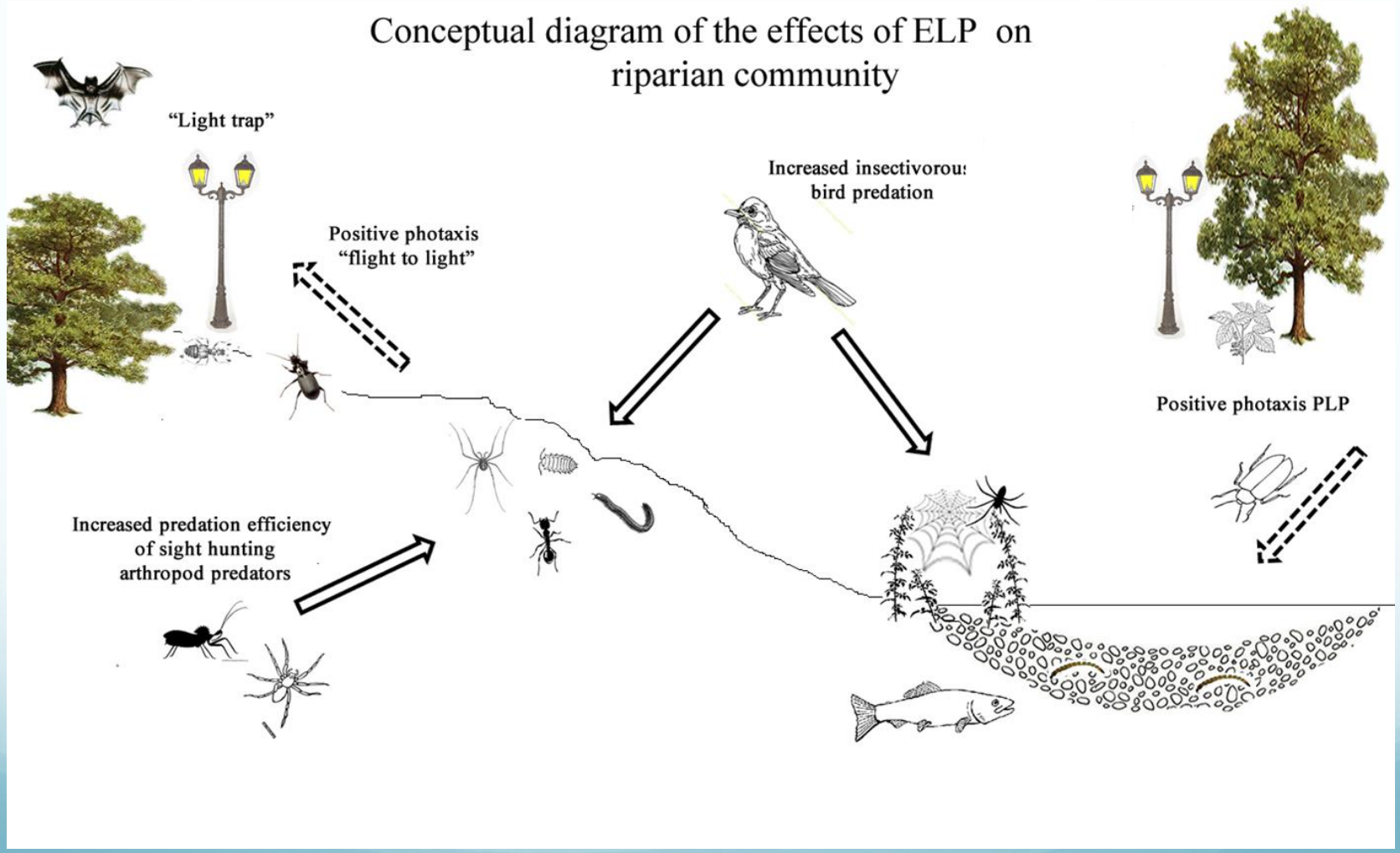
Synthesis


Conceptual diagram of the effects of ELP on riparian community
"Light trap"
Positive photaxis "flight to light"
Increased insectivorous bird predation
Positive photaxis PLP
Increased predation efficiency of sight hunting arthropod predators

Stream Methods

- Characterized 15 stream reaches along an ELP gradient of 0.1 – 4.0 lux (riparian arthropods)
- Characterized light into three levels commonly found in area at 9 stream reaches (2010-2011) (cross-boundary)
  - Low: 0.01- 0.5 lux
  - Moderate: 0.6 – 2.0 lux
  - High: 2.1 – 4.0 lux
  - Experimentally added lighting in following year – 10-12 lux
- 30-m stream reaches
  - in subwatershed of the Scioto River
  - Comparable geomorphology, riparian buffers, and chemical water quality
- Equipment
  - Extech EA #403125
  - Extech EA #33
  - ILT1700 Photometer

- Across 74 readings < 10 lux, we found **no difference between the EA 33 [6.03 lux (SD 3.48)] and the EA 403125 [5.60 lux (SD 3.18)]** (t = 0.802, p = 0.423). E
  - **no difference between the EA 403125 and the EA 33 among the lowest 24 readings in our set (all < 4 lux, which was the highest used in the current study): EA 33, 1.14 lux (SD 0.85) vs. EA 403, 1.12 lux (SD 0.83)** (t = 0.096, p = 0.924).
  - In the field, only observed a mean difference of **0.027** lux between Extech EA #403125 and ILT1700 Photometer
- Used ranges of lux in our study, the purpose being to compare ecological responses across **relative** low, med, and high light levels in our system.