Impacts of Climate Change, Human Land Use, and Mercury Contamination on Southern Appalachian Plethodontid Salamanders



Ph.D. Dissertation Defense

M. Kevin Hamed

Amphibian Declines

33% of Amphibians and **47%** of salamanders are threatened globally

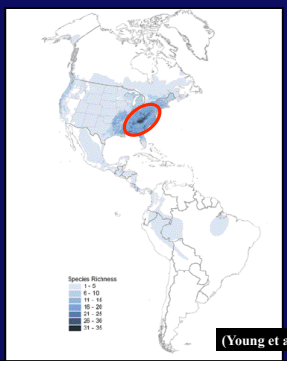
IUCN 2008

6th Mass Extinction

Wake & Vredenburg 2008

- Habitat Loss
- Over-exploitation
- Climate Change
- Chemical Contamination
- Diseases & Pathogens
- Synergistic Interactions

Center for Diversity



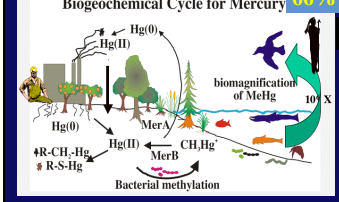
(Young et al. 2004)

Temporal & Spatial Changes of Mercury Contamination of Black-bellied Salamanders (*Desmognathus quadramaculatus)*

Mercury

6600 metric tons

Biogeochemical Cycle for Mercury



66% Anthropogenic Sources

~50% Power Plants

US emissions peaked 1970s

Effects to Humans & Wildlife:

- **Reduce reproductive success**
- **Impair neurological function**
- **Alter hormone production**

Driscoll et al. 2007

Amphibian Declines & Mercury

>

Bank et al. 2005

Eurycea bislineata

LC_{50} =103 µg/L

Ambystoma opacum

- **Decreased responsiveness & capture speed**

Burke et al. 2010

Sparling et al. 2000

Southern Appalachian Void

Temporal Changes

Museum Specimens

100 years

Berg et al. 1966

Amphibians ?

Hill et al. 2010

40 years

1910 - 1980

Fredrick et al. 2004

Other Fish Studies:
Costa et al. 2006; Kamimura 1975; Kelly et al. 1975; Gibbs et al. 1974; Barber & Cross 1972

Objectives

I. Non-lethal Sampling

II. Spatial Comparison

III. Efficiency of Museum Specimens

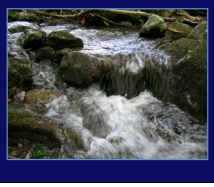
IV. Temporal Comparisons

Study Area

Whitetop Mt.
(Grayson, Smyth, Washington Co. VA)

Big Branch
- North Slope (945 – 1280 m)

Whitetop Creek
- South Slope (1158 – 1554 m)



Whitetop Mountain

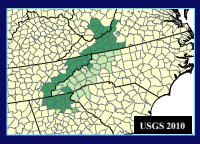
150 cm of wet precipitation

50 cm cloud water deposition

Mean pH of cloud water 3.49 (minimum 2.59)

- Fossil Fuels Major Contributor (Vong et al. 1991)

Black-bellied Salamander
Desmognathus quadramaculatus



- Largest Desmognathine salamander
- Long-lived 13+ years (Bruce 1988)
- 3.5 year aquatic larval period (Organ 1960)

Apex Predator

=

Larvae:
82% Aquatic Inverts

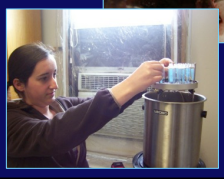
Adults:
36 % Aquatic Inverts
(Davic 1991)

22% >1 meter from stream
(Peterman et al. 2008)

Tissue Collection & Preparation

Big Branch – September 2011
Whitetop Creek – June/July 2012

Tail & Liver Samples



1865 THE UNIVERSITY OF MAINE
Sawyer Environmental Chemistry Laboratory

Freeze Dried – 48 hours

Effects of Preservation

30 salamanders – Big Branch

UM Preservation Protocol:
- 7 Days 10% Buffered Formalin
- 2 Days of Water Rinse
- 65% Ethanol

Tissue Collected at Day:
40
80
120
160

Museum Specimens

Dr. James Organ (1957-59)
Elevational Transects

UNIVERSITY OF MICHIGAN MUSEUM OF ZOOLOGY

Each specimen identified

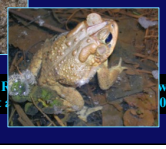
- March 2010 & June 2012
- Tail samples collected & processed

Mercury Analysis

EPA Method 7473

DMA-80 (Milestone Inc.)
- Thermal decomposition
- Amalgamation
- Atomic Absorption

(Bergeron et al. 2010)



- Water
- Soil
- Invertebrates
- Fish

Hill et al. 2010; B… 2007; Haynes et …

…well and Drenner 2009; Bergeron et al. …05; Sarica et al. 2004; Boylan et al. 1996

Mercury Analysis

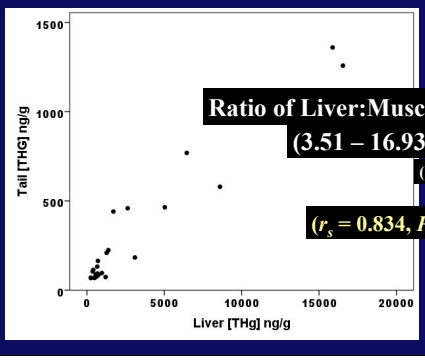
Detection Limits: 1.00 – 100.29 ng

Replicate Sample Analyses: 3.87 ± 0.34 % (n=42)

Standard Reference Material
Dogfish Muscle – National Research Council of Canada

Cell 1: 98.44 ± 0.44 % (n=42)
Cell 2: 97.39 ± 0.67 % (n=17)

Results: Non-lethal Collection

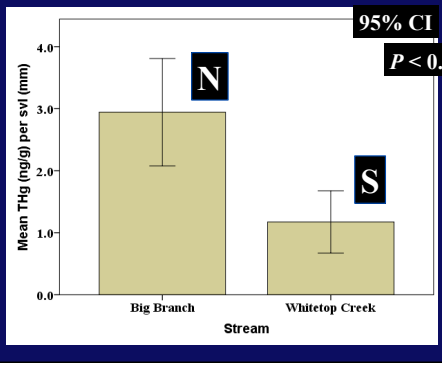


Ratio of Liver:Muscle Tissue
(3.51 – 16.93) > 1

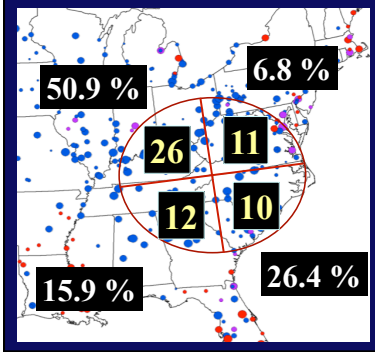
(Sorensen 1991)

(r_s = 0.834, P < 0.01)

Results: Aspect Comparison



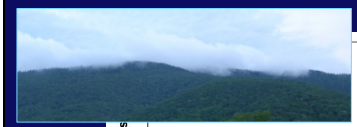
Atmospheric Deposition



EPA Station 1994-9

500-3,400 MW (EPA 2011)

Results: Elevation Comparison



Comparison to Other Sites

Tail Samples:

(Bergeron et al. 2010)

~200 ng/g Contaminated Site - VA

110 ng/g Vermont – Elevated Deposition

(Rimmer et al. 2010)

Mean: 134 ng/g (north slope only 188 ng/g)

Liver Samples:

(Ugarte et al. 2005)

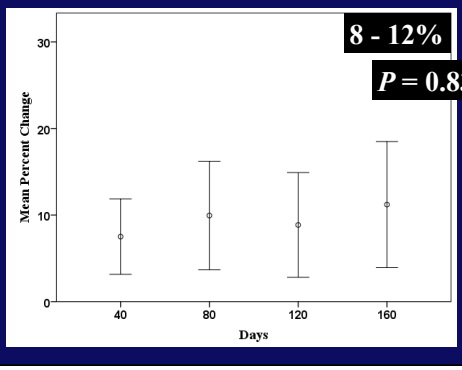
269 – 544 ng/g ww Everglades

1,228 ng/g Caddo Lake TX

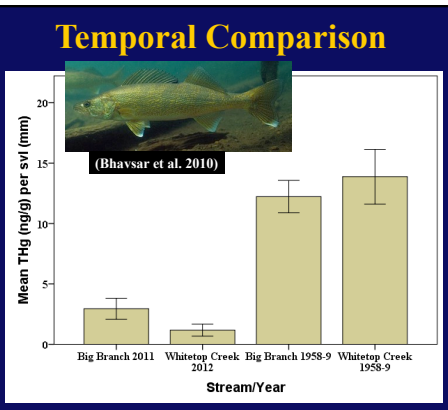
(Chumchal et al. 2011)

68 – 4,136 ng/g; Mean: 2,784 ng/g (17 – 1,034 ng/g ww)

Results: Preservation Effects



Temporal Comparison



Summary

- Tail tissue provides a valid non-lethal sampling method
- Mercury uptake in black-bellied salamanders is ongoing
- Mercury concentrations are greater on the northern slope and at higher elevations
- Museum specimens may provide an accurate measurement of historical mercury contamination
- Mercury concentrations in black-bellied salamanders have decreased since the 1950s on Whitetop Mt.

Changes in Salamanders Distributions Along an Elevational Gradient In the Mt. Rogers National Recreation Area

Climate Change

- 2003 – 2012 warmest on record — NOAA 2012
- Past 50-years > of past 1300 — 1.06 °C since 1880 — IPCC 2007

Shifting Range Limits:

- Plants
- Invertebrates
- Fish
- Amphibians
- Reptiles
- Birds
- Mammals

- 41% have shifted
- 6.1 km per decade

Parmesan 2006

Tingley et al. 2012

~ 50% ↑

Comte and Grenouillet 2013 ; Kopp and Cleland 2013; Tingley and Beissinger 2013; Chen et al. 2011; Sinervo et al. 2010; Rovito et al. 2009; Moritz et al. 2008

Amphibian & Climate Change

Yellowstone NP

Lithobates luteiventris

Patala et al. 2009

Costa Rica

Bufo periglenes

Atelopus sp.

Pounds et al. 2004

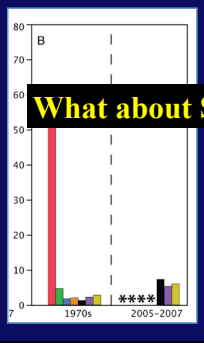
Indirect Effects:

- 64% Breeding earlier (up to 59 days)
- Increased competition

Yiming et al. 2013

Salamanders & Climate Change

(Rovito et al. 2008)



What about Southern Appalachia?

Historic Salamander Dataset

Dr. James & Della Organ

- Mt. Rogers National Recreation Area
- Elevational Transects (914 – 1707 m)
- Sampling intervals 30.5 m (100')
- 1957-59 & 1990-91

Organ 1960, 1990, 1991

Objectives

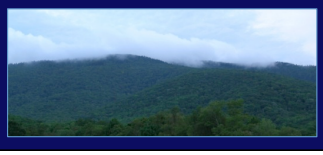
I. Document salamander distribution changes since the 1950s & 1990s

II. Examine regional weather patterns to determine potential impact

Study Area

Beech Mt.
945 – 1494 m
Bluff Mt.
1097 – 1490 m
Whitetop Mt.
1158 – 1676 m

(Grayson, Smyth, Washington Co. VA)

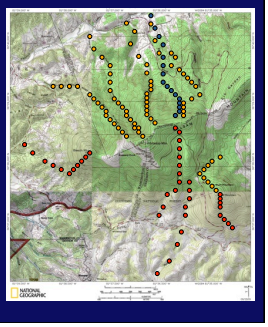


15 Plethodontid salamander species

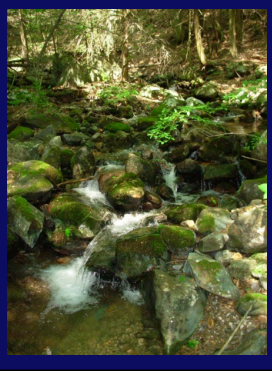
Sampling

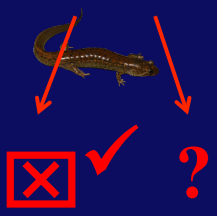
10 transects (2008 – 2011)

Whitetop Ck & Dells Br.
2009 - 2011



Detection





Detection/Occupancy Modeling

Imperfect detection leads to false range changes

Overestimate extinctions by 56% Kery 2006

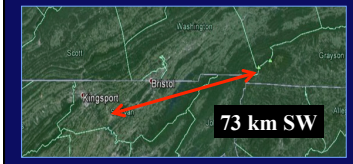
Necessary for historical comparisons

Moritz et al. 2008; Tingley and Beissinger 2009

- Modeled current detection and applied to historical data Tingley and Beissinger 2009
- Modeled occupancy corrected for imperfect detection

Regional Climate

- Absence of Whitetop historic climate data
- NOAA since 1948



Results: Distribution Changes

Mean Midpoint Changes: **Median:**

1950s = 7.6 m (1.5 m / decade) = 15.2 m (3.0 m)

1990s = 9.6 m (4.9 m / decade) = 0 m

Meta-analysis 11.9 m Chen et al. 2011

Moths (Boreno) 15.9 m Chen et al. 2009

Fish (France) 13.9 m Comte and Grenouillet 2013

Herpetofauna (Madagascar) 15 – 51 m Raxworthy et al. 2008

Southern Appalachians

Plants 24 m Lenori et al. 2008

Stoneflies 29 m Sheldon 2012

Results: Distribution Changes

Lower Range Limits

1950s: 16.7% ↓, 25.0% ↑

1990s: 16.7% ↓, 8.3% ↑

↑ 25% Small Mammals
↓ 25 % Rowe et al. 2010

Upper Range Limits

1950s: 8.3% ↓, 41.7% ↑

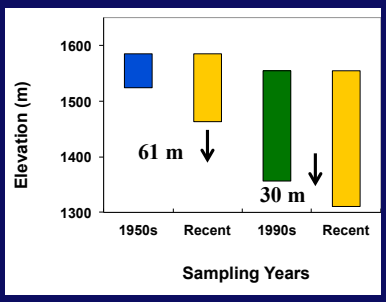
1990s: 0.0% ↓, 41.7% ↑

↑ 50% Birds Tingley et al. 2012

↑ 13.3% Small Mammals
↓ 26.7 % Rowe et al. 2010

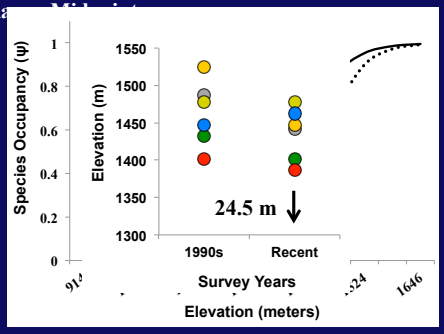
Weller's salamander

Median Range Limit Changes



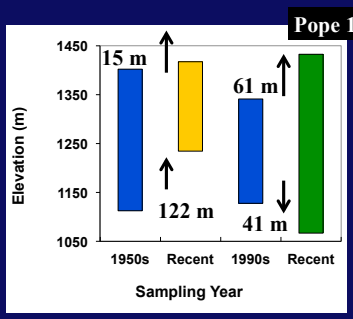
Weller's salamander

Ra



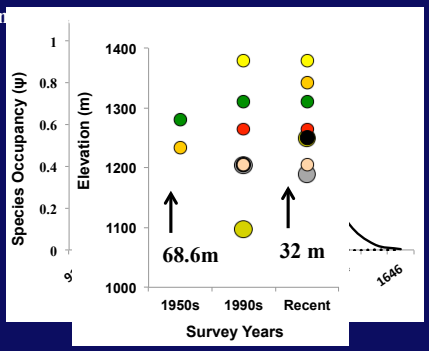
Yonahlossee salamander

Median Range Limit Changes



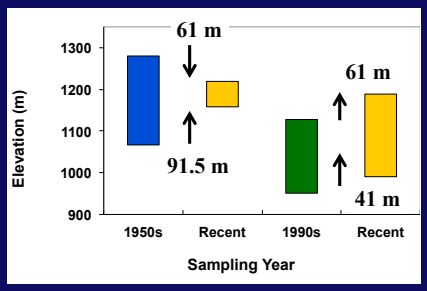
Yonahlossee salamander

Ran



Slimy salamander

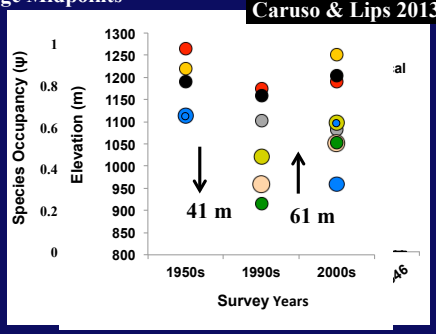
Median Range Limit Changes



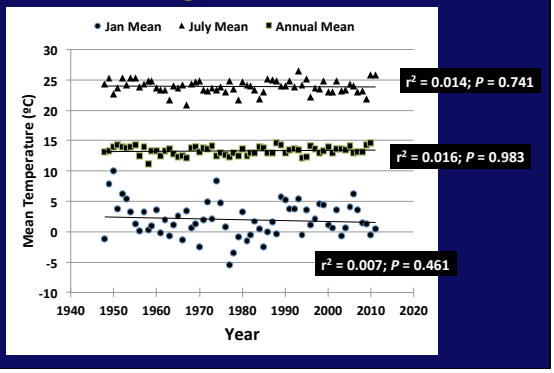
Slimy salamander

Range Midpoints

Caruso & Lips 2013



Regional Climate



Summary

- Lack of consistent elevation midpoint, upper limits, and lower limit changes
- *Plethodon welleri* shifted downslope
- *Plethodon yonahlossee* expanded upslope
- *Plethodon cylindraceus* constricted its range limits
- Regional climate did not indicate changes

Impact of Powerline Right-of-Way Mowing on Four-toed Salamander (*Hemidactylium scutatum*) Nesting and Larval Survival



Amphibian Declines & Habitat Loss

90% of IUCN listed Amphibians

14 million

Petranka et al. 1993

Lithobates draytonii

Davidson et al. 2002

Effects of canopy loss:

- Barriers for juvenile dispersal
- Desiccation and mortality
- Reduced abundances

Semlitsch et al. 2009

Habitat Loss & Right-of-Ways

2.8 million hectares of ROWs

~11,000 miles²

Mechanical mowing

Negative impacts to other species of he

Salamanders?

> 2,500

Gopherus polyphemus

Wetland Mitigation Sites

New Regulations

August 2003

September 2013

Federal Energy Regulatory Commission (FERC)

- Utility will face significant fines
- Recommend clearing beyond minimum

Objectives

I. Impact on Nesting

II. Female Site Fidelity

III. Impact on Larval Development

IV. Time Needed for Recovery

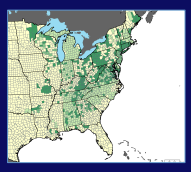
Study Area

TVA
South Holston River
Weir Dam
(Sullivan Co., TN)

- Floodplain Forest
- 3 Utility Transmission Line
- ROWs mechanical mowed every 5 years

August 2007 & 2012

Four-toed Salamander
Hemidactylium scutatum



- "In Need of Management"
- Species of Greatest Conservation Need – Tier 1

Pool Breeding Plethodontid

Shallow moss lined temporary pools

Females guard eggs

Larvae fall into pools after hatching

(Bruce 1988)

Nesting Parameters & Site Fidelity

Located nests March/April 2007 - 2012

- Number of eggs
- Female SVL & TL
- Noted female absence

Photographed female ventral surface

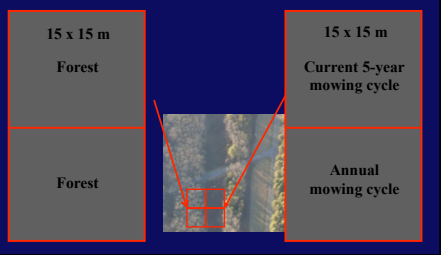
Harris & Ludwig 2004

Nesting Success

1-L buckets below nests caught hatchlings

Larval Success

- Larval period
- Survival rates
- Size at metamorphosis



ROW Mowing

August 2010
3 summers of growth

August 2011
4 summers of growth

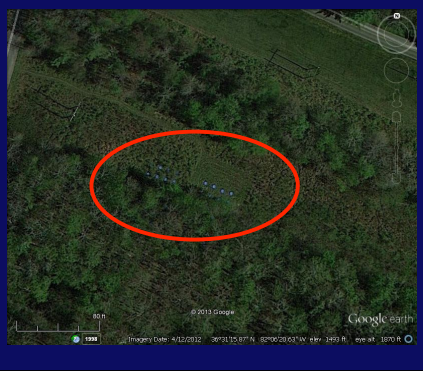
August 2009
2 summers of growth

Mesocosm Pools

5-y
Mo

An
Mo

Mesocosm Pools



Mesocosm Pools

Added
- 10 larvae
- 100 g leaf litter
- 2 g rabbit chow
- 1 l zooplankton

Water temperatures

Pools searched weekly

Weight, SVL, & TL

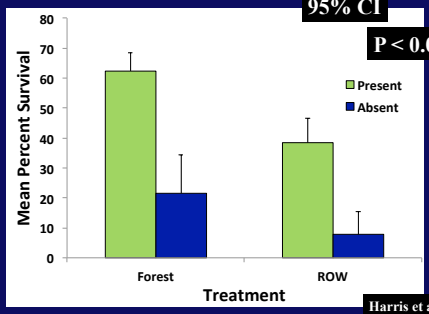
NPP = measured DO

Earl & Semlitsch 2012

Results – Nesting Success

95% CI

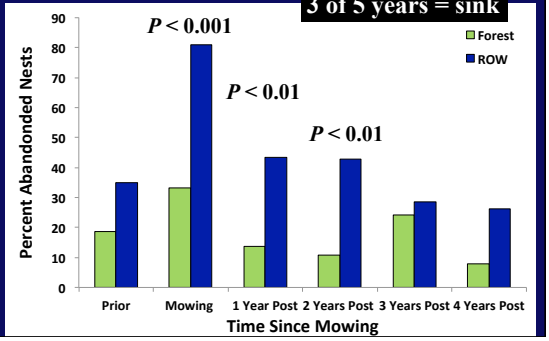
P < 0.001



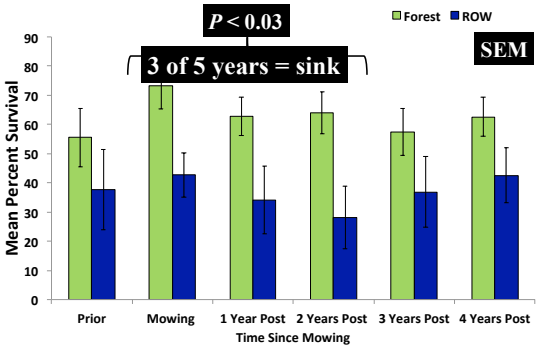
Harris et al. 1995

Results – Nesting Success

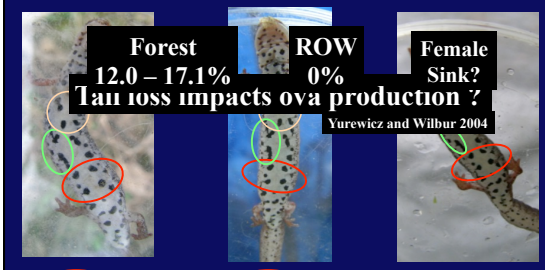
3 of 5 years = sink



Results – Nesting Success



Results – Nesting Site Fidelity



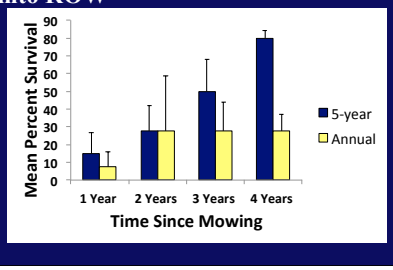
Results – Larvae

Reduced survival 9 m into ROW for 1 & 2 years

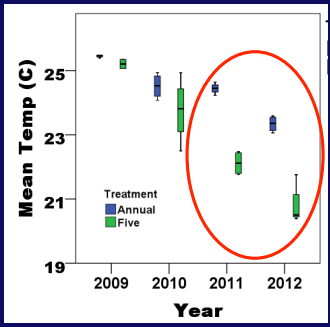
6 m for 1 year PM

2/5 years sink

9 m into ROW



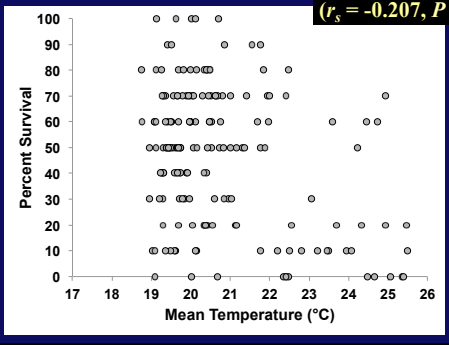
Results – Temperatures



Vegetation cooled pools 3 years PM

9 m & 6 m into ROW warmer

Results – Larvae



Results – Metamorphs

Smaller metamorphs (TL) 9 m into ROW from the AT

2-years $P < 0.03$
4 -years $P < 0.02$

Smaller size : Decreased survivorship and adult fitness

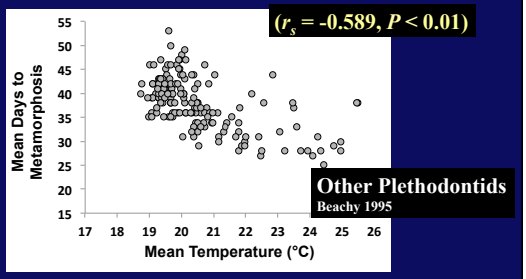
Semlitsch et al. 1988
Scott et al. 2007

Wilbur-Collins Model 1973

Unfavorable conditions:
- Smaller
- Reduced time to metamorphosis

Results – Larvae

Quicker metamorphosis 6 & 9 m into ROW in both treatments



Summary

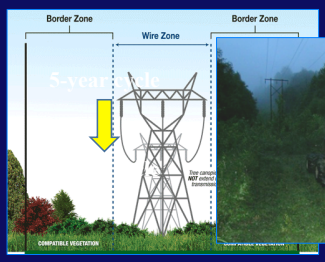
- Impacts of ROW Mowing last for at least 3 years of the 5- year mowing cycle
- ROW nests are abandoned significantly more than forest nests for 3 years PM
- Females nesting in the ROW appear to not return for future nesting attempts
- Embryonic survival is significantly less in ROW for 3 of 5 years

Summary

- Larval survival was significantly reduced 9 & 6 m into the ROW, but improved 3 years PM
- Larvae metamorphosed significantly smaller 9 m into the ROW within the AT
- Larvae metamorphosed significantly quicker 9 & 6 m into the ROW
- Time to metamorphosis was negatively related to temperatures

Management Recommendation

Integrated Vegetation Management (IVM)



Yahner et al. 2001

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Questions