Dragonfly Migration

Continental-scale Movement with a Climate-driven Pulse

John H. Matthews ° 2 August 2008

Global Climate Change Program • WWF-UK & WWF-US

Do Dragonflies Migrate South in Fall?

with Jay Banner, Tom Juenger, Larry Mack, & Len Wassenaar

What Is Migration?

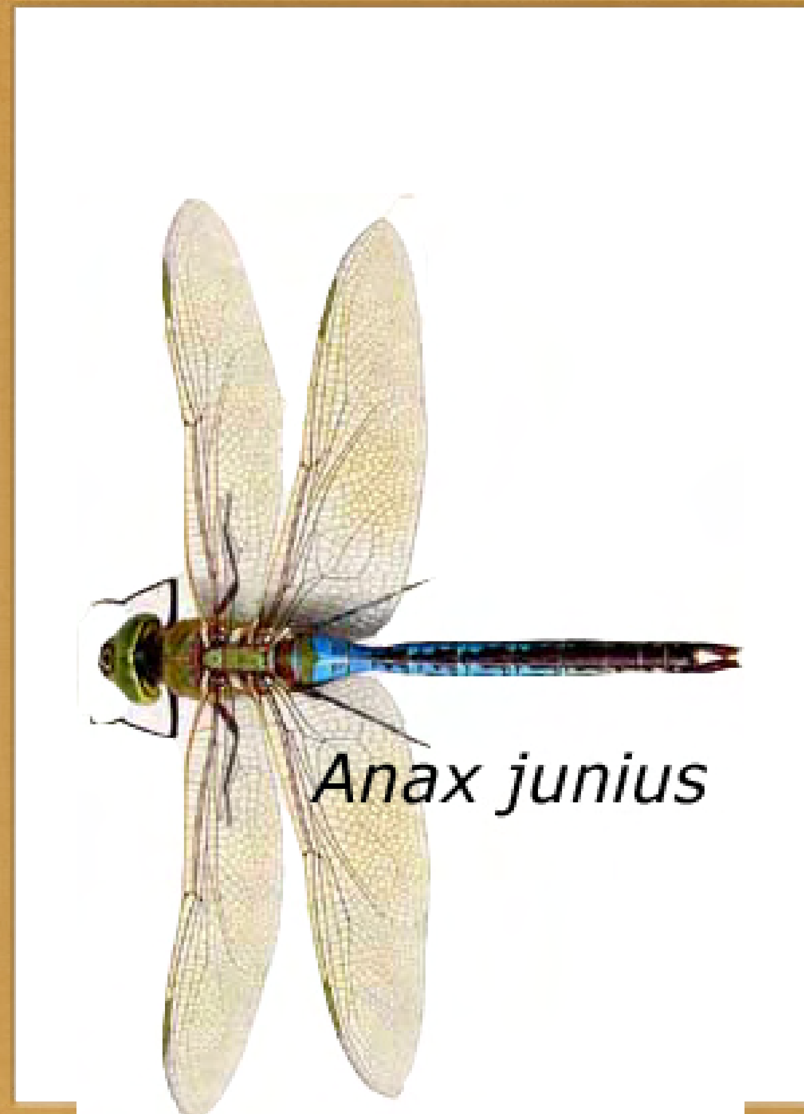
- Johnson, Kennedy, & Dingle: 1960 to 1996
- Consensus: “Persistent, undistracted motion”
- Need not be two-way movement or **to/from** specific localities
- Often associated with special behaviors, physiological states (Dingle)
- Large-scale movement rarely described in small-bodied organisms, especially insects
- Movement over large scales presents strong conservation challenges

Allegations of Migration

- $>5 \times 10^6$ individuals passing single localities in a day

- Telemetry & <u>gross</u> (not net) movement: up to 100 km in a day (Wikelski et al. 2006)

- One of ~15 odonate species believed to migrate long distances
- More Than a century of anecdotal reports
- Oil platforms: individuals >100km from shore crossing Gulf of Mexico
- Larvae are completely aquatic, specializing in small standing wetlands



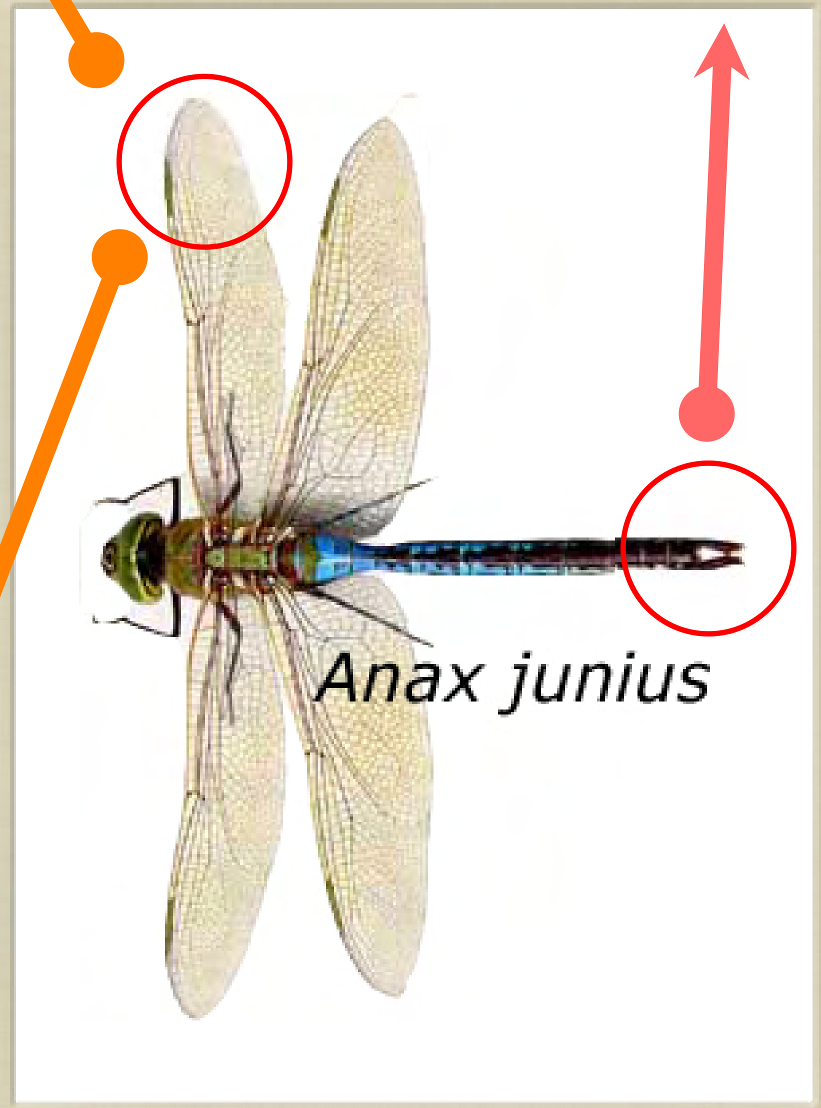
Hydrogen isotope processing

Estimates north-south movement

Microsatellite DNA

Reproductive Strategy, Biogeography

Studying Movement by Individuals and Across Generations



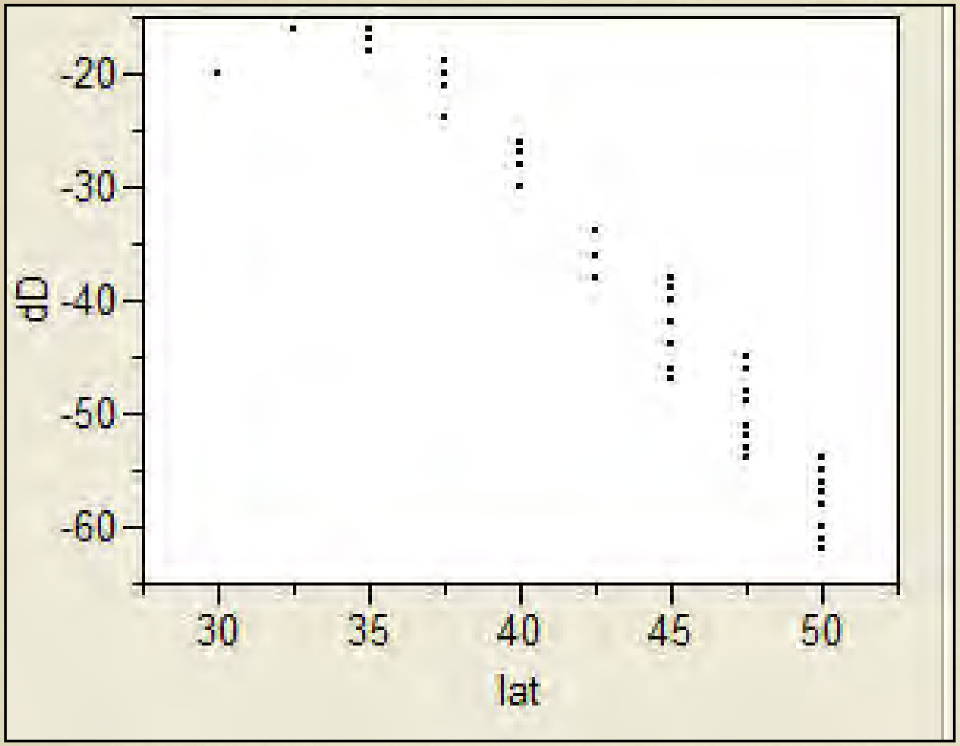
Strontium isotope processing

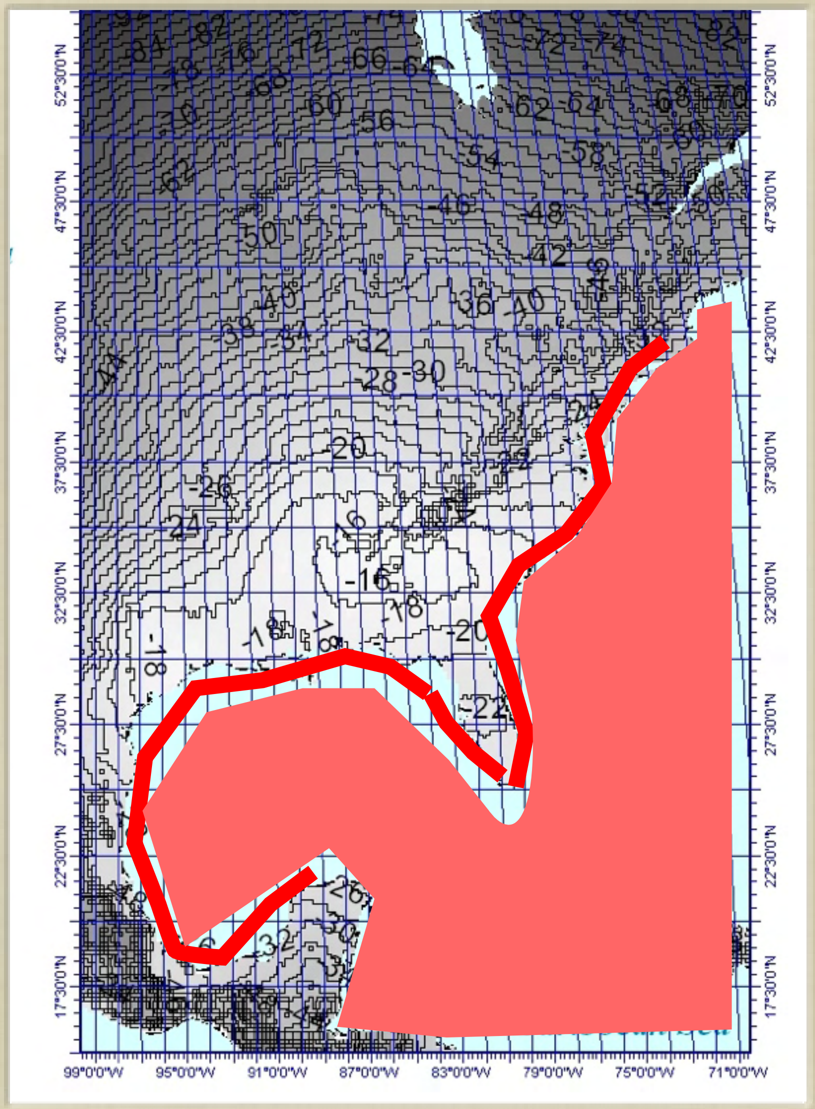
Are Adults from Coastal Areas?

Individual-based Methods : | : Population-based Methods

Isotopic Ratios & Movement

Precipitation Hydrogen isotope ratios (δD) Have a Strong Latitudinal Component





Marine and near-coastal water strontium ratios ($^{87}Sr/^{86}Sr$) are uniform and distinct

Precipitation δD values

Runoff, underlying geology $^{87}Sr/^{86}Sr$ ratios

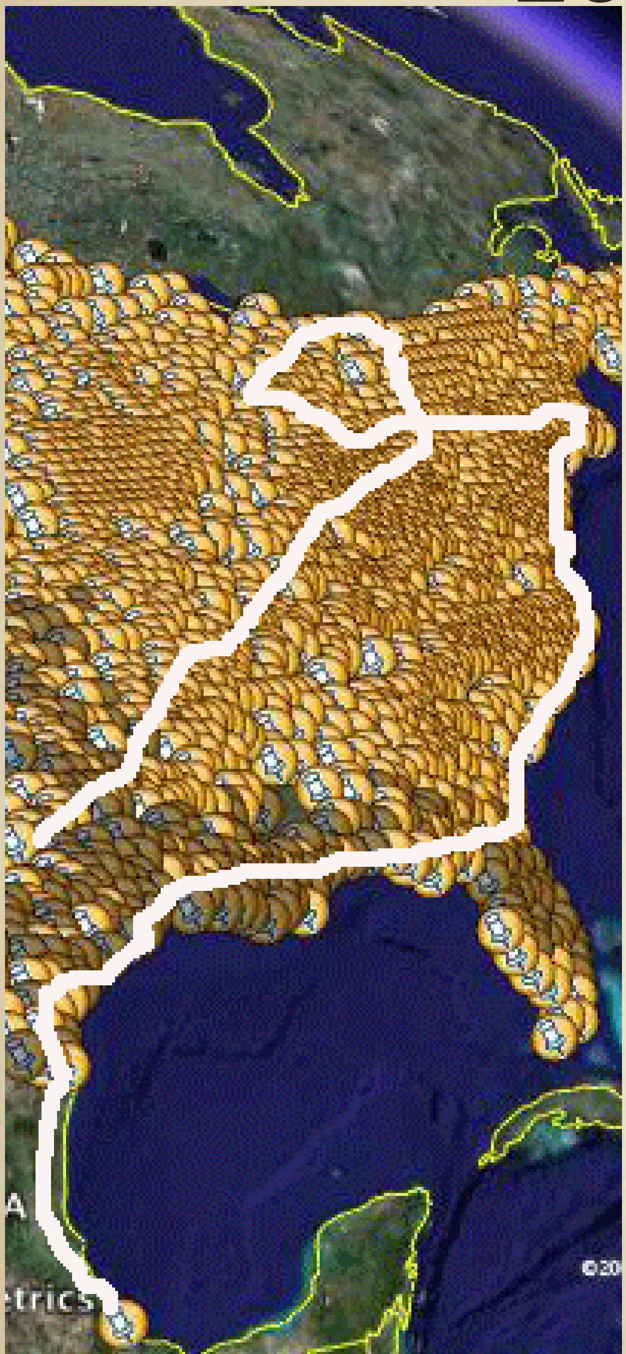
— fractionated —

— Negligible Fractionation —

new δD value, locked in wing tissue

Ambient $^{87}Sr/^{86}Sr$, locked in wing tissue

August–October 2005: 16,000-km Sampling Route

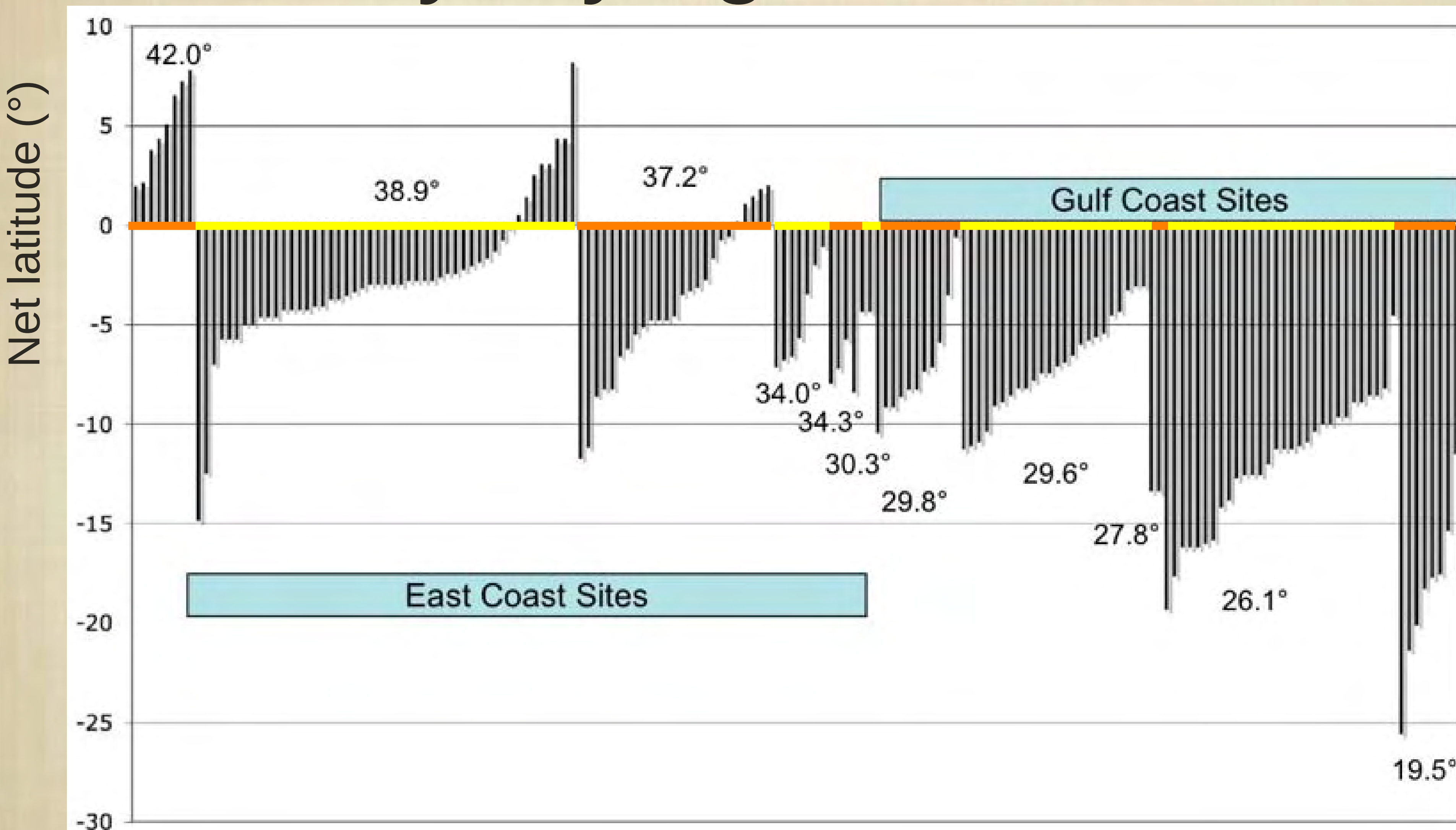


47° latitude

19° latitude

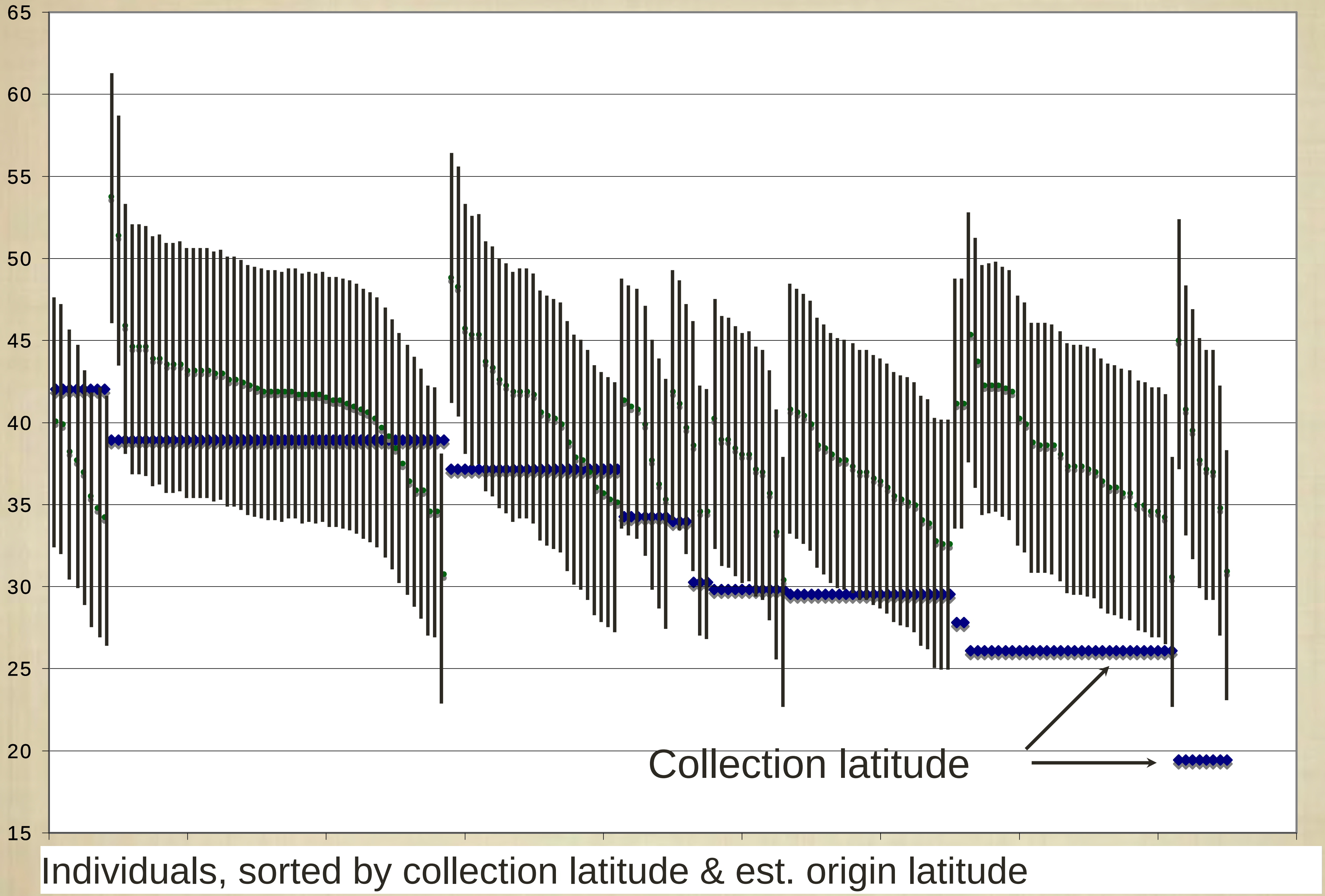
How Many Degrees of Latitude Are They Flying?

northwa
d



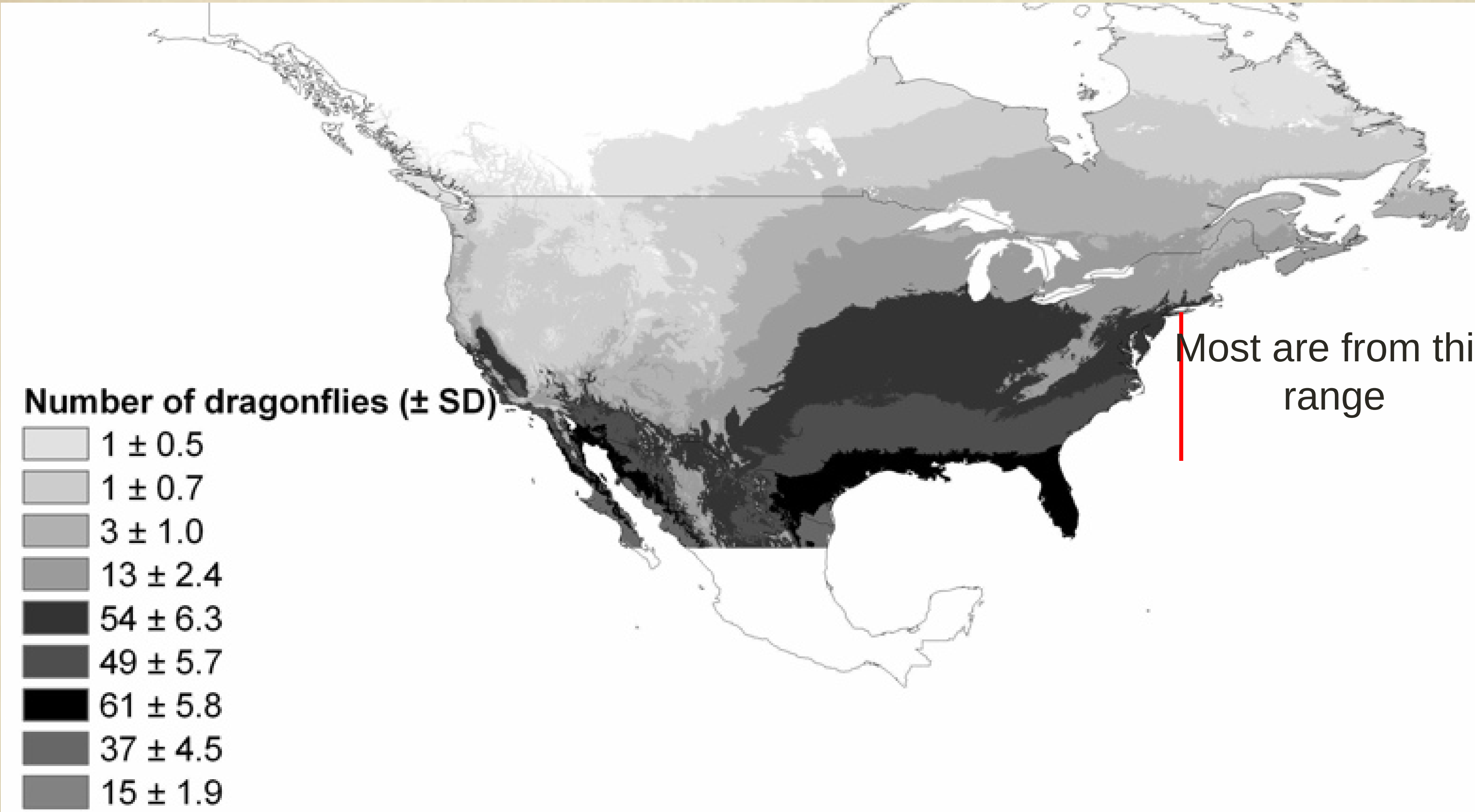
Southw
ard

95% Prediction Intervals for Migration Origination Latitude

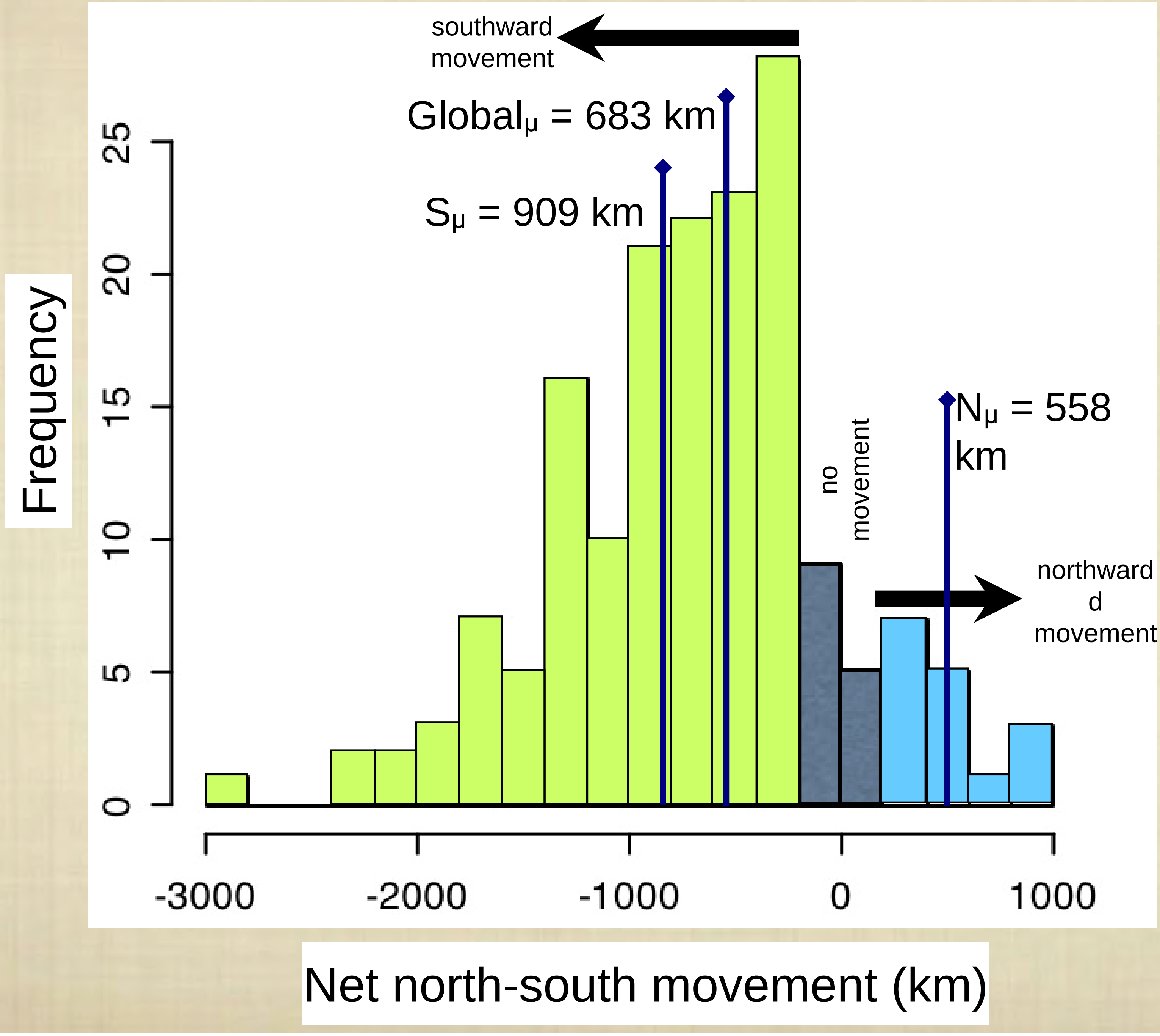


late August → mid October

Where Did They Come From?

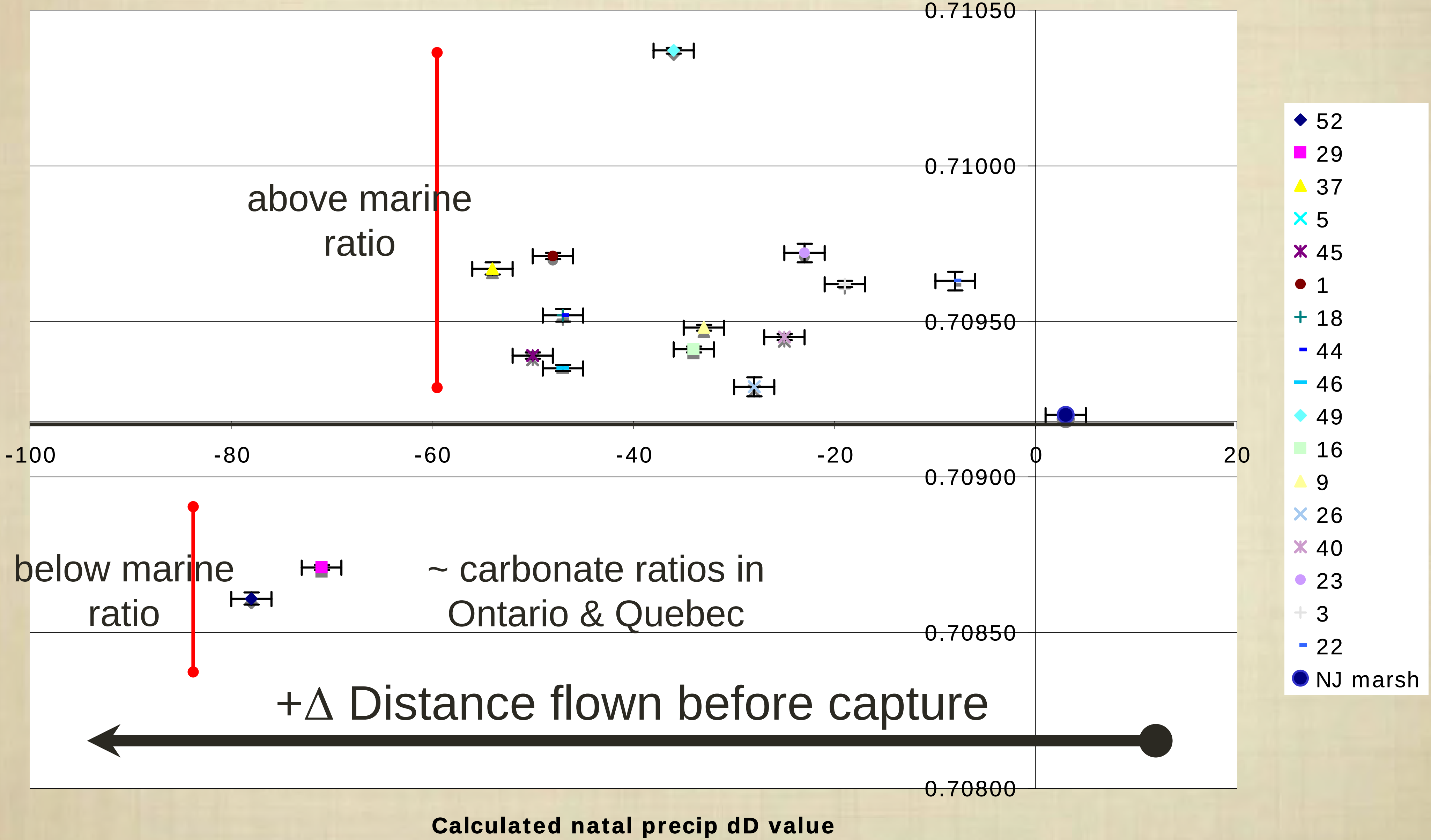


Intra-generational Movement

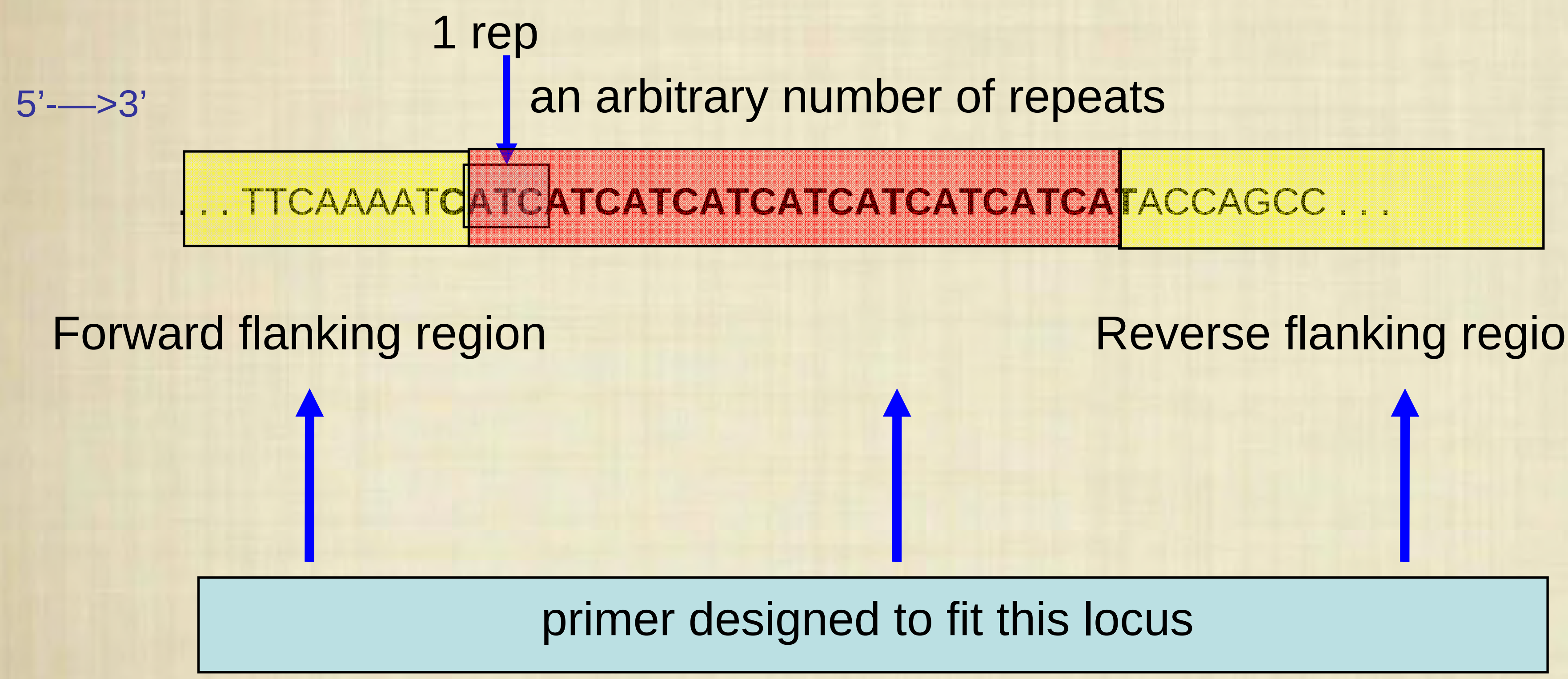


How Are Swarms Organized?

Profiling one Flight Group in southern New Jersey



What is microsatellite DNA?



PCR amplifies this region; with two chromosomes with this locus (one from each parent), an individual might inherit two different versions of this locus

Inter-generational Movement

- 180 adults
- 12 microsatellite loci developed, 9 used
- Global Fst: 0.04
- Mantel: no relationship
- Bayesian clustering methods (Pritchard et al. 2000; Structure 2.2)
- Optimal clustering is low (1 to 2 "populations")

Adults Form a Single Population Across 27° Latitude in Eastern North America

Testing genetic hypotheses: Microsatellite results

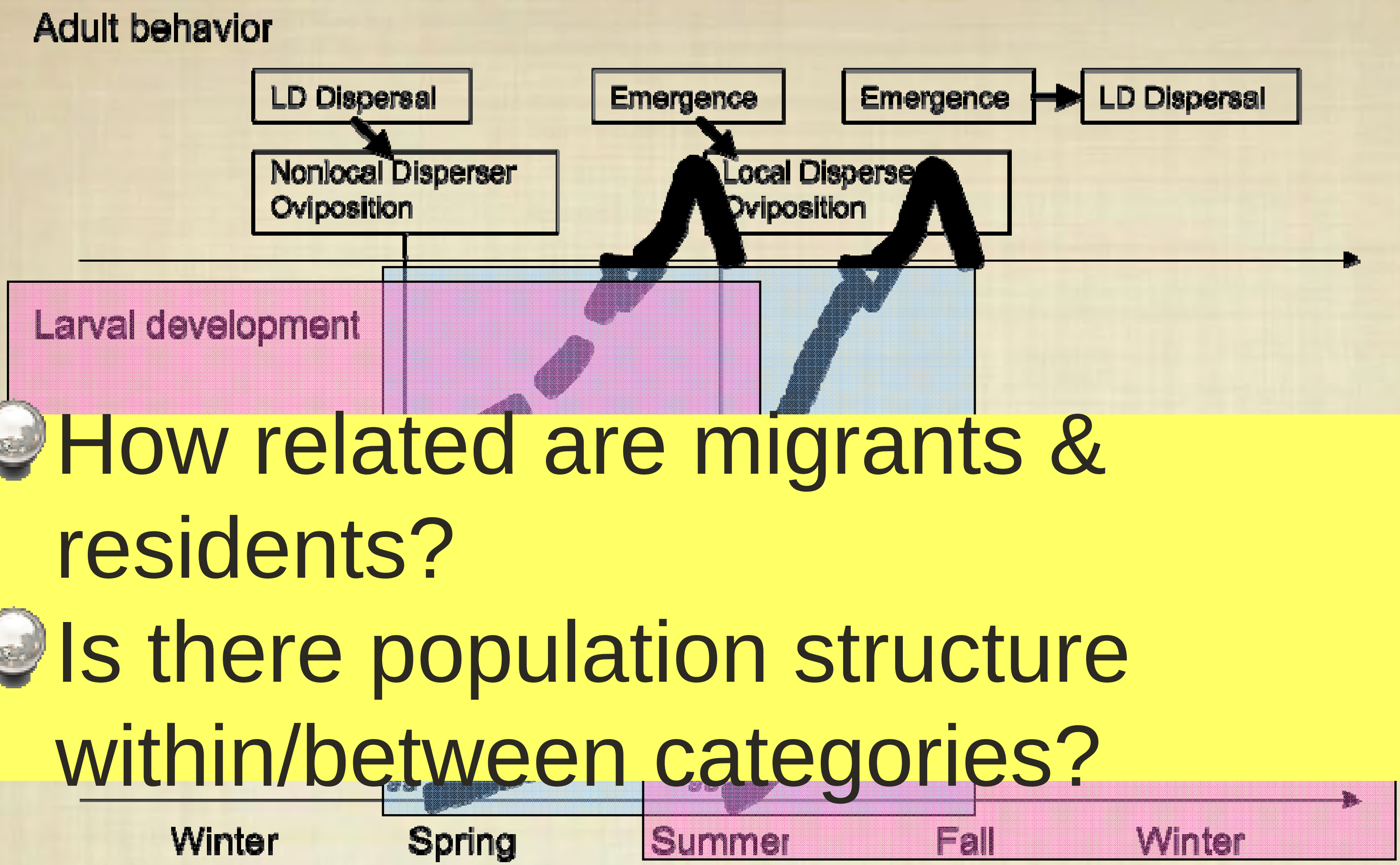
clustering Type (130 genotypes)	Number of clusters	Overall Fst	P Value
Adult collect site	10	0.032	<0.001
Males v. females	2	0.007	0.003
Atlantic coast, Gulf coast, Lake Huron, Ontario	3	0.009	<0.001
Collected above/below 30° N Lat	2	0.003	0.02
Individual based Bayesian clustering	optimal: 2	0.052	NA

Migration Conclusions

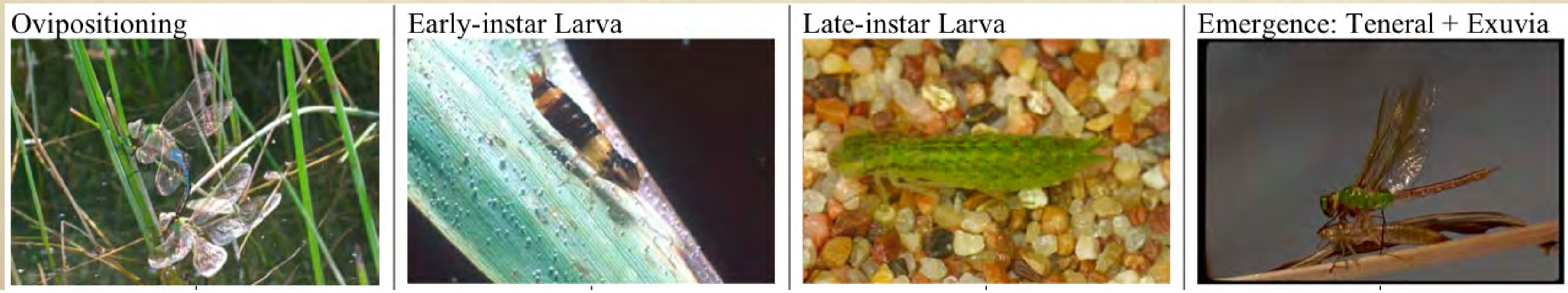
- First conclusive proof of large-scale odonate migration
- Individuals traveling up to 2800 km net north-south distance
- One of the largest-scale insect migrations ever described
- Spring northern movement must be explored in more detail
- New suite of inexpensive & synergistic techniques to describe large-scale movement by insects
- Should have a wide variety of conservation applications

Are Anax junius Populations Spatially Structured?

With Tom Juenger & Sandra Boles



- How related are migrants & residents?
- Is there population structure within/between categories?



Scales of Genetic Organization Across the Landscape

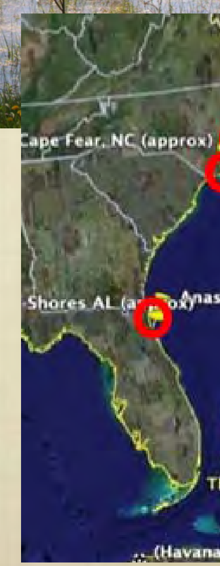
In a set of eggs

- Females, males mate with multiple individuals
- Other odonate females store sperm
- May only be half-sibs

Within a single pond

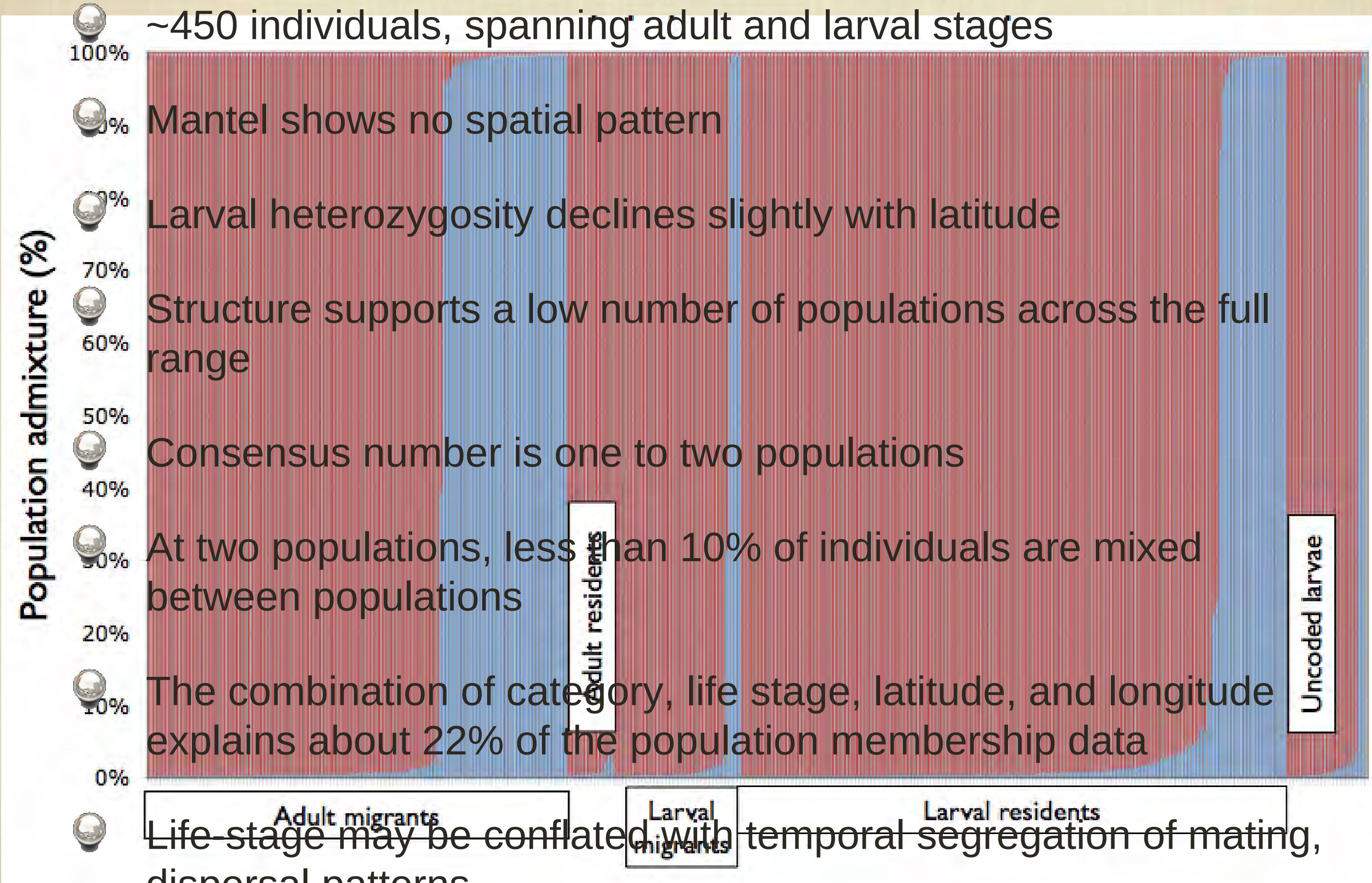
- Males guard shorelines, females visit ponds on a more-transient basis
- Hundreds visit a single pond/day
- Kinship coefficients for 19 collection sites: ~0.05 (Ritland `96)

Throughout a region



- Regional patterns are weak descriptors of structure (R^2<0.10)
- Migration over 100s of km
- Mating/egglaying en route

Spatio-temporal Patterns



- ~450 individuals, spanning adult and larval stages
- Mantel shows no spatial pattern
- Larval heterozygosity declines slightly with latitude
- Structure supports a low number of populations across the full range
- Consensus number is one to two populations
- At two populations, less than 10% of individuals are mixed between populations
- The combination of category, life stage, latitude, and longitude explains about 22% of the population membership data
- Life-stage may be conflated with temporal segregation of mating, dispersal patterns

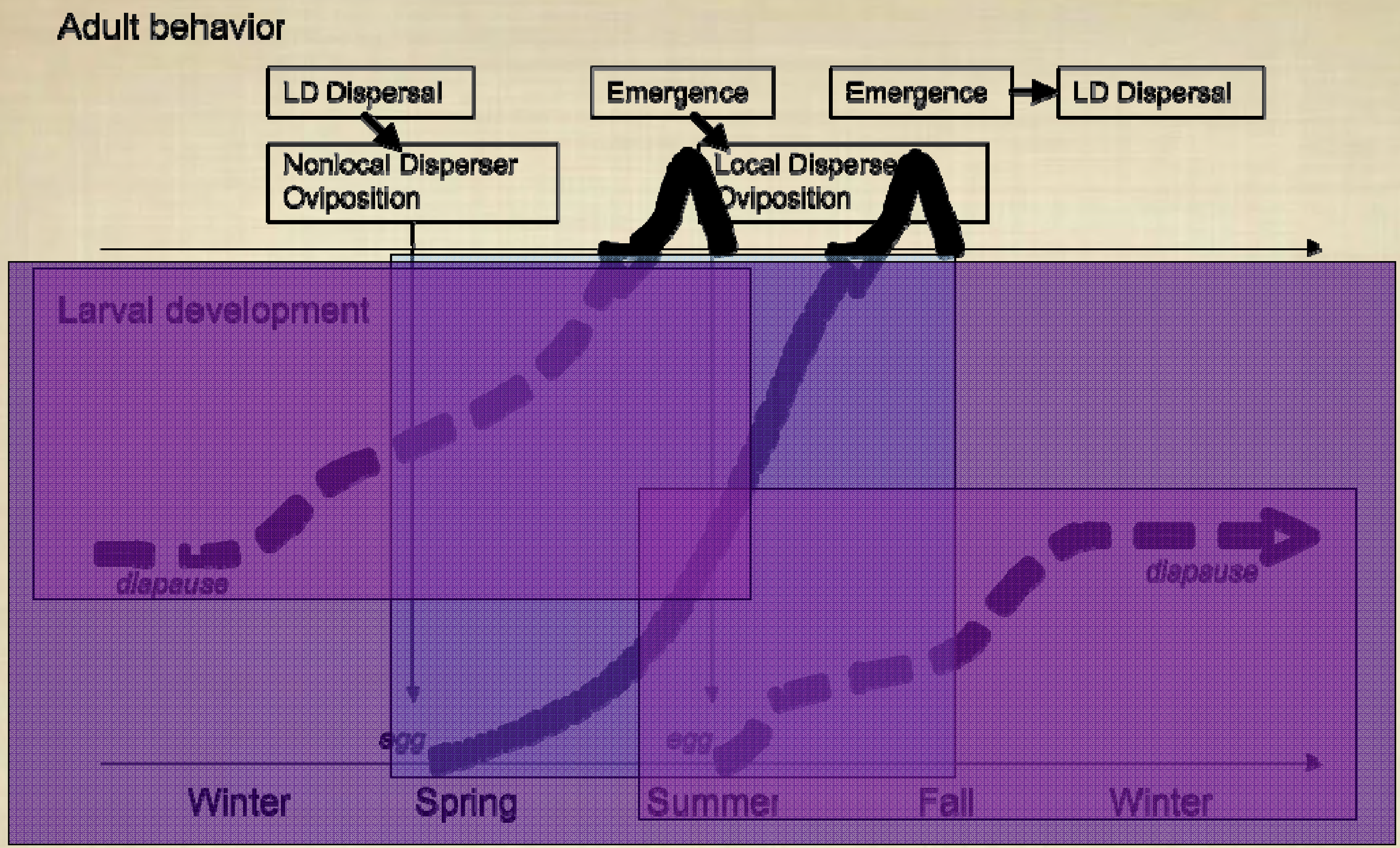
Biogeography conclusions

- Two complex suites of behavior are maintained over large spatial scales
- Novel form of migration, more typical of marine than terrestrial species
    - adults do not leave reproductive state during the movement process
    - reproduction coupled with migration

Why Don’t All Anax junius Migrate South?

determinants of life-history trajectory

With Camille Parmesan,
Morgan Kelly, & Tom Juenger



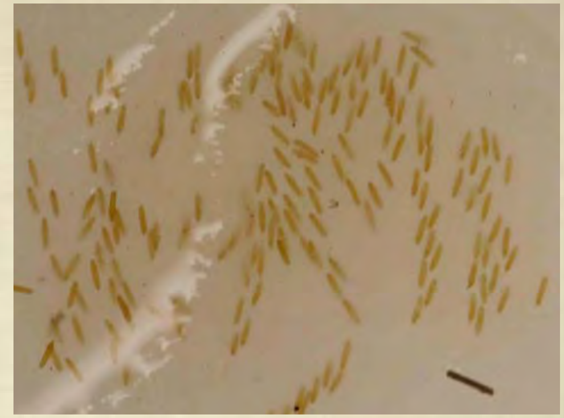
Genetically, residents & migrants form a single group with two different phenologies and adult behaviors.

- How does an individual know to follow one or another path?
- Why are there two paths? Why not one? three? or seven?

Could life-history path be a form of phenotypic plasticity?

- Phenotypic plasticity: an external cue signals to an organism to follow a particular developmental path. Two obvious cues:
  - Larval growth rate can be regulated by temperature (Trottier 1970); common in insects — | hold constant
  - Photoperiod (daylength) had “some” influence on developmental rate on a congeneric (Corbet 1956); reliable over large scales — | vary by treatment

Eggs from a single female (unknown # males)



Individuals raised in cups in a growth chamber

spring treatment

Increasing photoperiod

Constant photoperiod

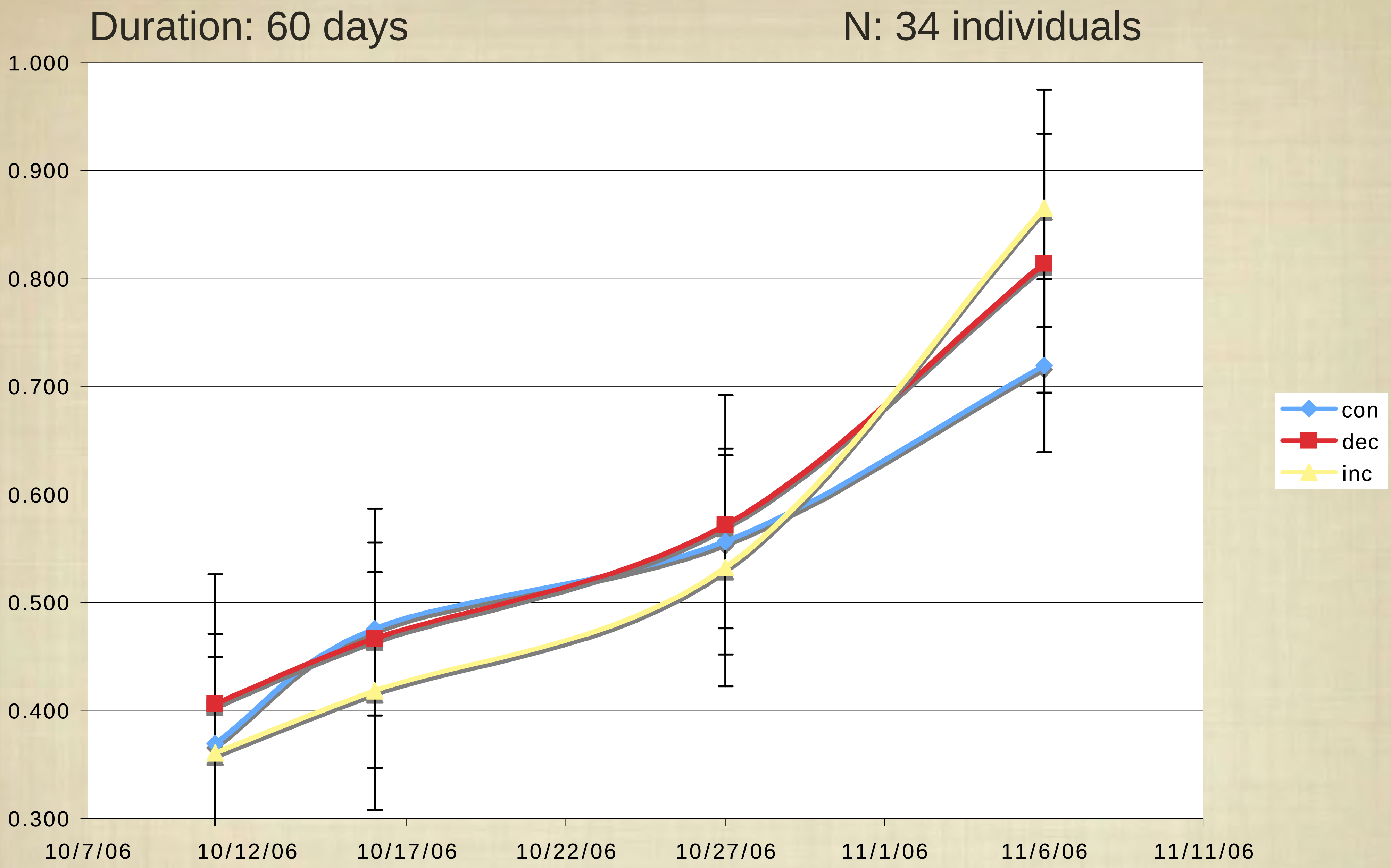
Decreasing photoperiod

Fall treatment

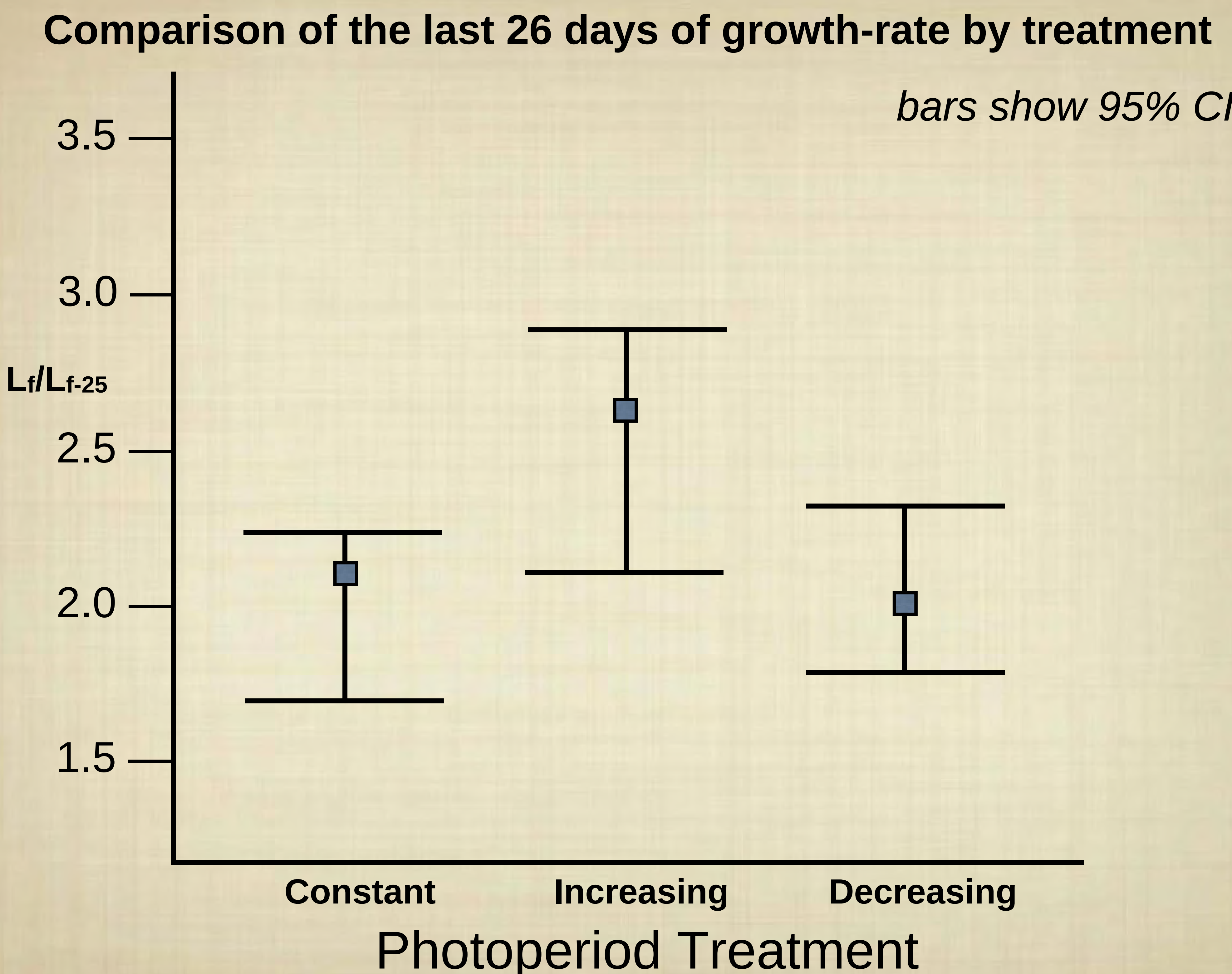
Migrants
fast

Residents
slow

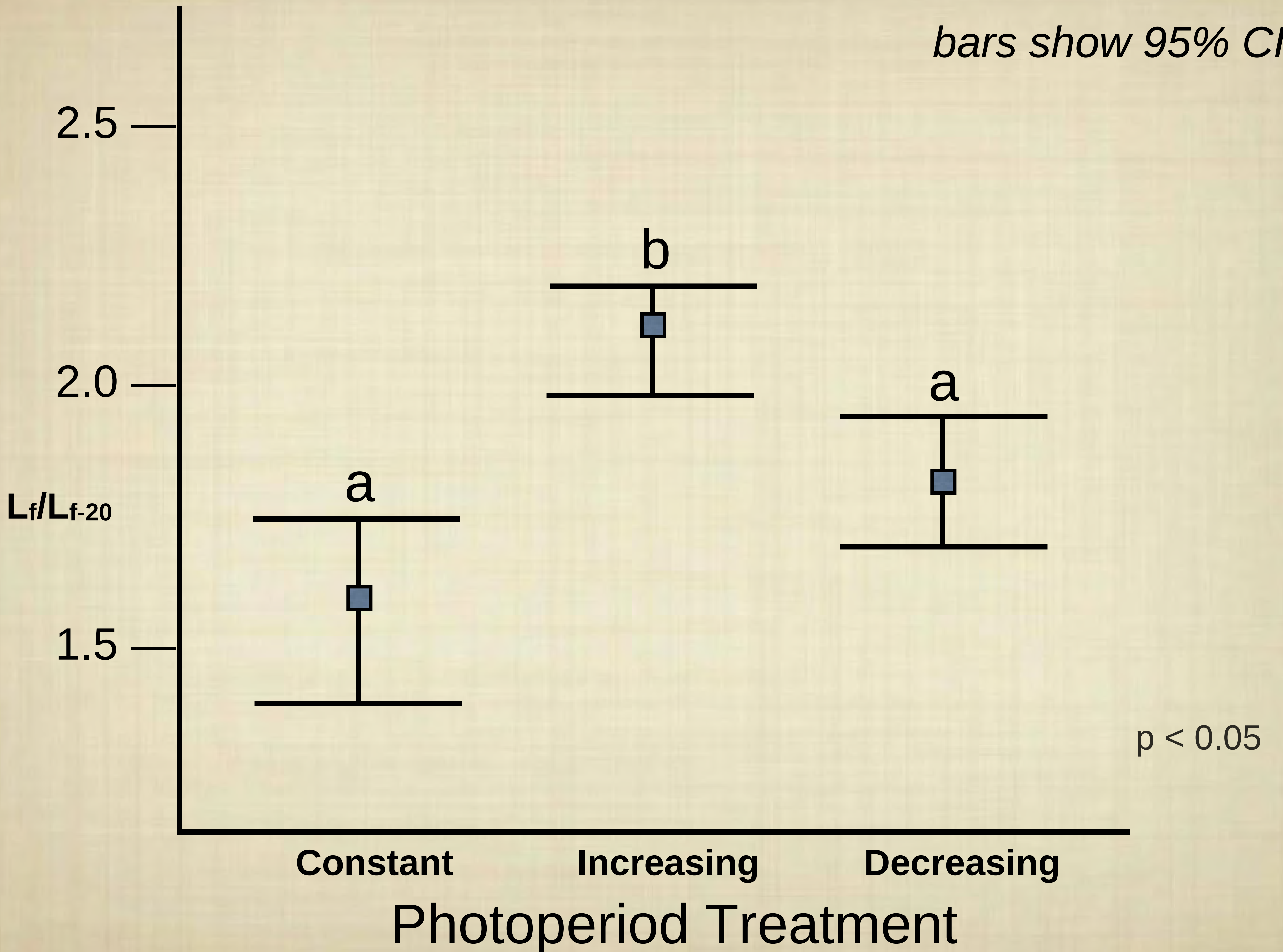
Experimental design



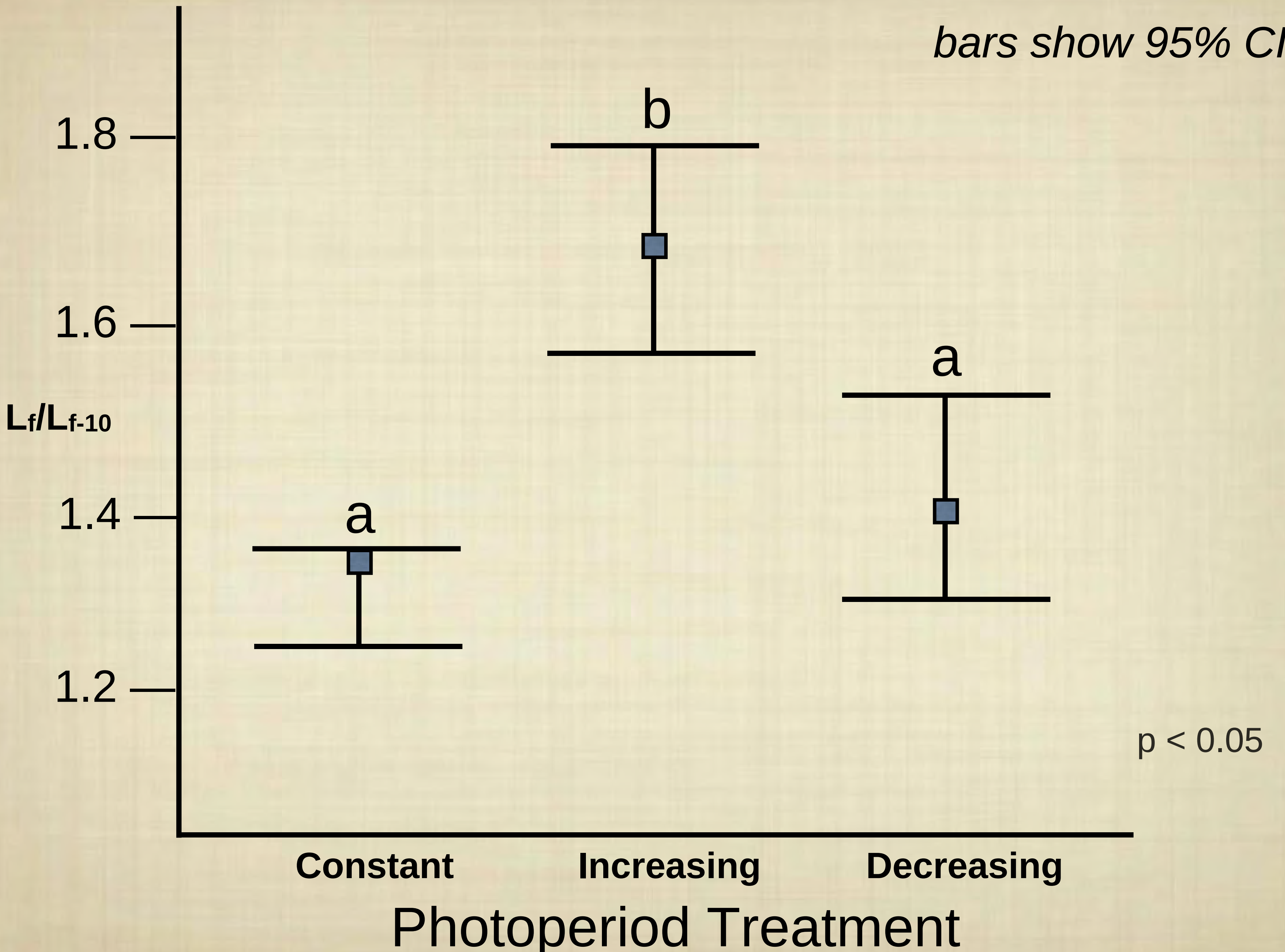
Experimental Results


Comparison of the last 26 days of growth-rate by treatment
bars show 95% CI
3.5
3.0
L_f/L_{f-25}
2.5
2.0
1.5
Constant
Increasing
Decreasing
Photoperiod Treatment

Comparison of the last 21 days of growth-rate by treatment



Comparison of the last 11 days of growth-rate by treatment



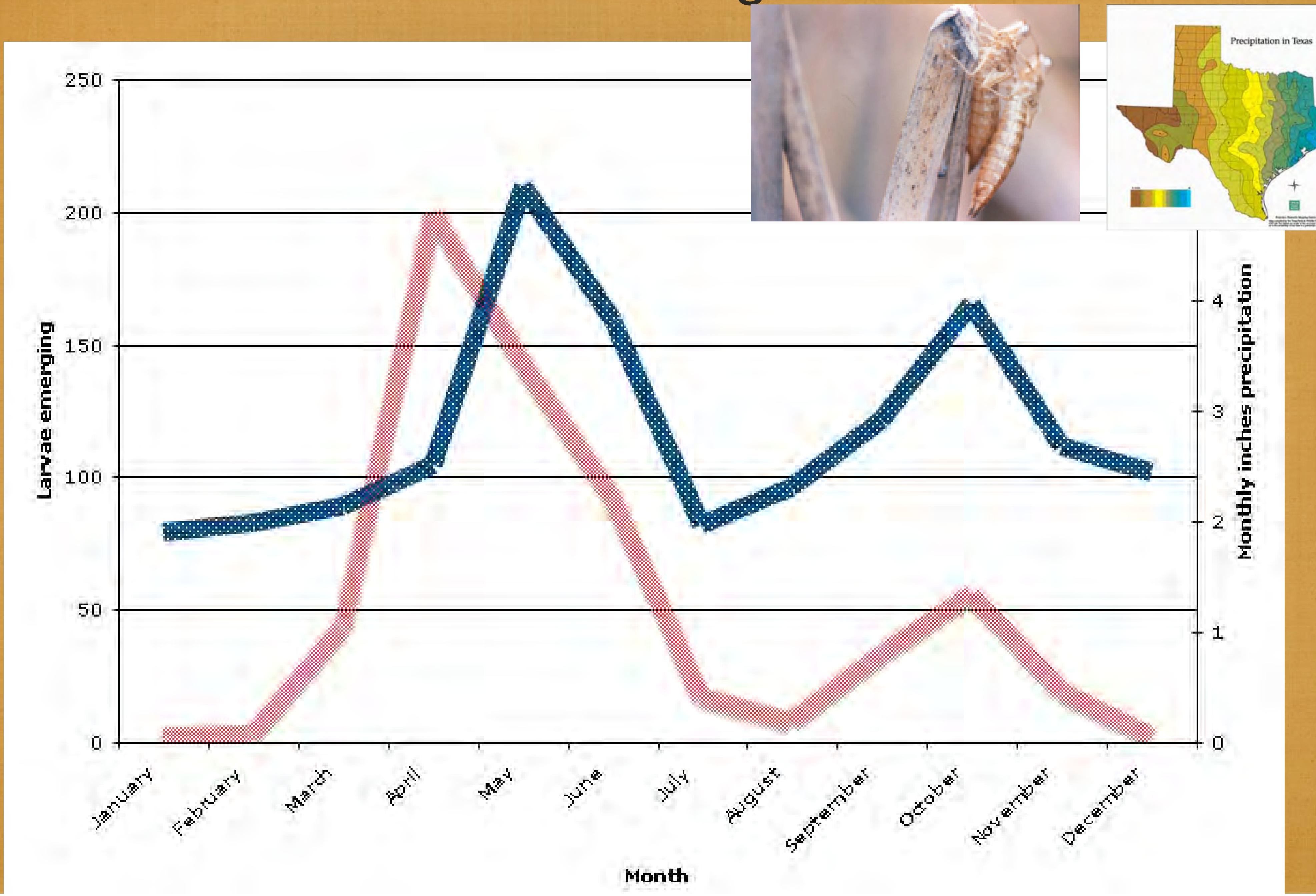
Life-history path conclusions

- Increasing treatment was significantly different than constant & decreasing treatments
- Treatments differentiated late in the experiment
- Weak family effects; clear direction for future work

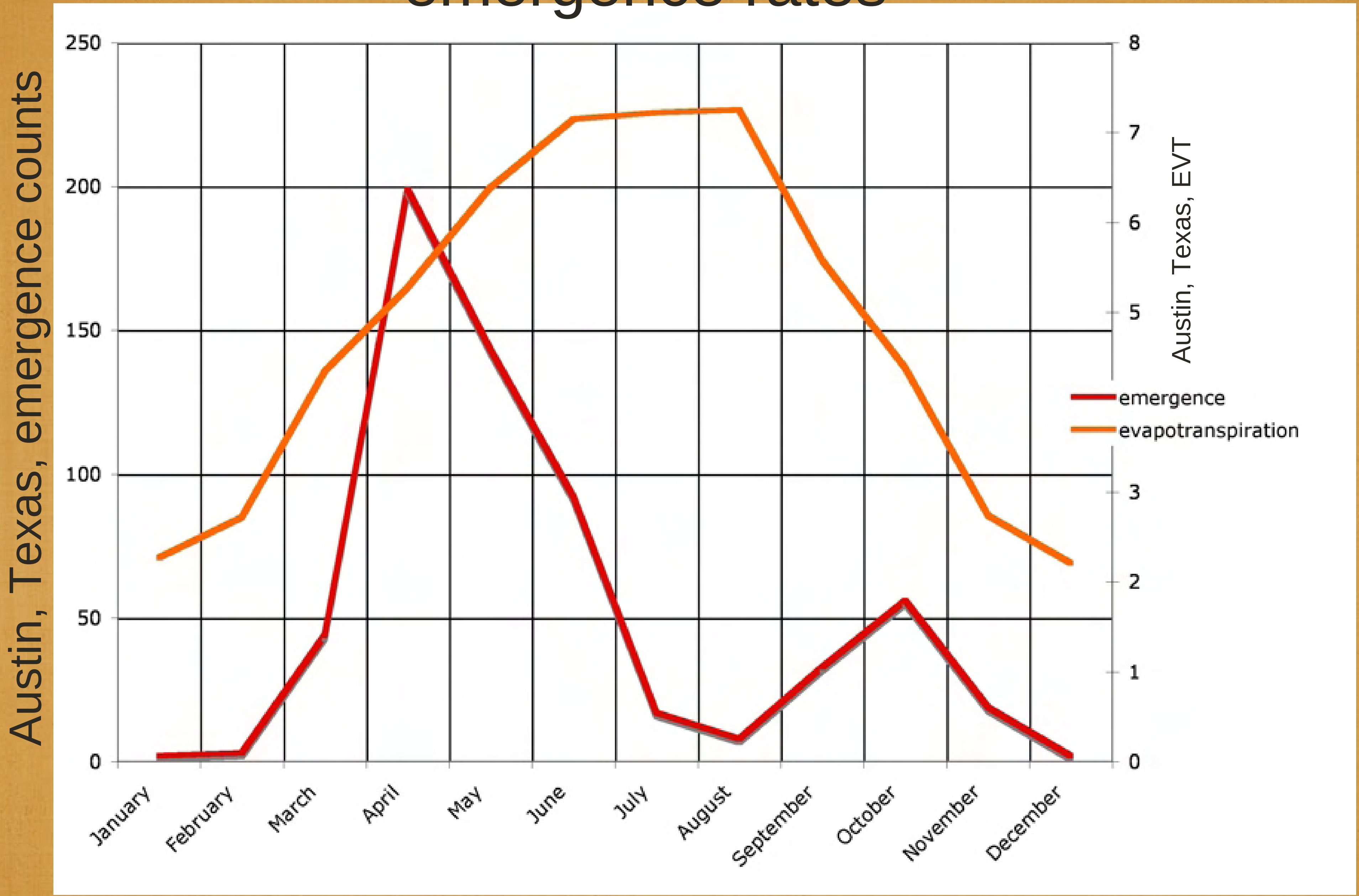
Rain, Rain, Go Away: Climate Change Impacts in Southern Ontario

with Camille Parmesan

Emergence phenology and precipitation normals are linked over large scales

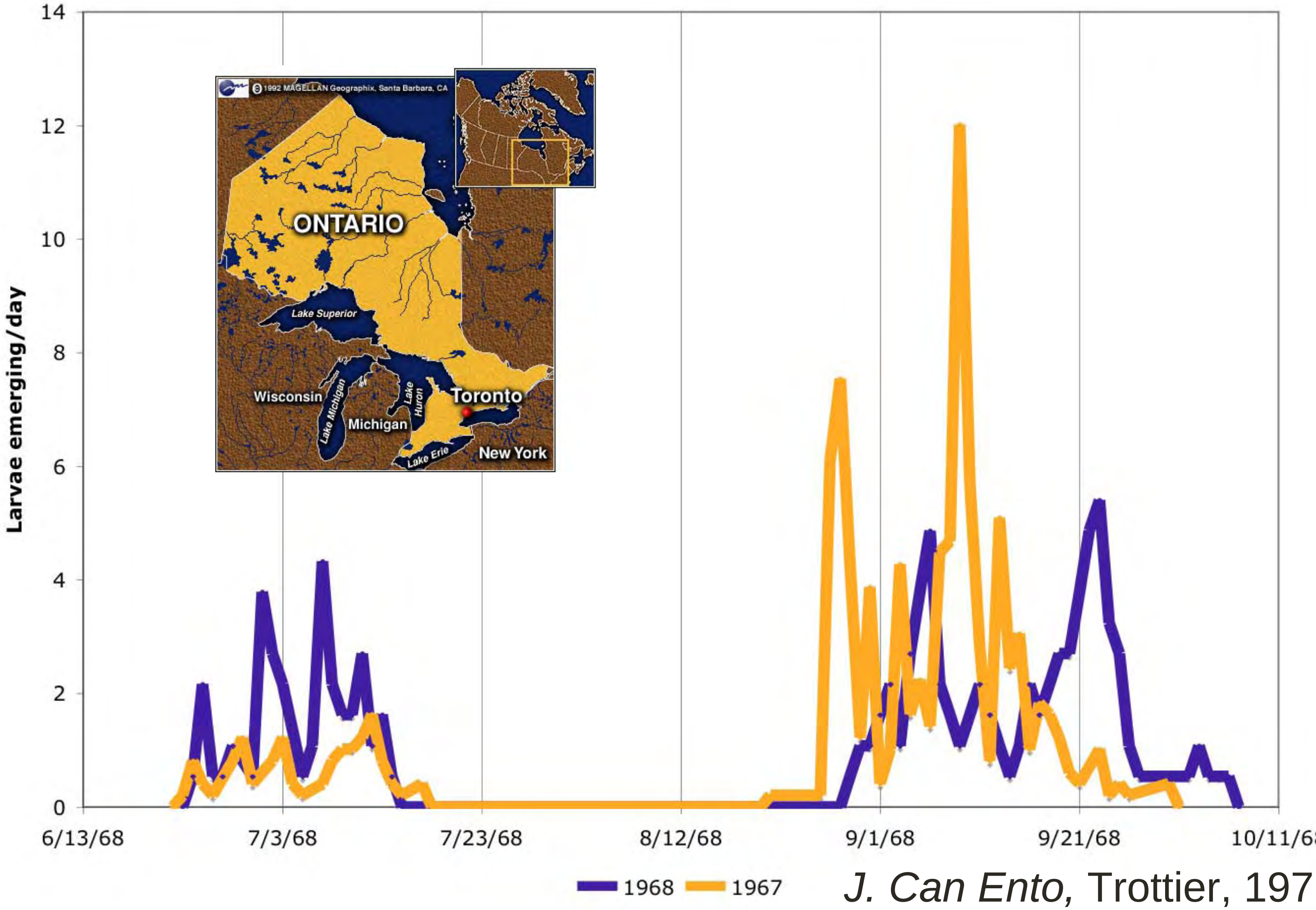


Evapotranspiration rates are inversely related to emergence rates



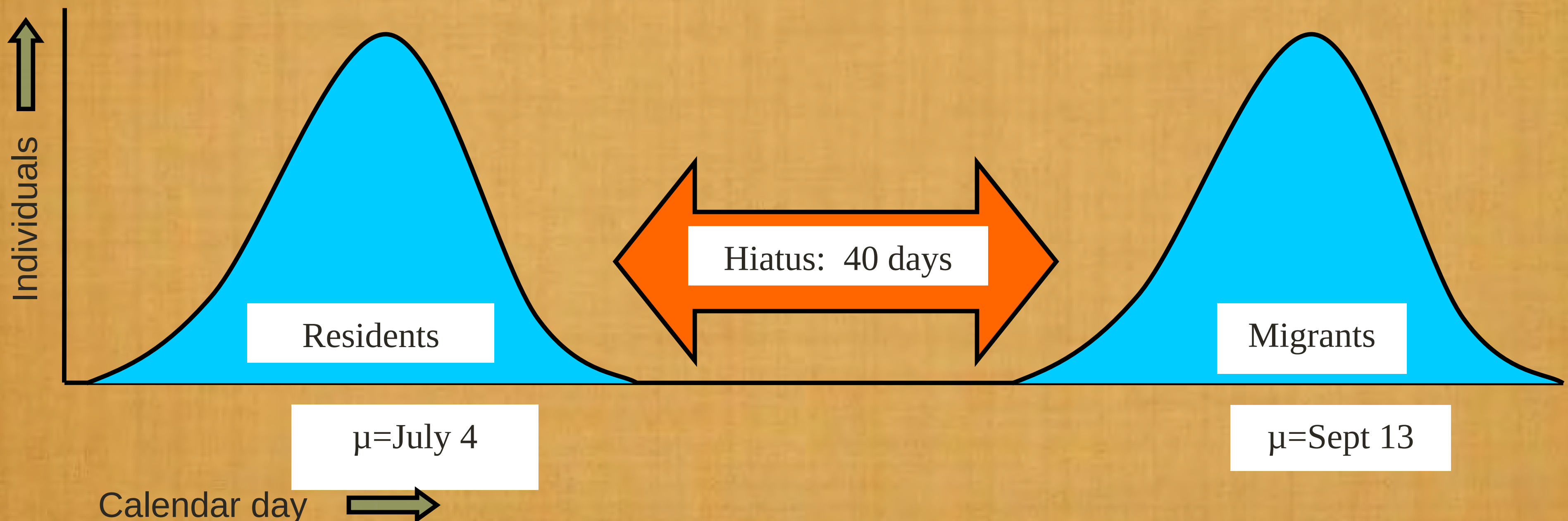
Austin, Texas, 20-year climate normal data

Caledon, Ontario: 1967–68



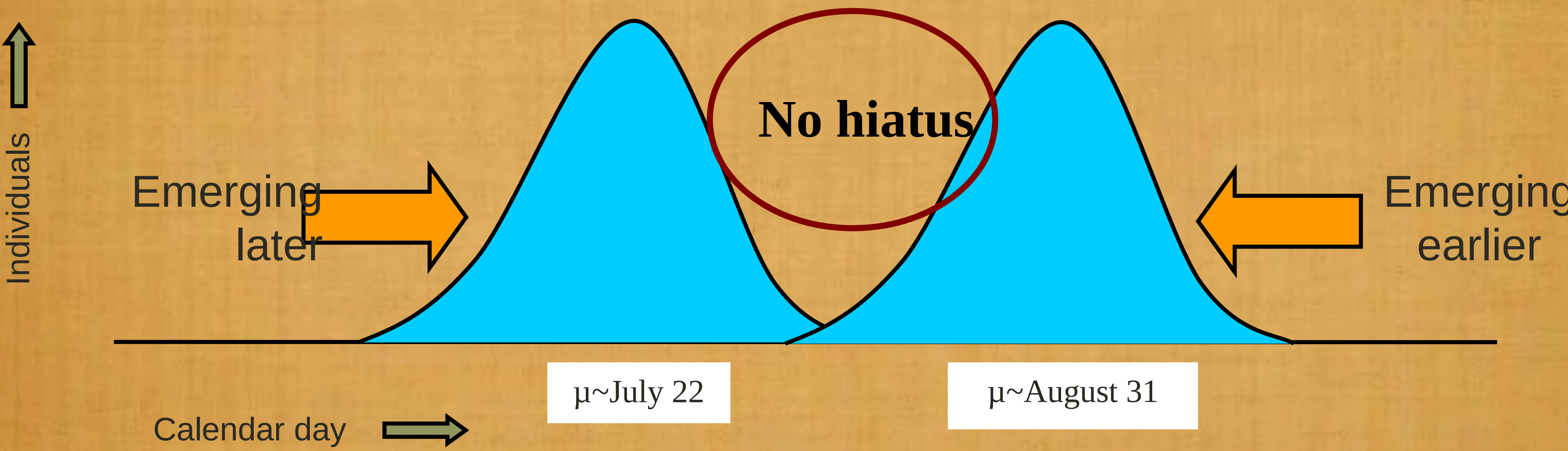
J. Can Ento, Trottier, 1971

Generalized Caledon emergence, 1967–68



Source: Trottier 1971

Generalized Caledon emergence, 2003–06

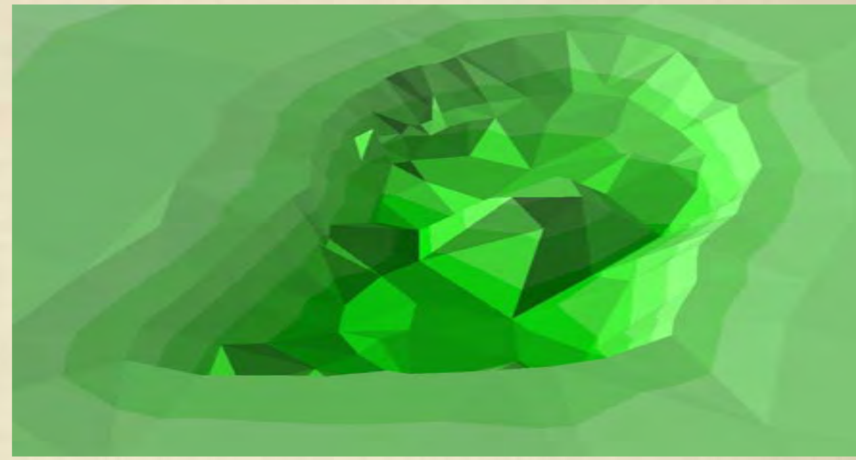


What explains opposing shifts in emergence phenology?

- Air temperature?
- Water temperature?
    - What drives water temperature in small standing wetlands?
    - What is the relationship between water temperature, the timing/amount of precipitation, and water volume?
    - Shallow-water temperatures are probably key since larvae are concentrated there

Testing drivers of shallow-zone water temperatures

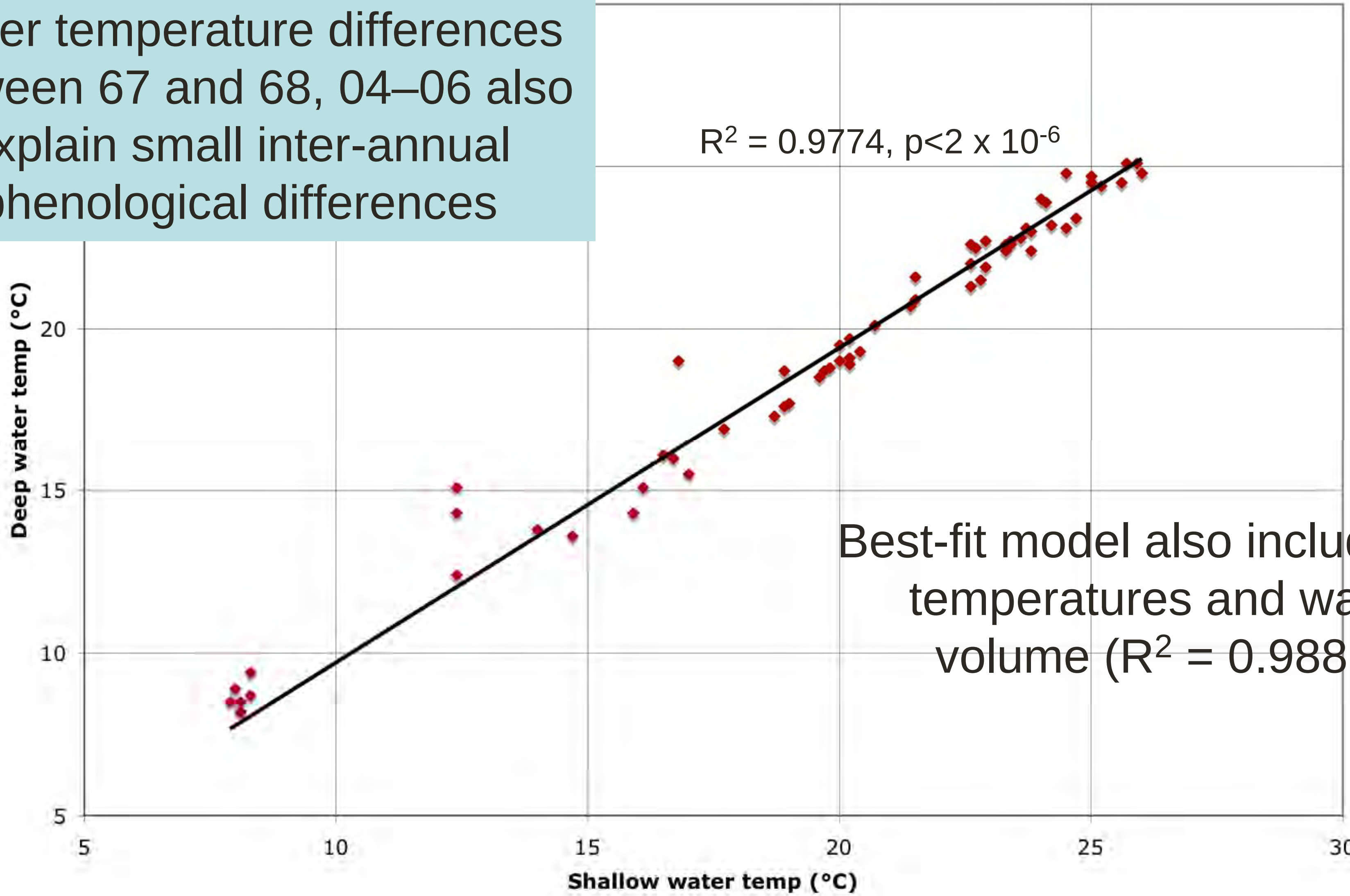
From depth to volume:
Some 120 sub-meter precision GIS sounding waypoints, to generate a TIN to model volume through time



From July 2003 to August 2006:
Water temps: 10 cm, 1 m depths
Air temps
Water depths
Emergence phenology

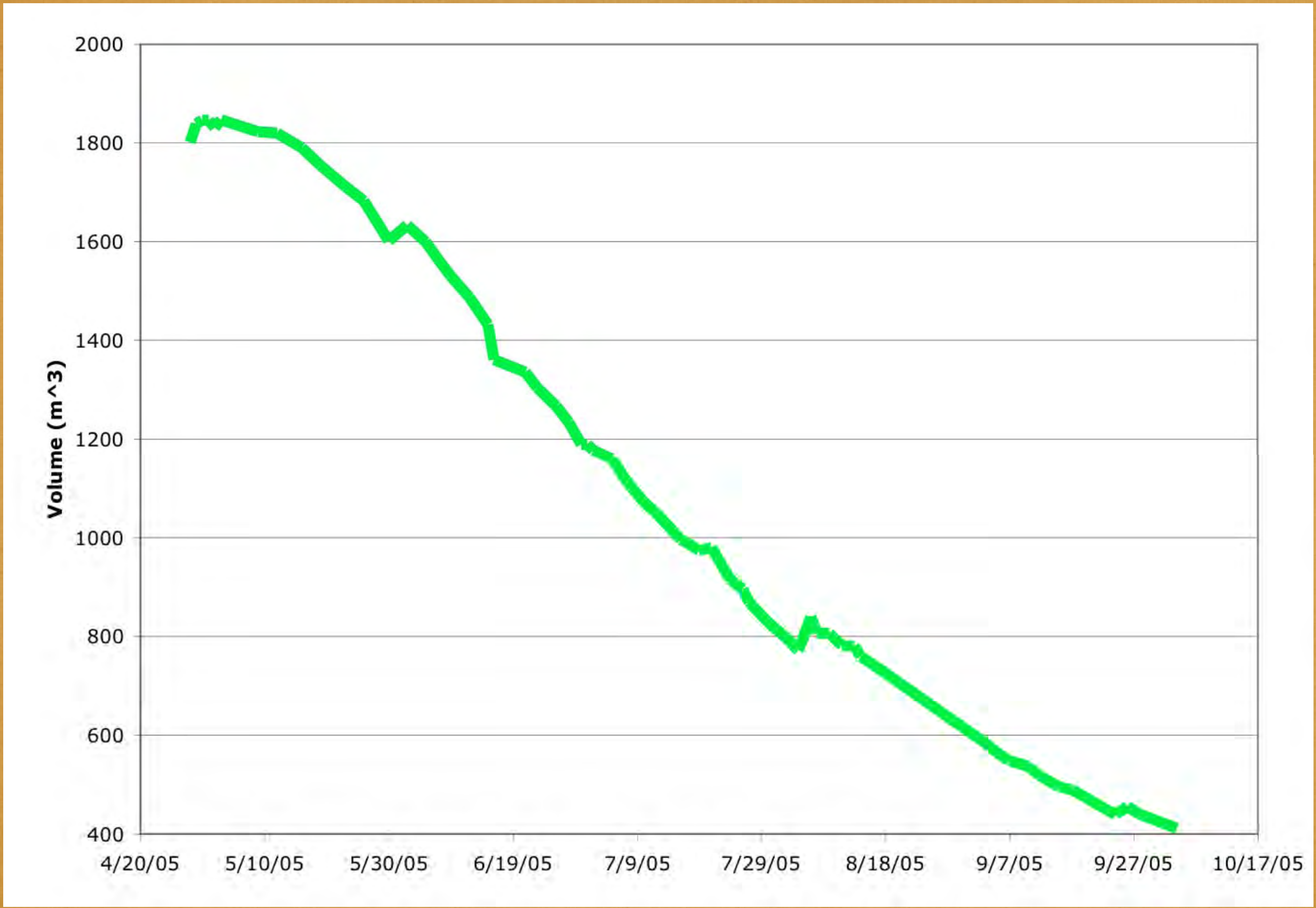
Deep-water temperatures drive shallow temperatures

Water temperature differences between 67 and 68, 04–06 also explain small inter-annual phenological differences

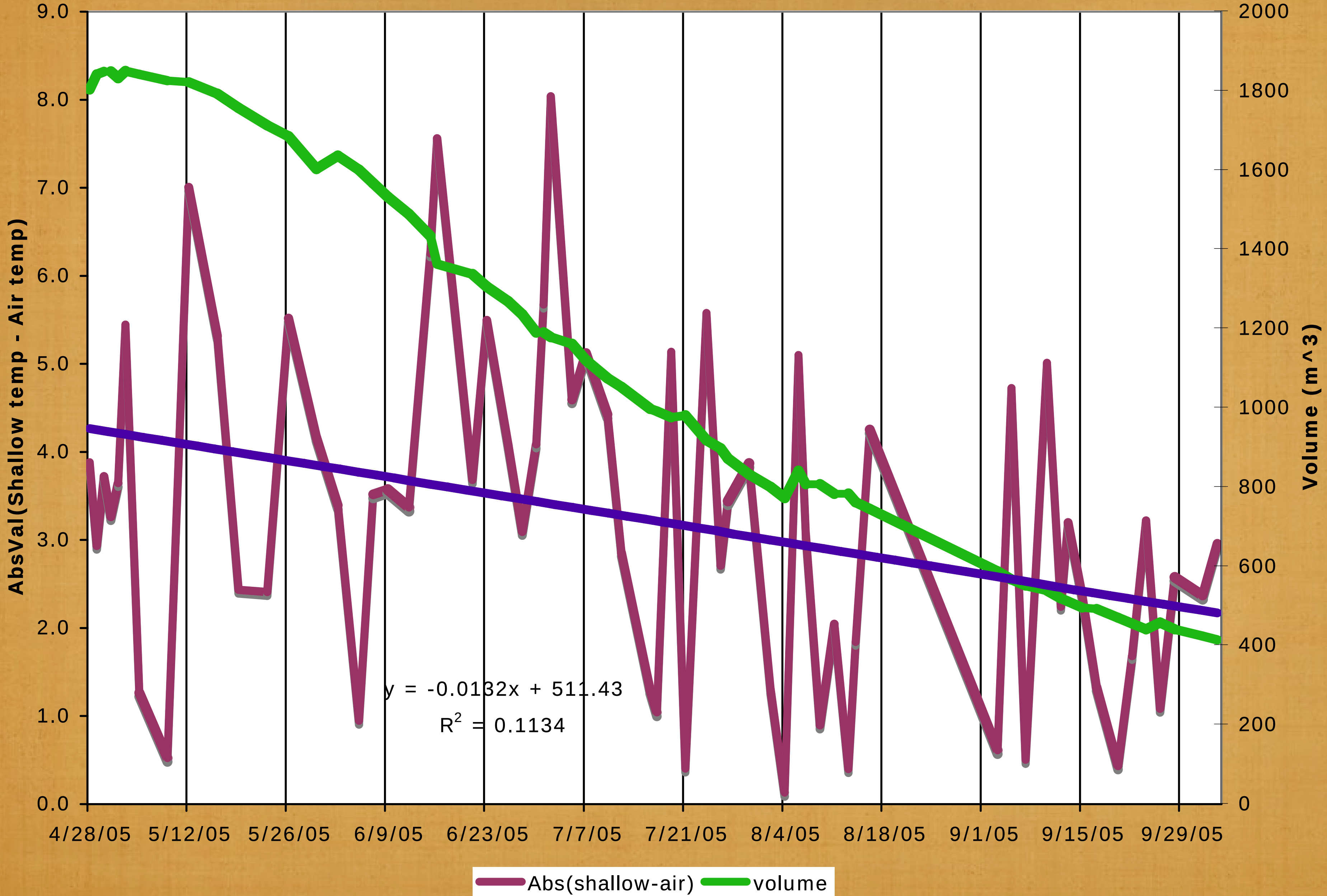


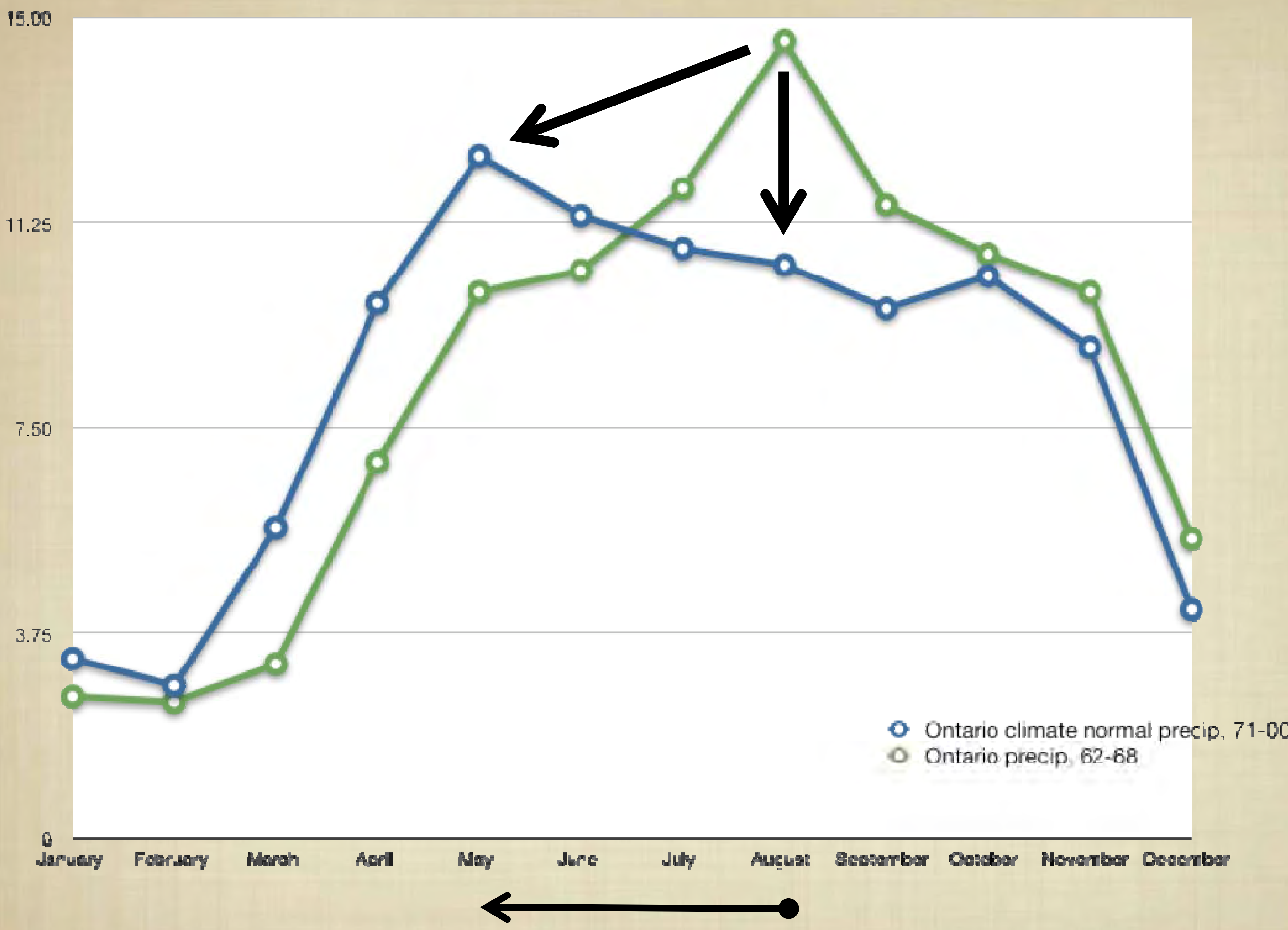
Best-fit model also includes air temperatures and water volume (R^2 = 0.9881)

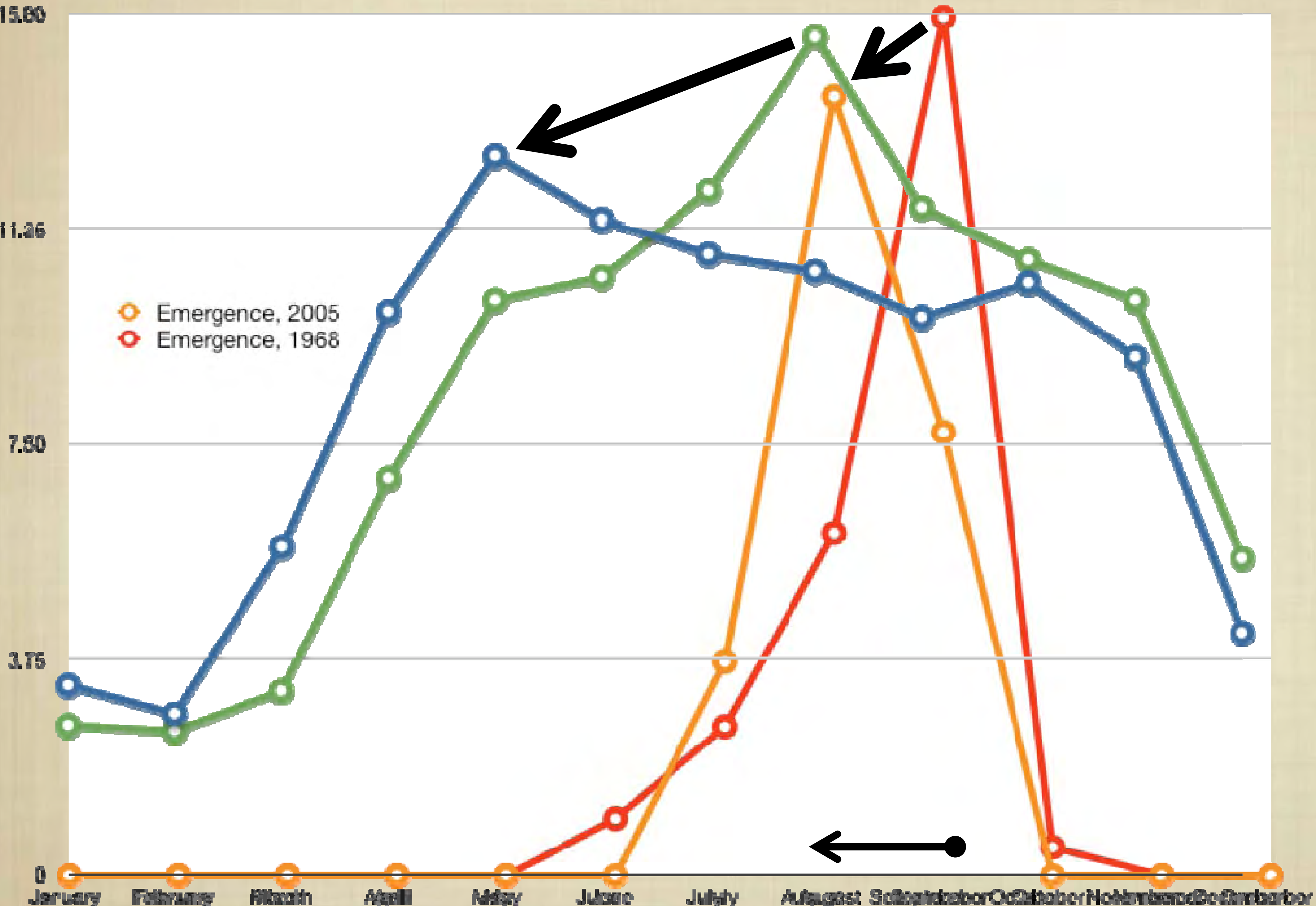
Between May and October, water volume declines



As thermal mass decreases, differences between air and water temp also decrease



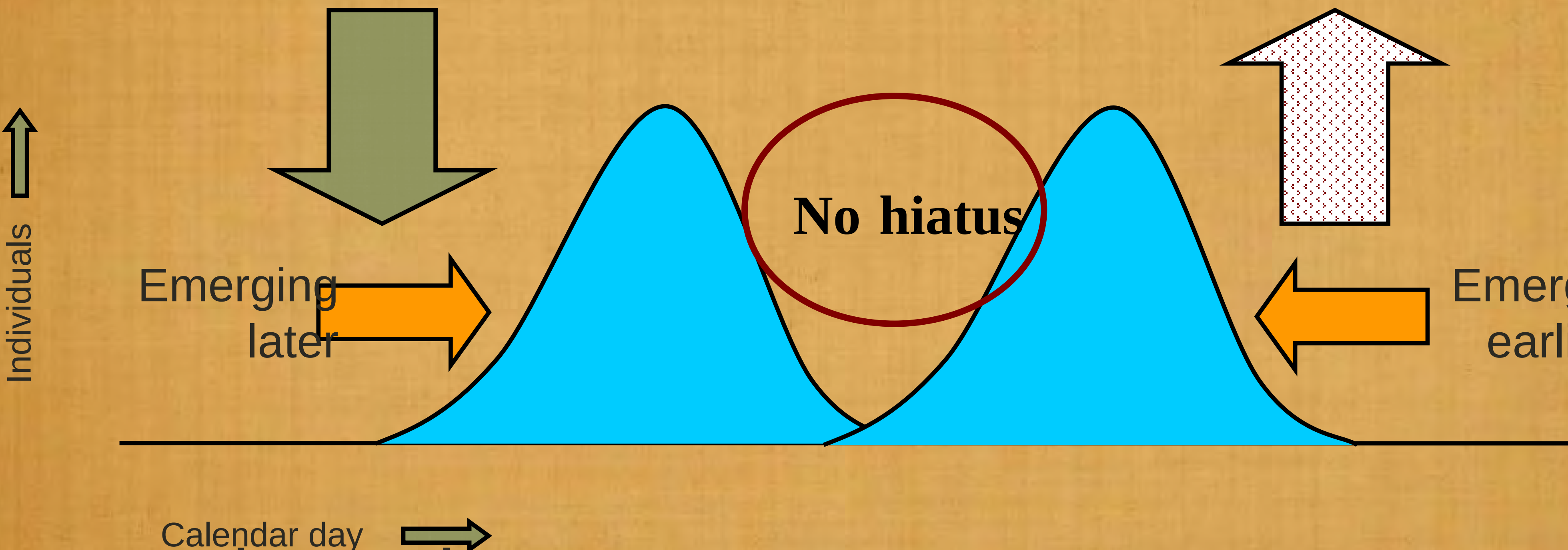

15.00
11.25
7.50
3.75
0
January
February
March
April
May
June
July
August
September
October
November
December
Ontario climate normal precip, 71-00
Ontario precip, 62-68


15.00
11.25
7.50
3.75
0
Emergence, 2005
Emergence, 1968
January

Dragonfly emergence 2003–06

Much more rain in May since 1968

Much less rain in August since 1968



More thermal mass, cooler water

Less thermal mass, warmer water, shorter hydroperiod

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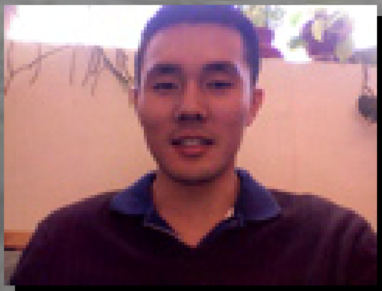
  - The Juenger lab





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