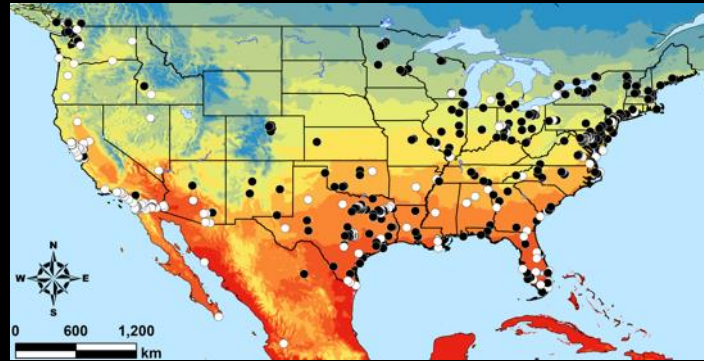


# Too hot to trot? Climate & color adaptation in dragonflies



Michael P. Moore, Ph.D.



@moore\_evo\_eco



CASE WESTERN RESERVE  
UNIVERSITY EST. 1826

Ohio Dragonfly Conference – June 1, 2019

# ***Male animals often develop conspicuous, eye-grabbing traits***



*Lizard Dewlaps*

PC: Nat. Geo.



*Beetle Horns*



*Peacock tails*

“The sight of a feather in a peacock’s tail, whenever I gaze at it, makes me sick!” - Charles Darwin, 1860

# ***Producing these traits provides mating advantages***



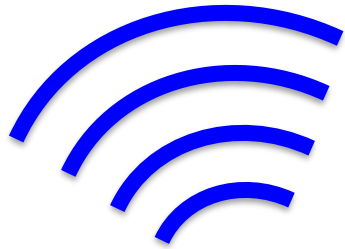
Compete with rivals for access to mates

***“male-male competition”***



Directly attract potential mates

***“female choice”***



***Larger, more conspicuous breeding traits usually help males get mates***

***If it's so beneficial to have very large breeding traits, why are individuals within a species so different?***



Johnston et al. 2013, *Nature*

PC: L Henderson

PC: S. Callander

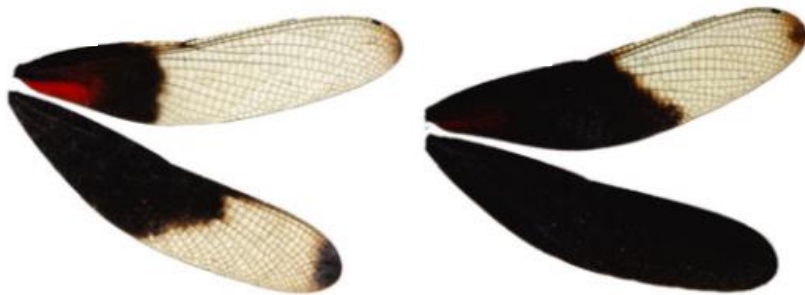
# Odonates are remarkably variable



PC: J. Jones



PC: jenniferf4



Smoky Rubyspot  
(*Hetaerina titia*)

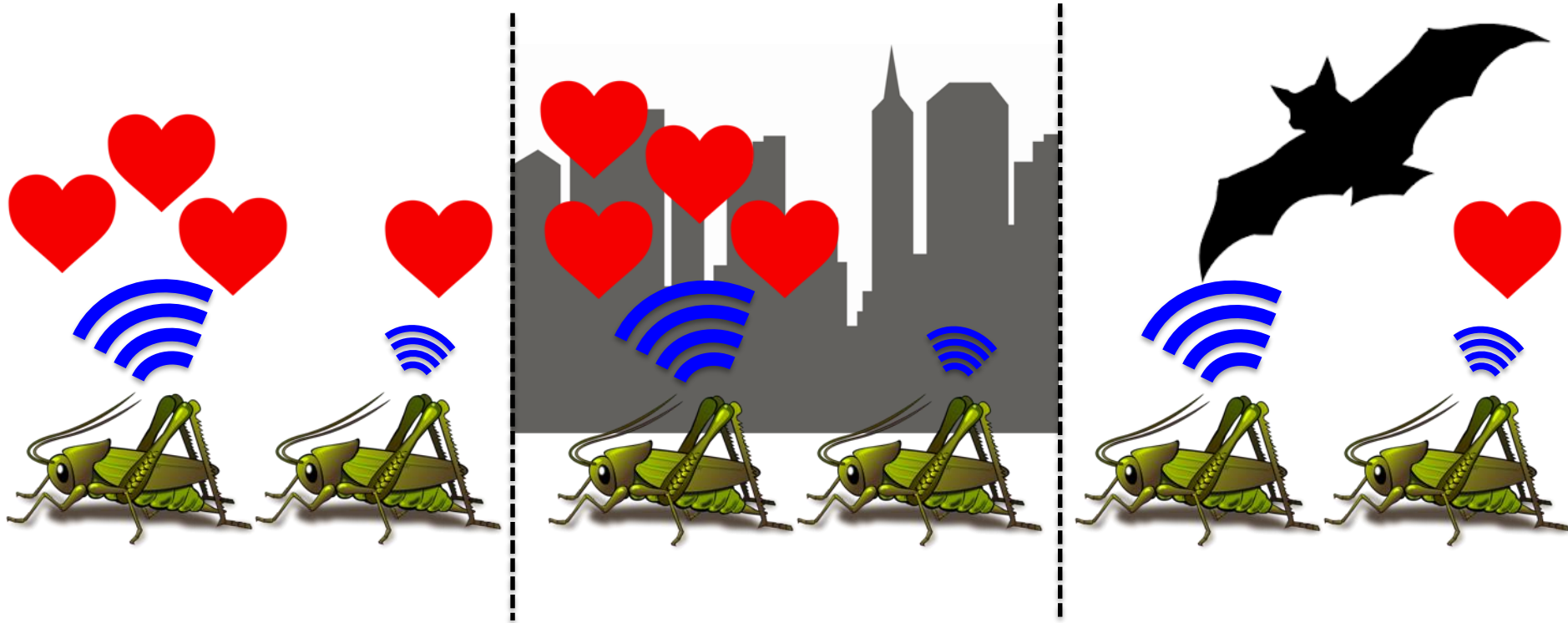
Drury et al. 2015, *J. Evol. Biol.*



Blue Dasher  
(*Pachydiplax longipennis*)

Moore & Martin 2016, *J. Evol. Biol.*

# *Environment determines how good or bad it is to be very conspicuous*



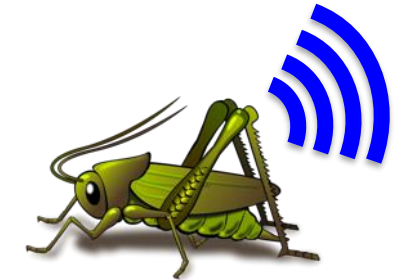
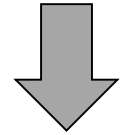
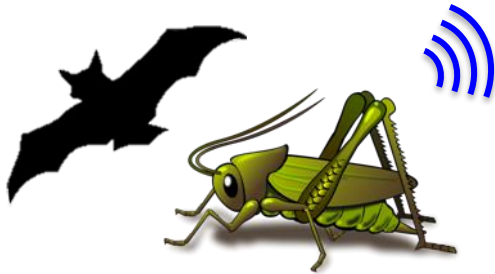
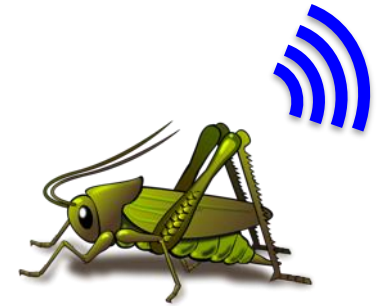
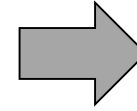
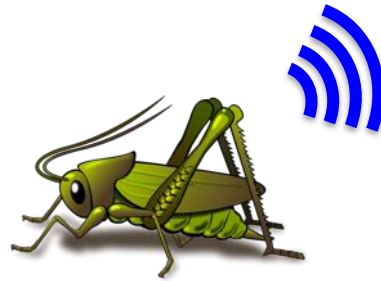
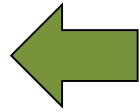
Larger traits improve mate attraction and/or competition with rivals

In some, habitats it's better to be even bigger or louder

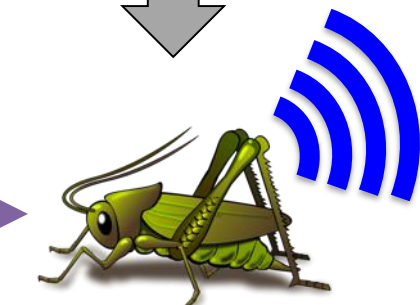
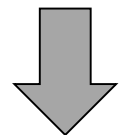
...while others that's really dangerous

“Adapt” to riskier habitats by becoming quieter

“Adapt” to safer habitats by becoming louder



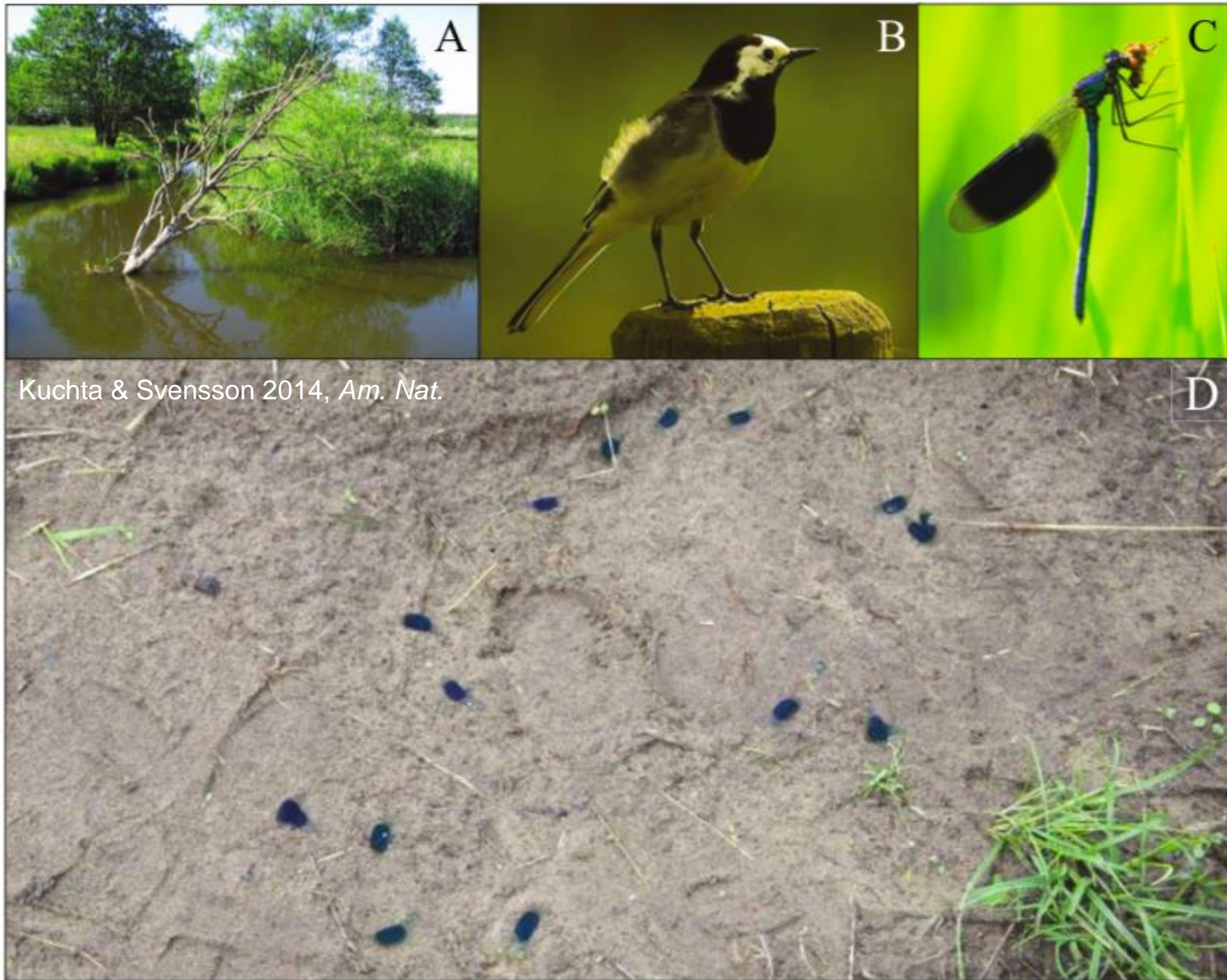
***Adaptation & Diversification***



“Diversify”



# ***Odonates are models for studying adaptation and diversification***

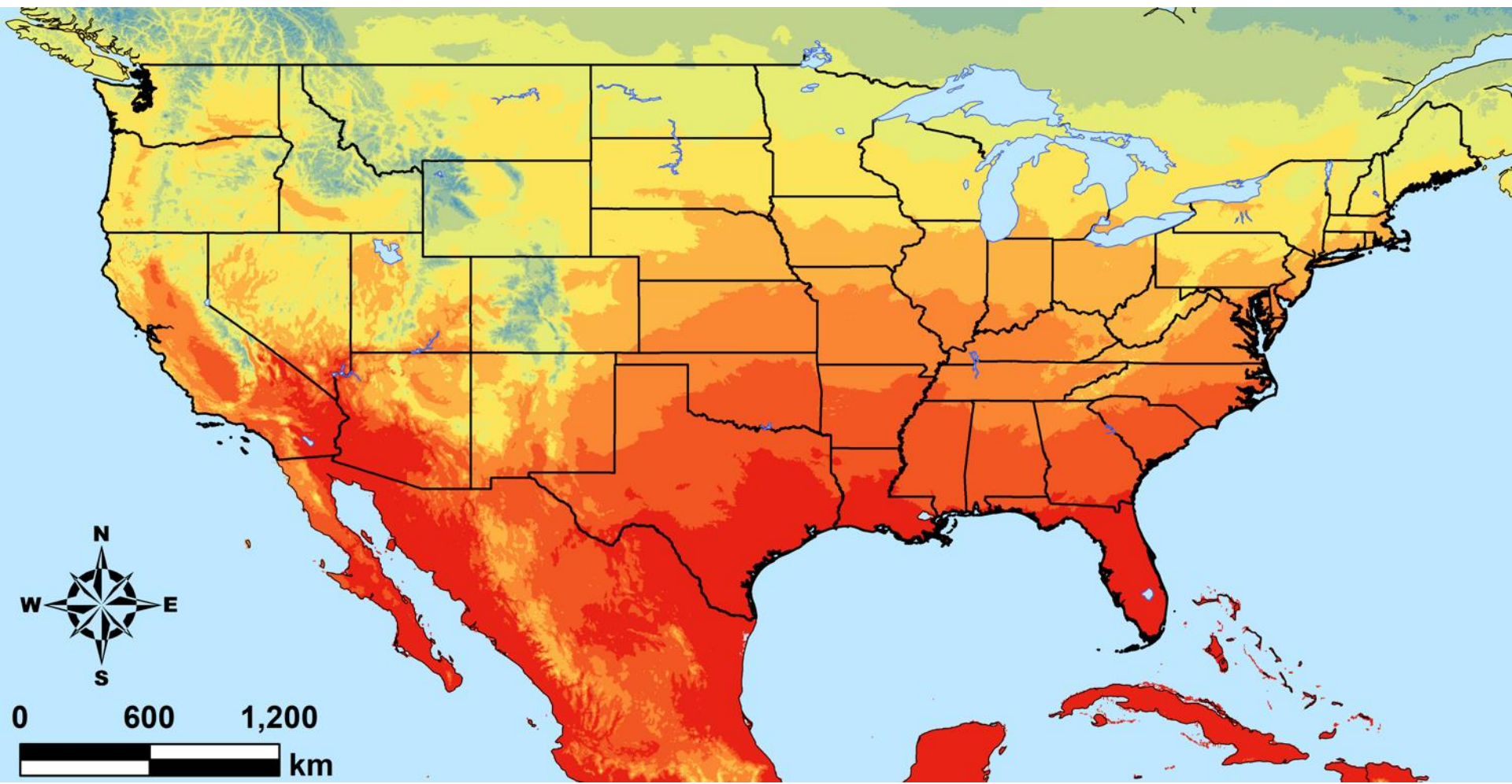


*Wing color patterns in banded demoiselles (*Calopteryx splendens*) adapt to be smaller in habitats with wagtails*

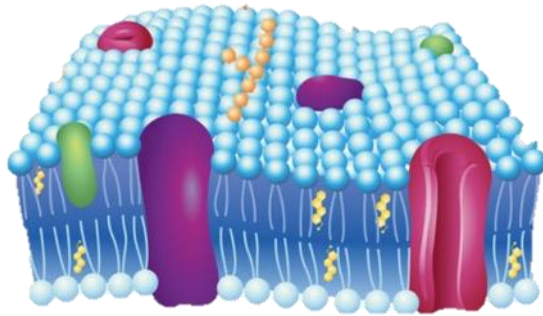
***How do breeding traits **adapt** to different kinds of habitats?***

***How does **adapting** to different habitats cause breeding traits to **diversify**?***

***Species often encounter considerable differences in temperature across their ranges***

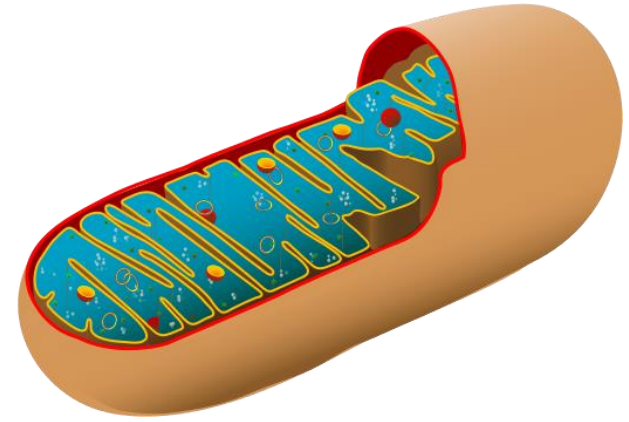


*Destabilized cells*



PC: cK-12

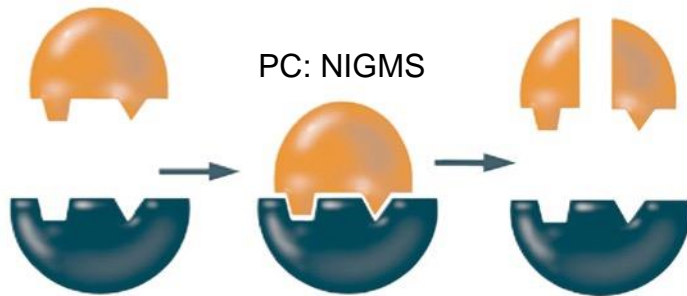
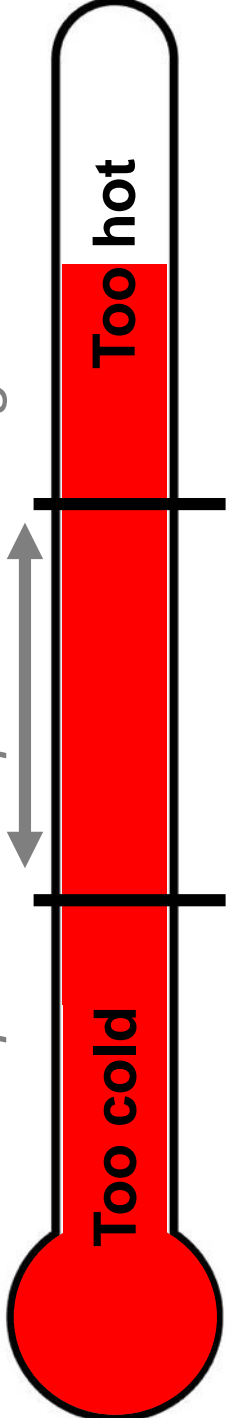
*Overly fast metabolism*



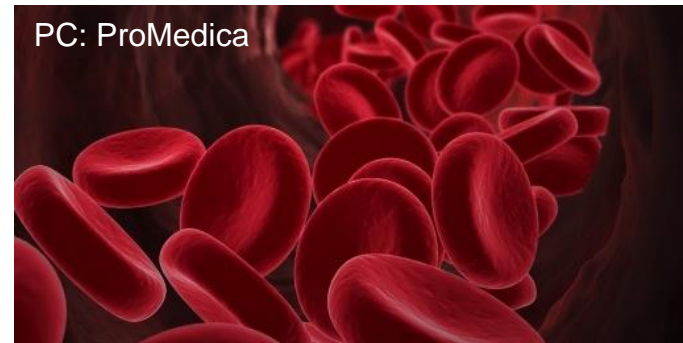
# ***Temperature controls many of an animal's physiological processes***

*Acclimate and/or adapt to maintain moderate body temperatures*

*Optimal Temperature Range*



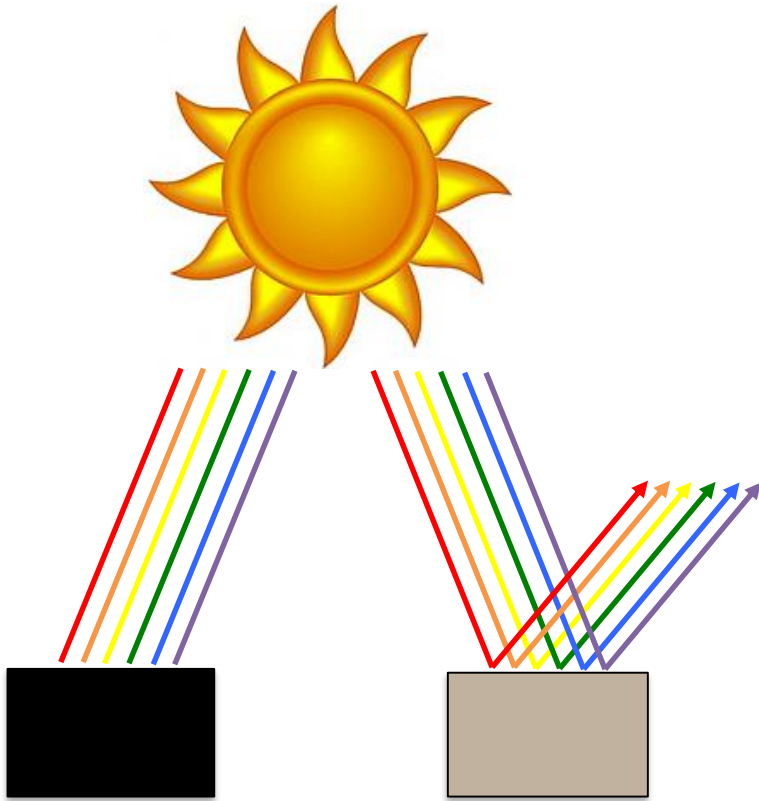
*Slow biochemical reactions*



*Viscous circulatory fluids*

PC: ProMedica

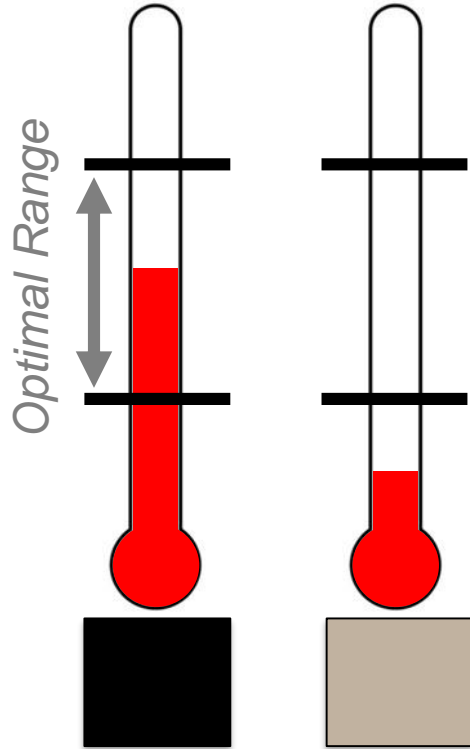
# ***Breeding colors can complicate things***



*Dark coloration absorbs more light, which gets converted into body heat*

*We experience this all the time with light vs dark colored clothes*

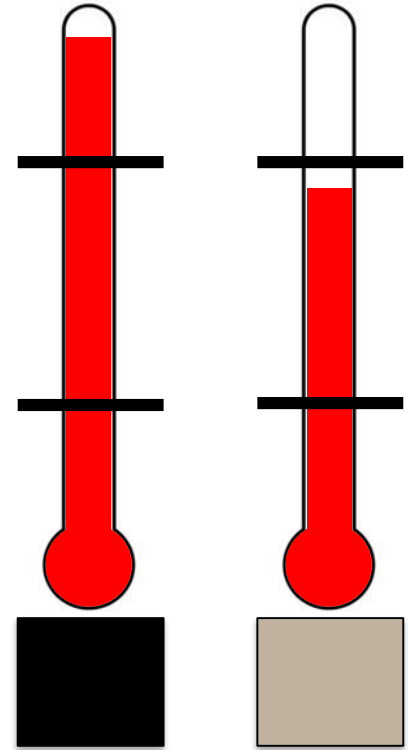
## Cool Conditions



*Sometimes this helps  
because it warms the  
animal up*

*Other times it's harmful  
because it causes the  
animal to overheat*

***Warm Conditions***

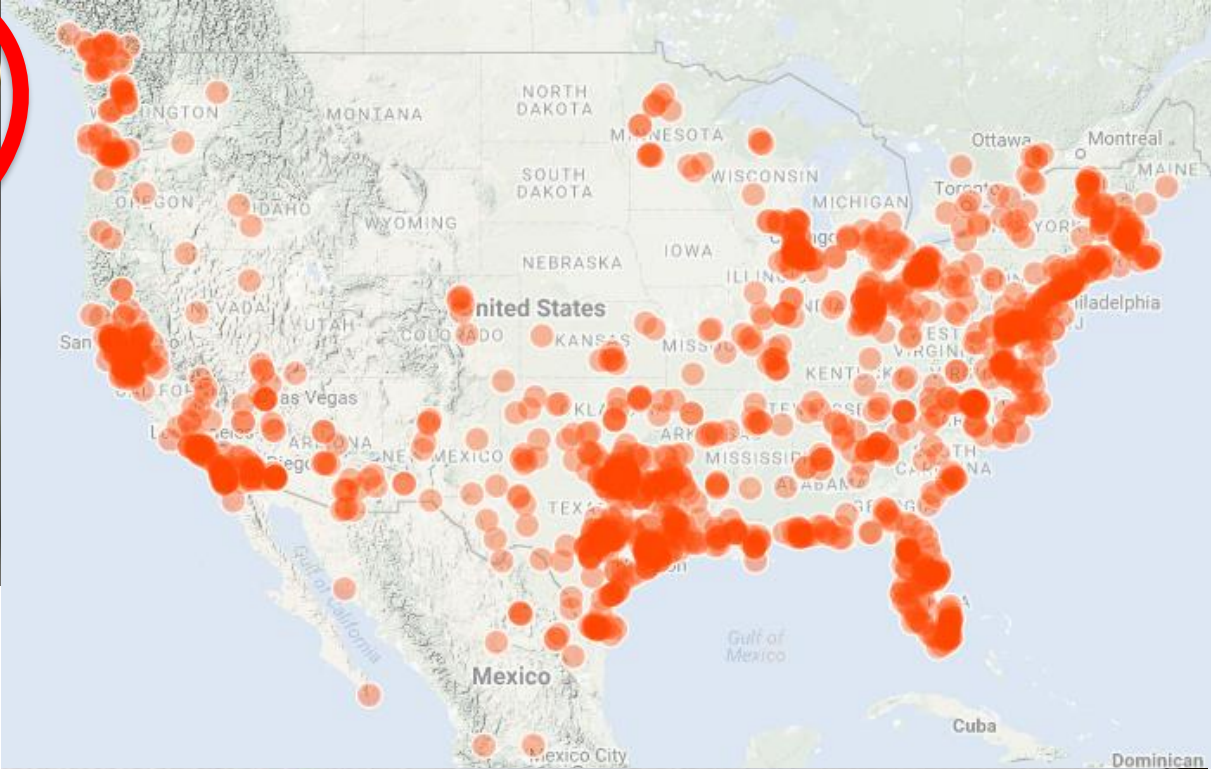


# Could breeding colors be *adapting* to differences in temperature?



Does *adapting* to different temperatures cause breeding traits to *diversify*?





PC: L. Clark

# Blue Dasher

*Pachydiplax longipennis*





PC: B. Bull

***Males***



PC: E. Isley

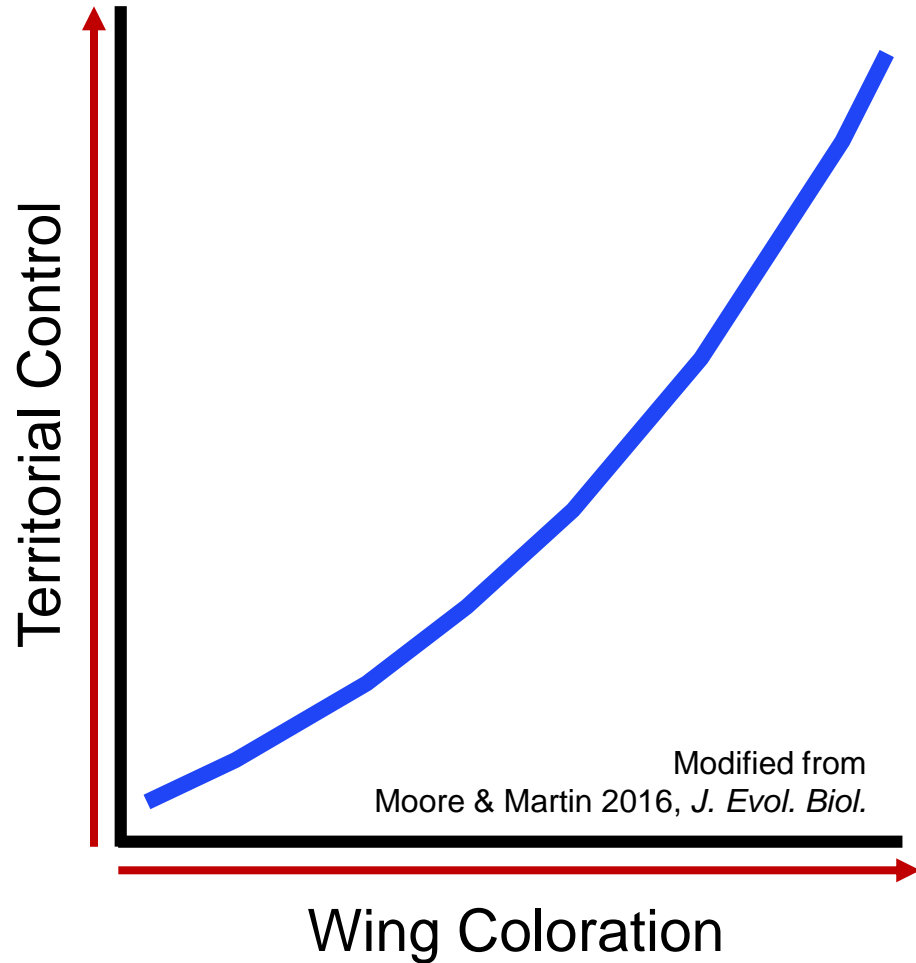
***Females***

***There's a ton of variation in wing color among males  
within a single population***

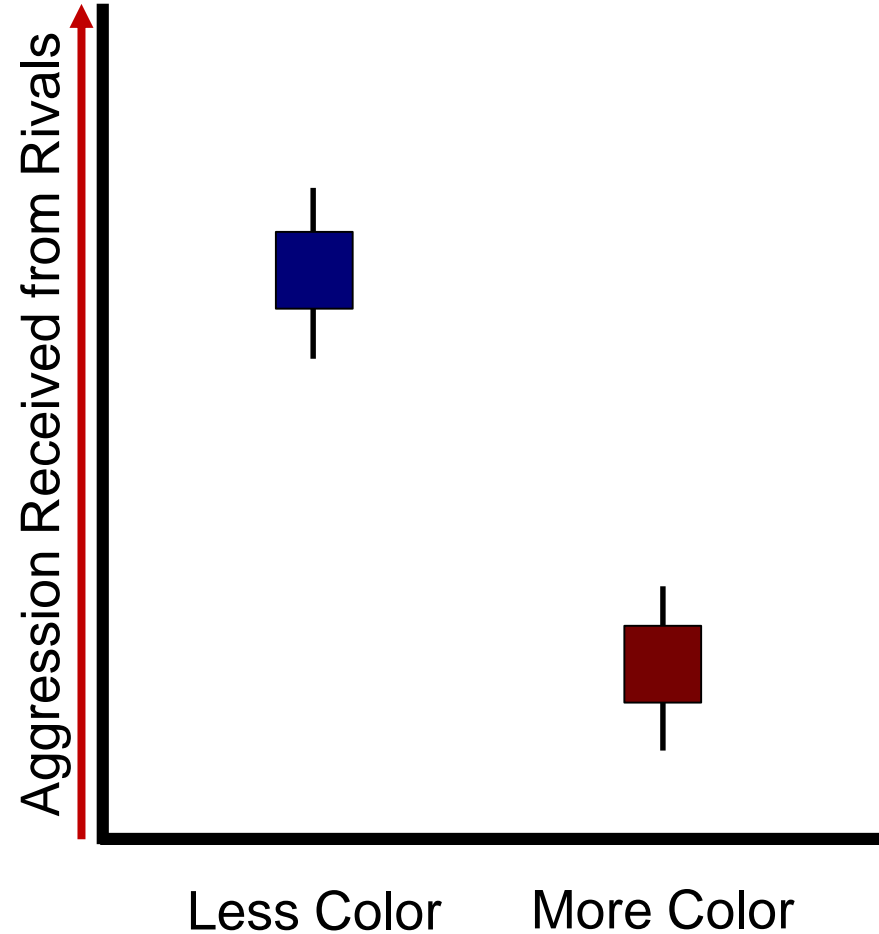


***CWRU Squire Valleevue Farm – August 2018***

# So, what is the wing color doing?

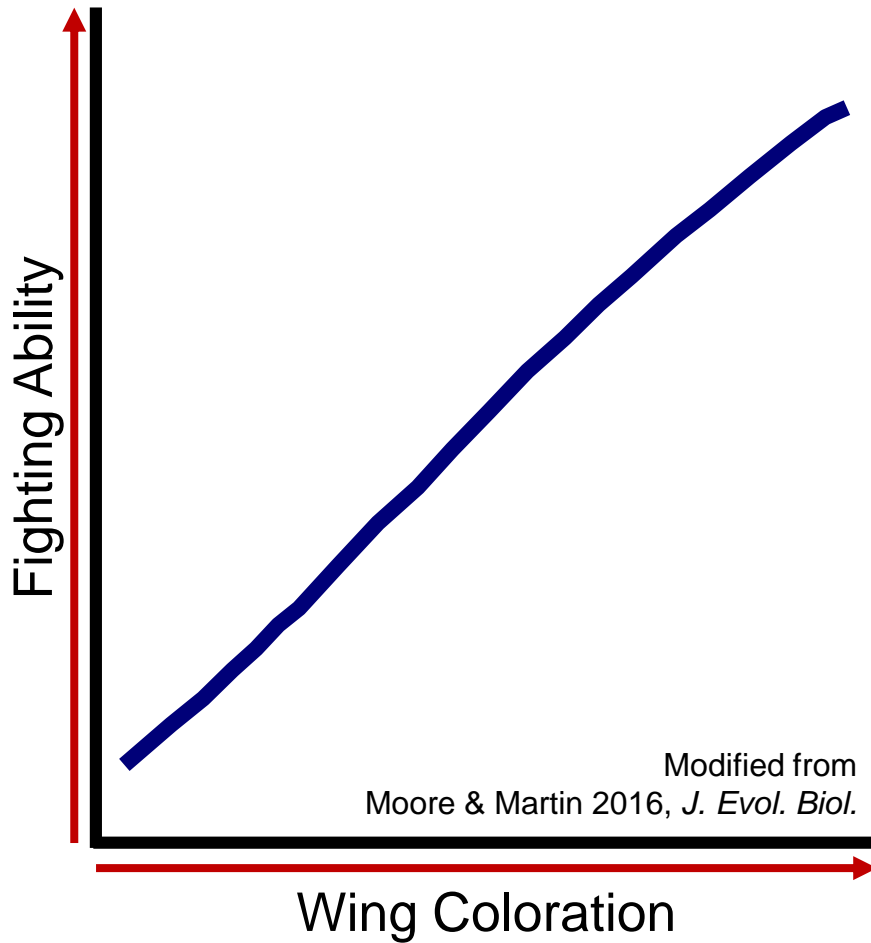


Helps males control breeding territories for longer throughout the day

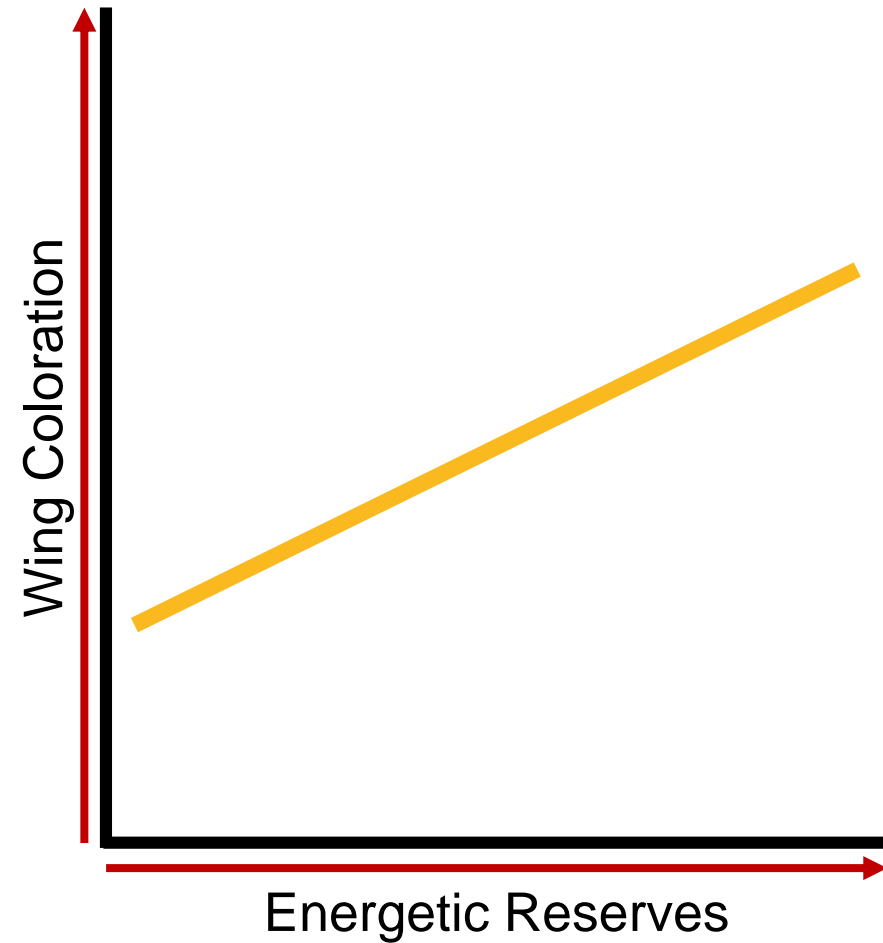


Males are scared of rivals with a lot of color – prevents fights from even starting

# Why are males scared of rivals with a lot of color?



Males with a lot of color are good fighters



Only males with a lot of energy can produce a lot of color

***Wing color helps males control breeding territories for longer by scaring off weaker rivals and preventing costly fights from starting***

PC: H.O. Salas



*Pachydiplax longipennis*



PC: daniel\_r

*Hetaerina americana*

***Wing color in odonates is commonly used in this purpose***

***The extent of wing coloration varies widely among males in eastern United States...***



***...yet, males in the western United States allegedly produce little to no wing coloration at all***



# Could **adapting** to different temperatures have caused geographic **diversification** in wing color?

1. Does external temperature change the costs and benefits of male wing color?

2. Do males produce different amounts of wing color where it's hot versus where it's cold?

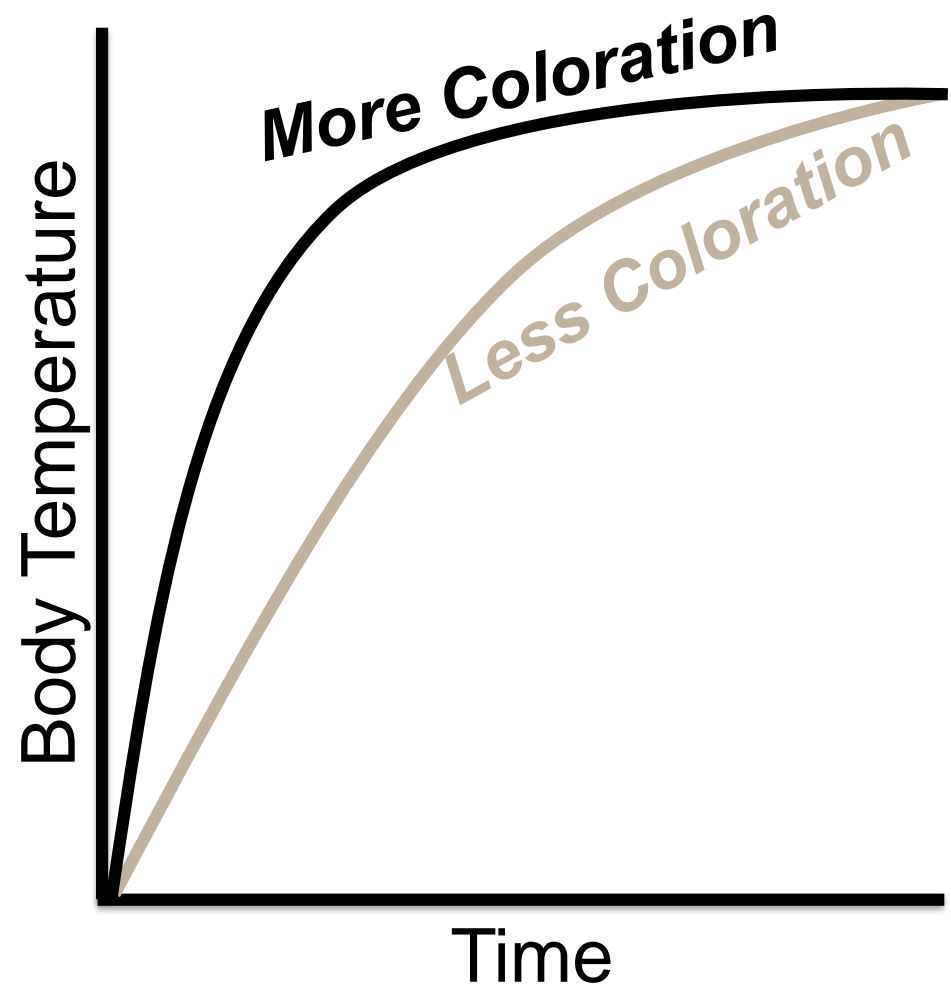
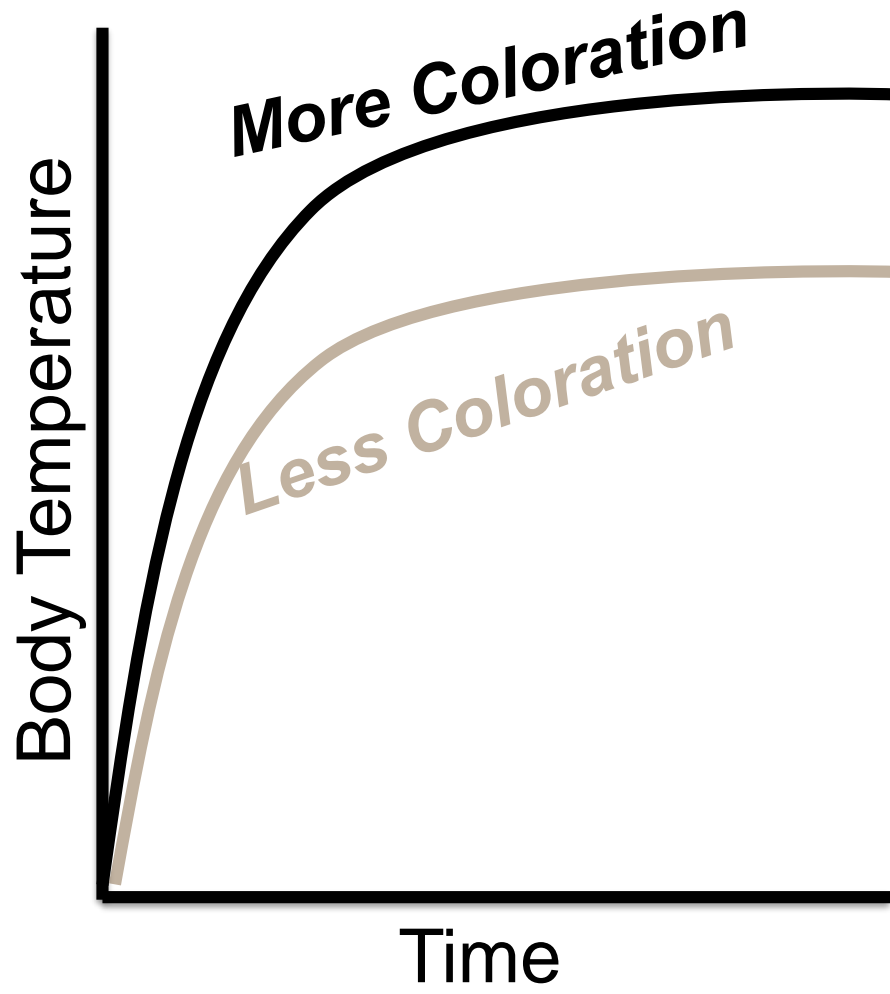
---

3. Did males gain wing color or lose it?

4. How will wing color adapt and diversify as the planet continues to warm?



# *Does wing coloration affect male body temperatures?*





Males with varying levels of wing coloration



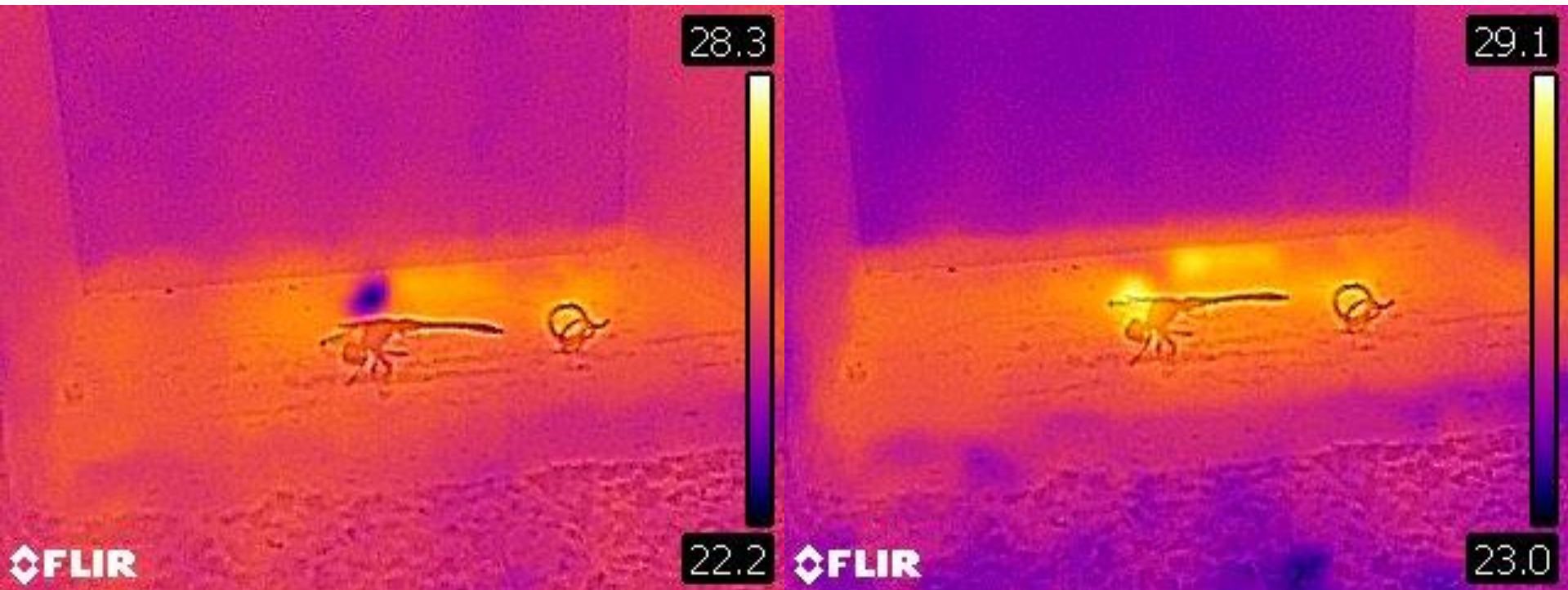
Tethered and warmed them under a lamp



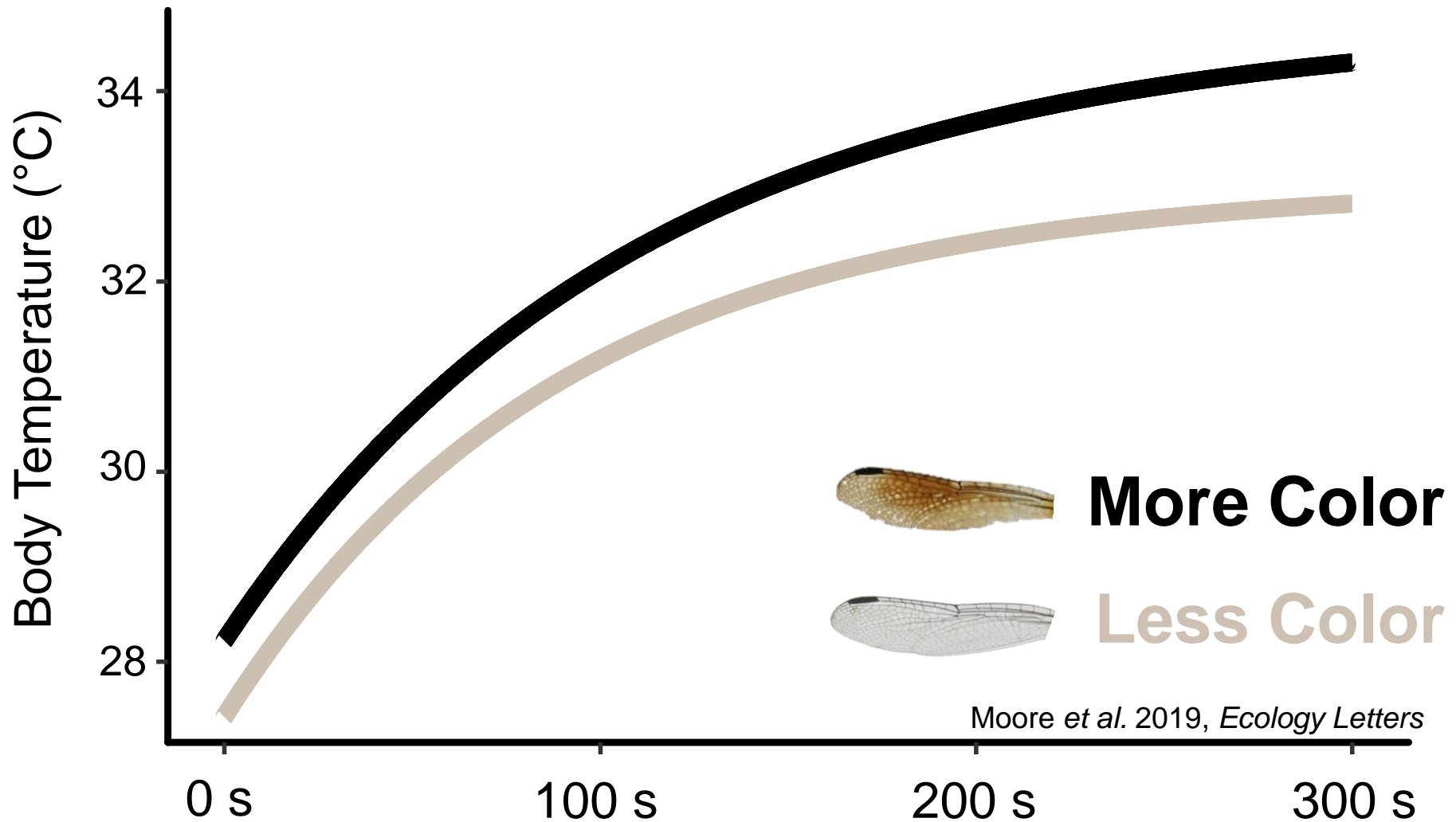
Measured body temperature every 30 seconds for 5 minutes

***After 30 seconds***

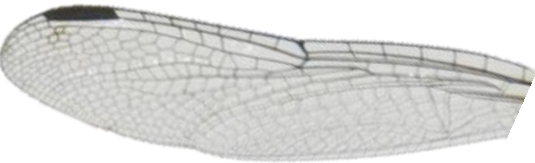
***After 120 seconds***



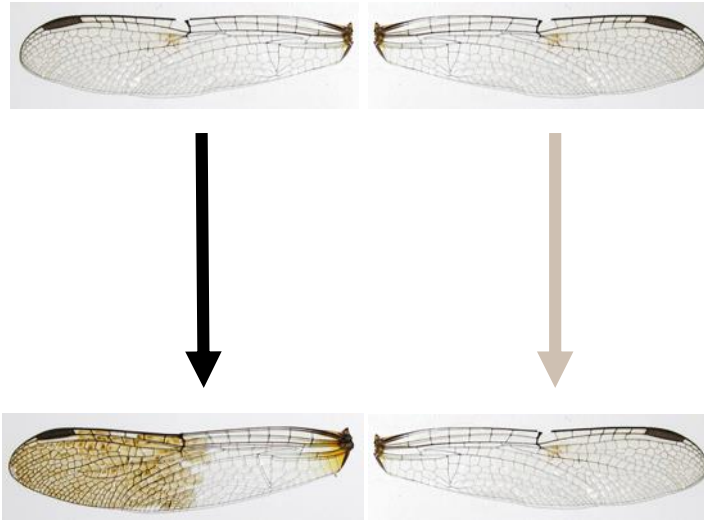
# ***Males with more wing coloration reach almost 2 °C warmer***



*But is wing color **CAUSING** these differences?*



Caught males  
with little to no  
pigmentation



Matched males in pairs  
by amount pigment

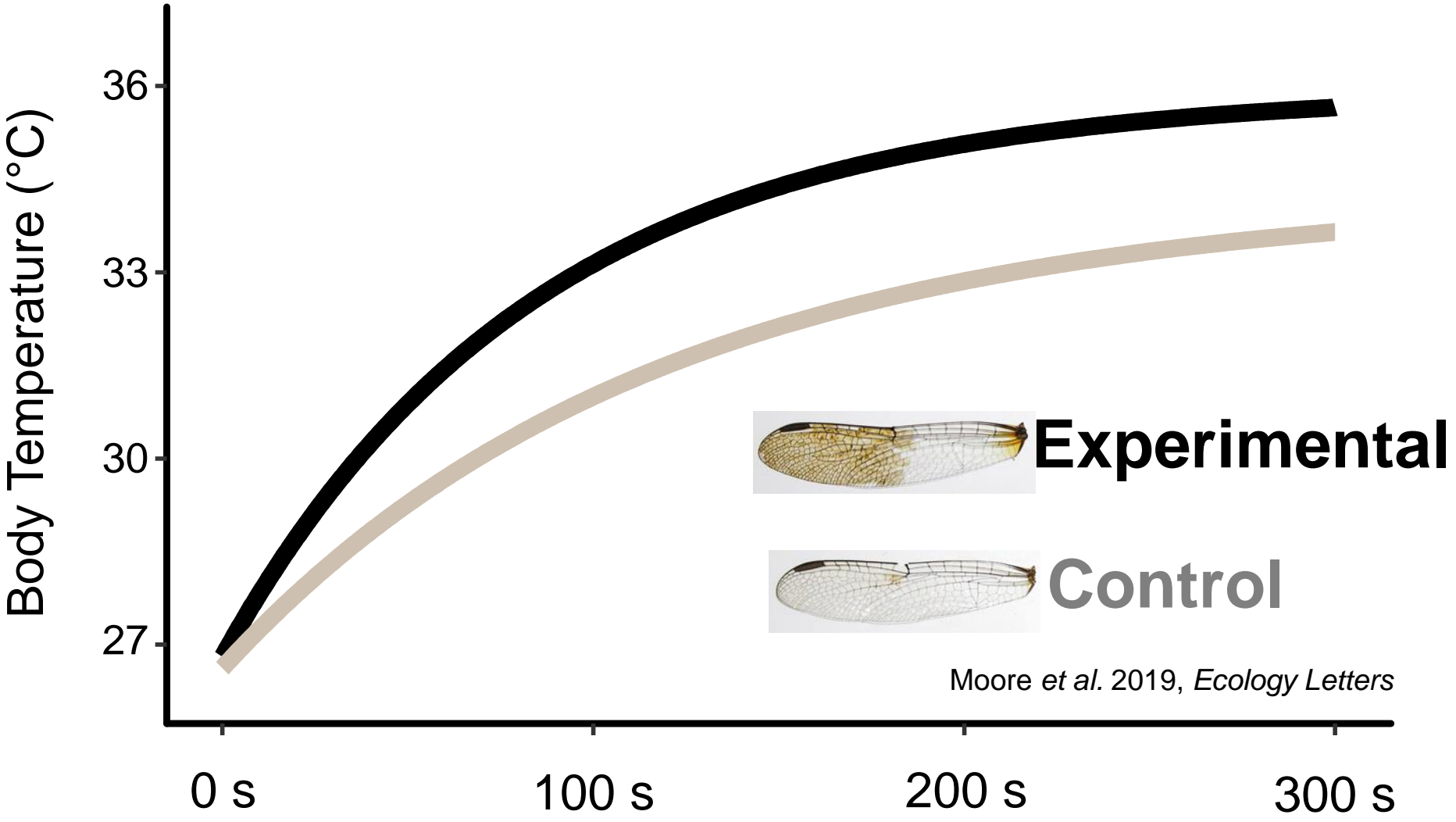
**Experimental:**  
Increase pigment with  
felt tip marker

**Control:**  
Marker on same area of wing  
- "colorless blending ink"



Tether  
Heat  
Measure!

# ***Giving males more wing color heats them up too!***



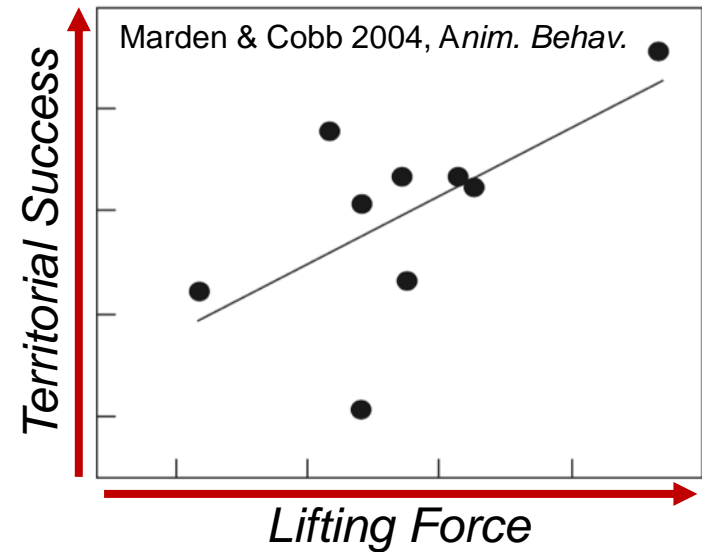
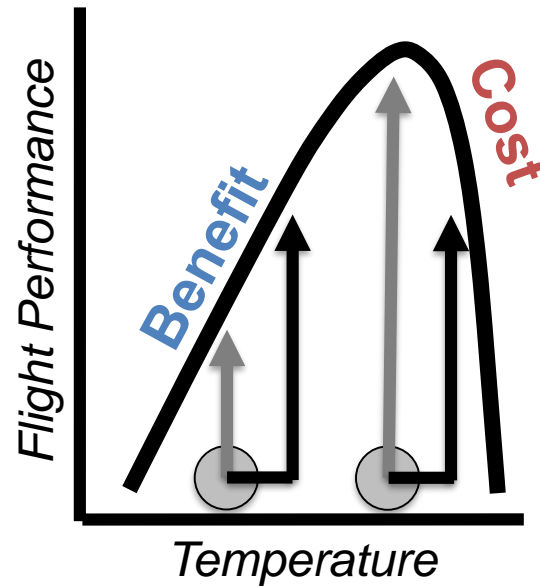
Moore *et al.* 2019, *Ecology Letters*

***Having more wing color causes  
males to **heat up** by 1-2 °C***

***What are the consequences of  
an extra 1-2 °C?***

# ***Relationship between temperature and flying ability***

## ***“Thermal Performance Curve”***



***How much does being 1-2 °C hotter affect flight performance?***



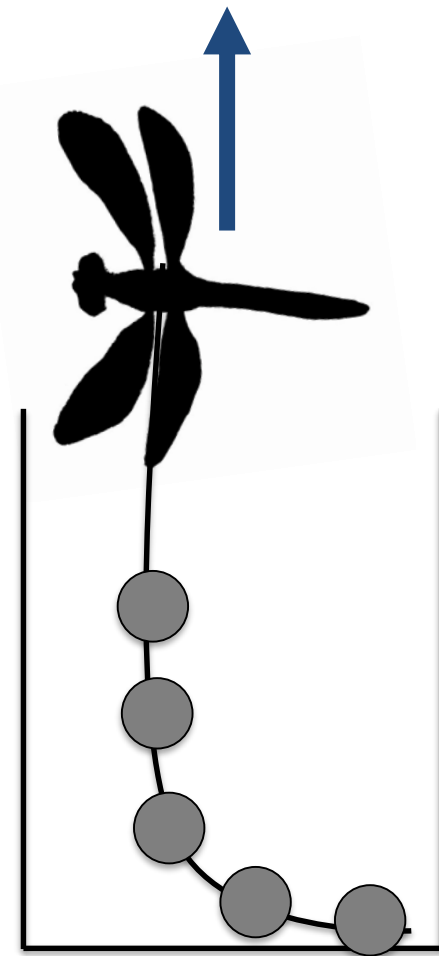


PC: E. Attaway

Caught males



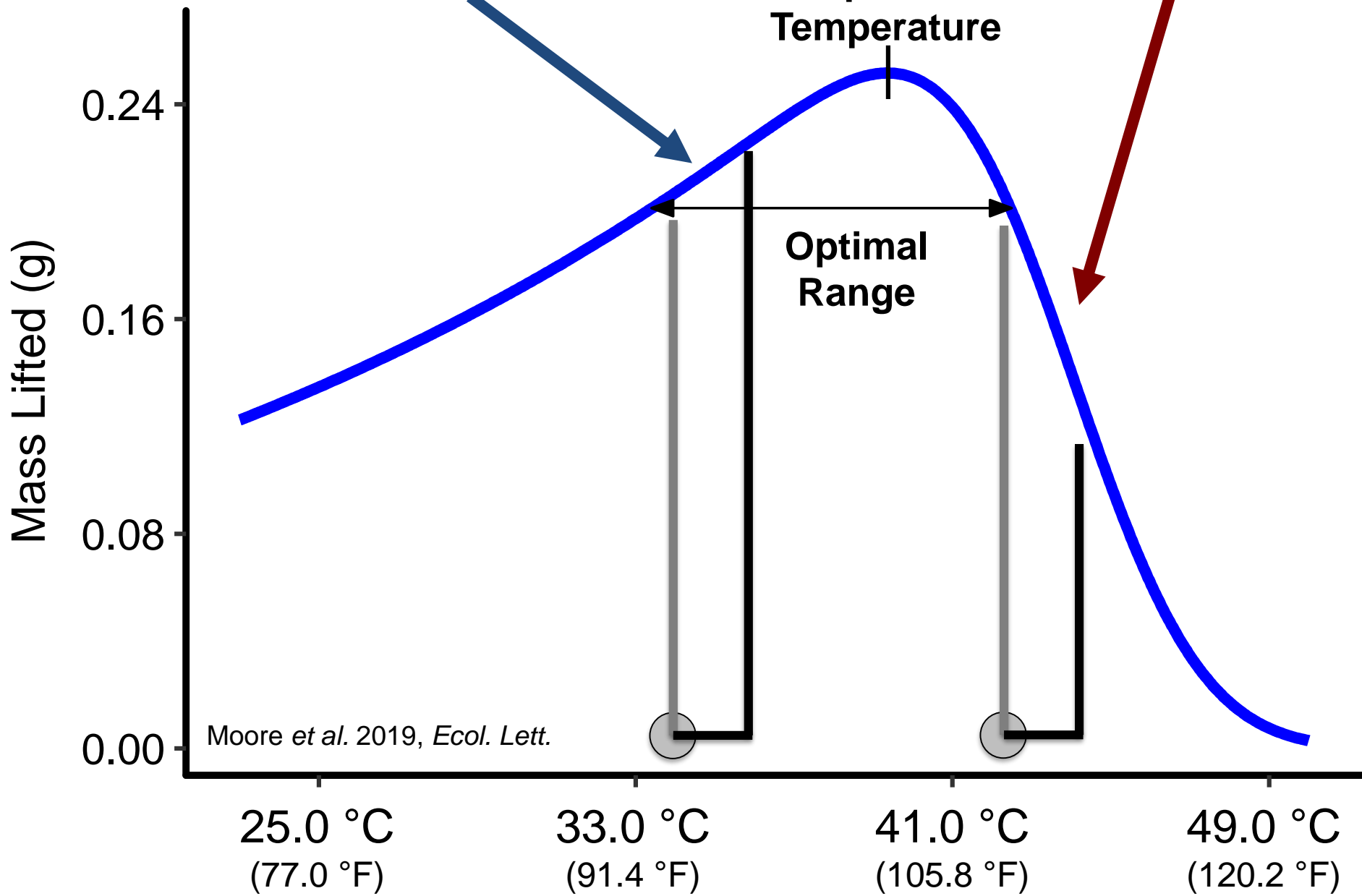
Acclimated to one of  
seven temperatures:  
25, 29, 33, 37, 41, 45, 49



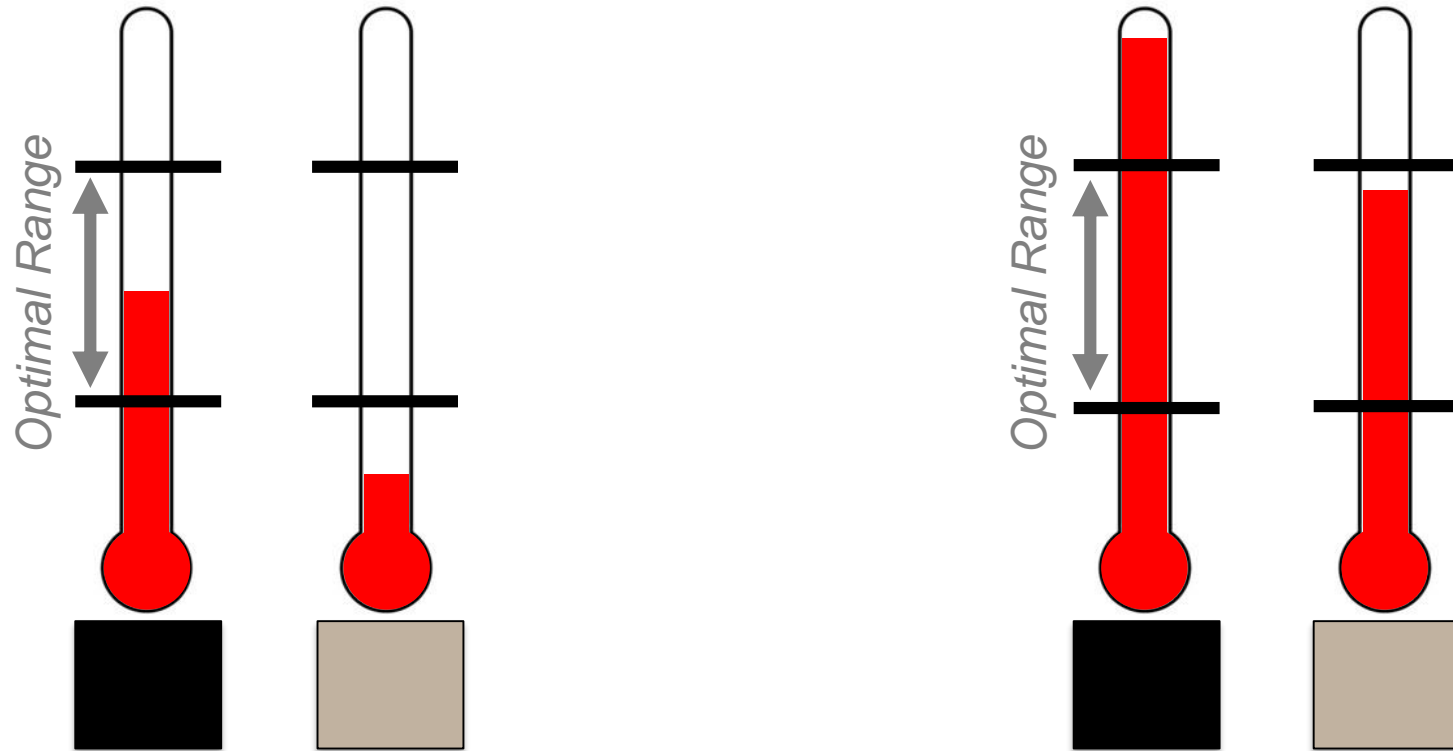
Measured  
average mass  
that each male  
lifted (3 trials)  
during initial  
take off

*1-2 °C warming improves flight  
by ~8% at cool temps...*

*...but reduces it by  
~32% at hot temps*



***1-2 °C heating helps males a little when they are cold, but hurts them a lot when they are warm***



***Can we see evidence of this in the field?***

*Caught,  
photographed, &  
measured*



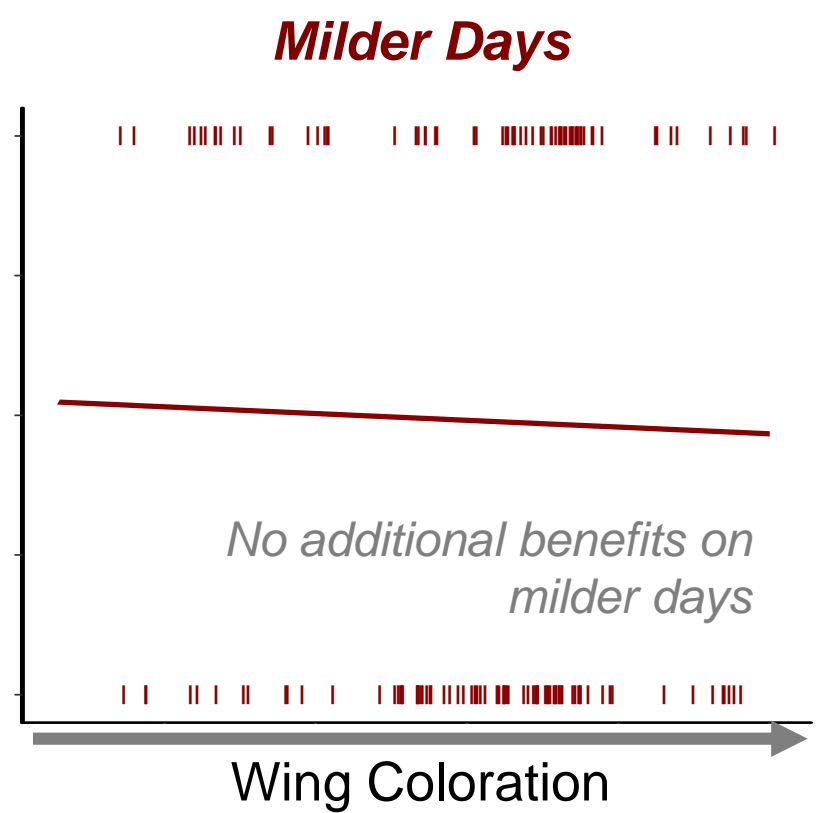
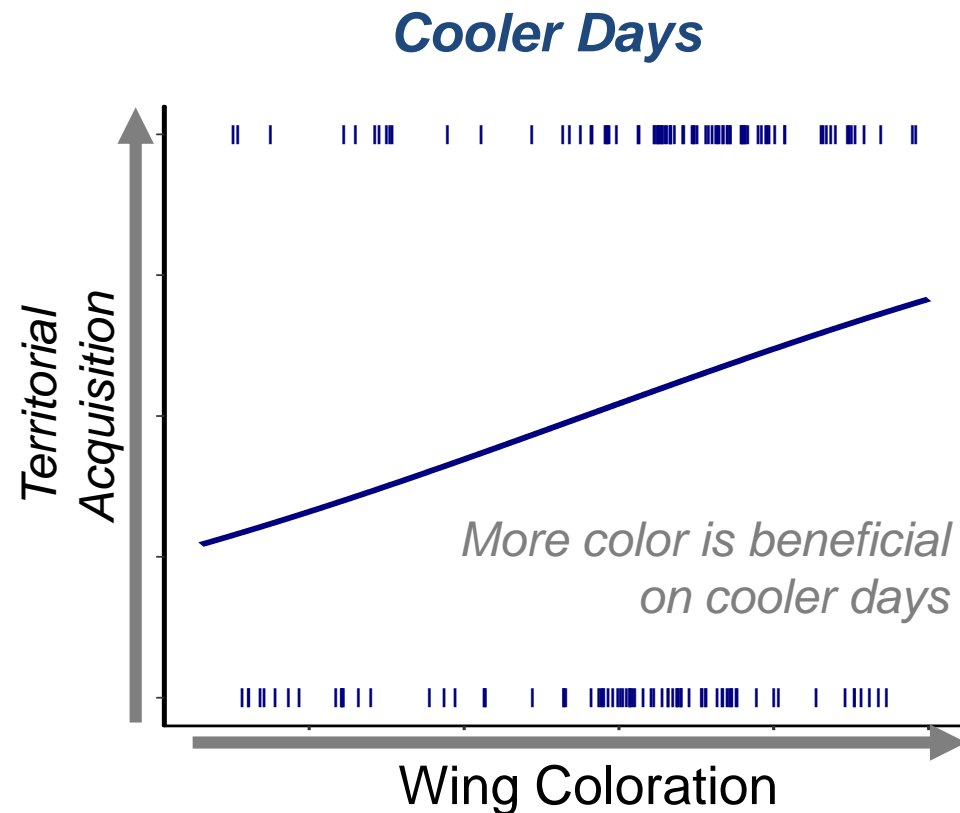
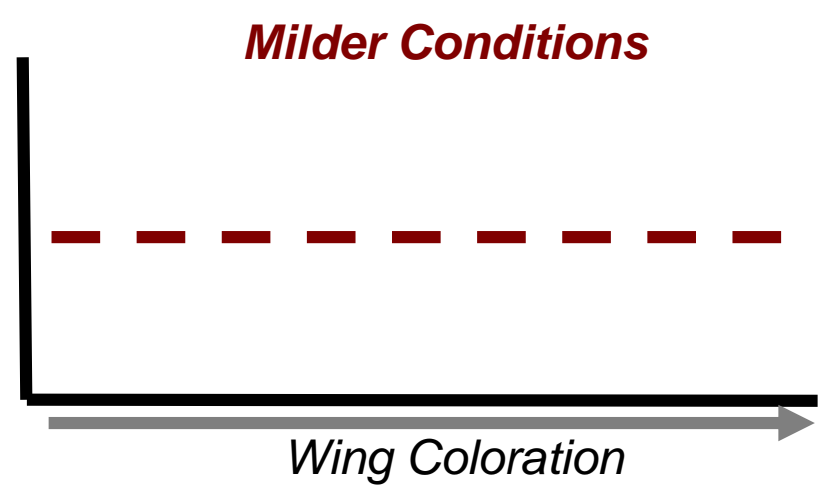
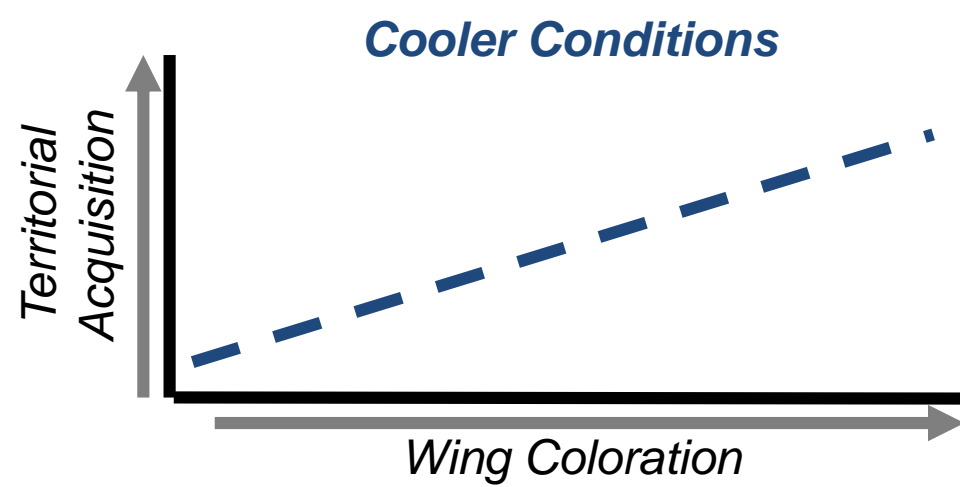
*Uniquely marked &  
observed territorial  
interactions every day*



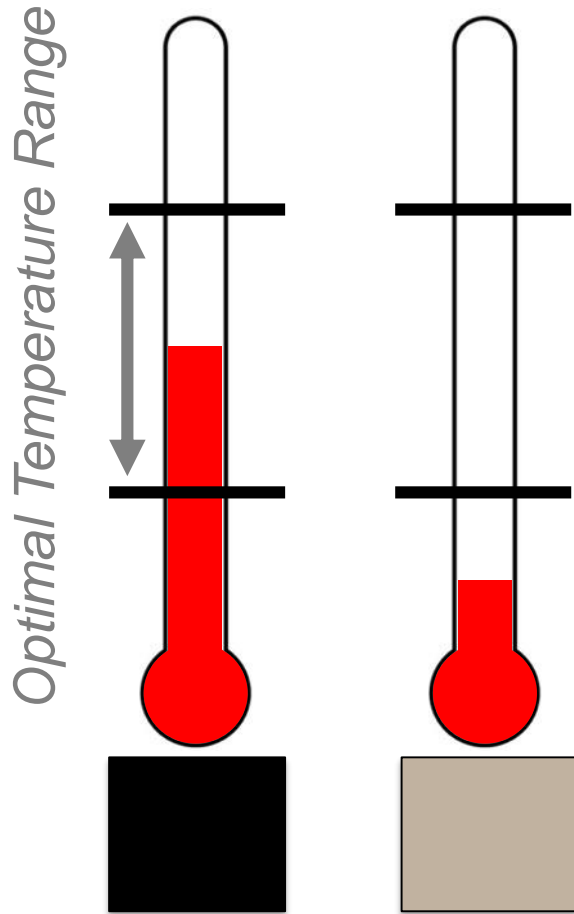
*Recorded the  
temperature for each  
day during that season*



***Are males with more wing coloration better at winning  
and controlling breeding territories on colder days?***



*Cooler Conditions*



***Better to have more color when it's colder!***

# Could **adapting** to different temperatures have caused geographic **diversification** in wing color?

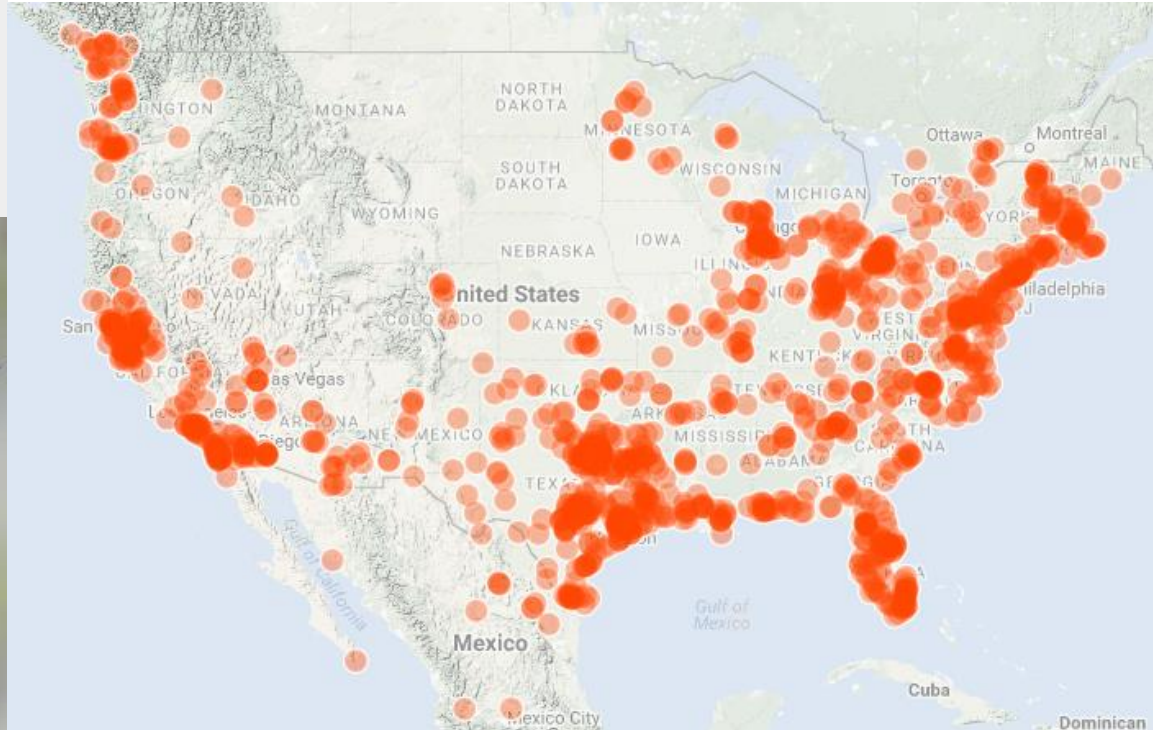
1. Does external temperature change the costs and benefits of male wing color? **YES**

2. Do males produce different amounts of wing color where it's hot versus where it's cold?

---

3. Did males gain wing color or lose it?

4. How will wing color adapt and diversify as the planet continues to warm?

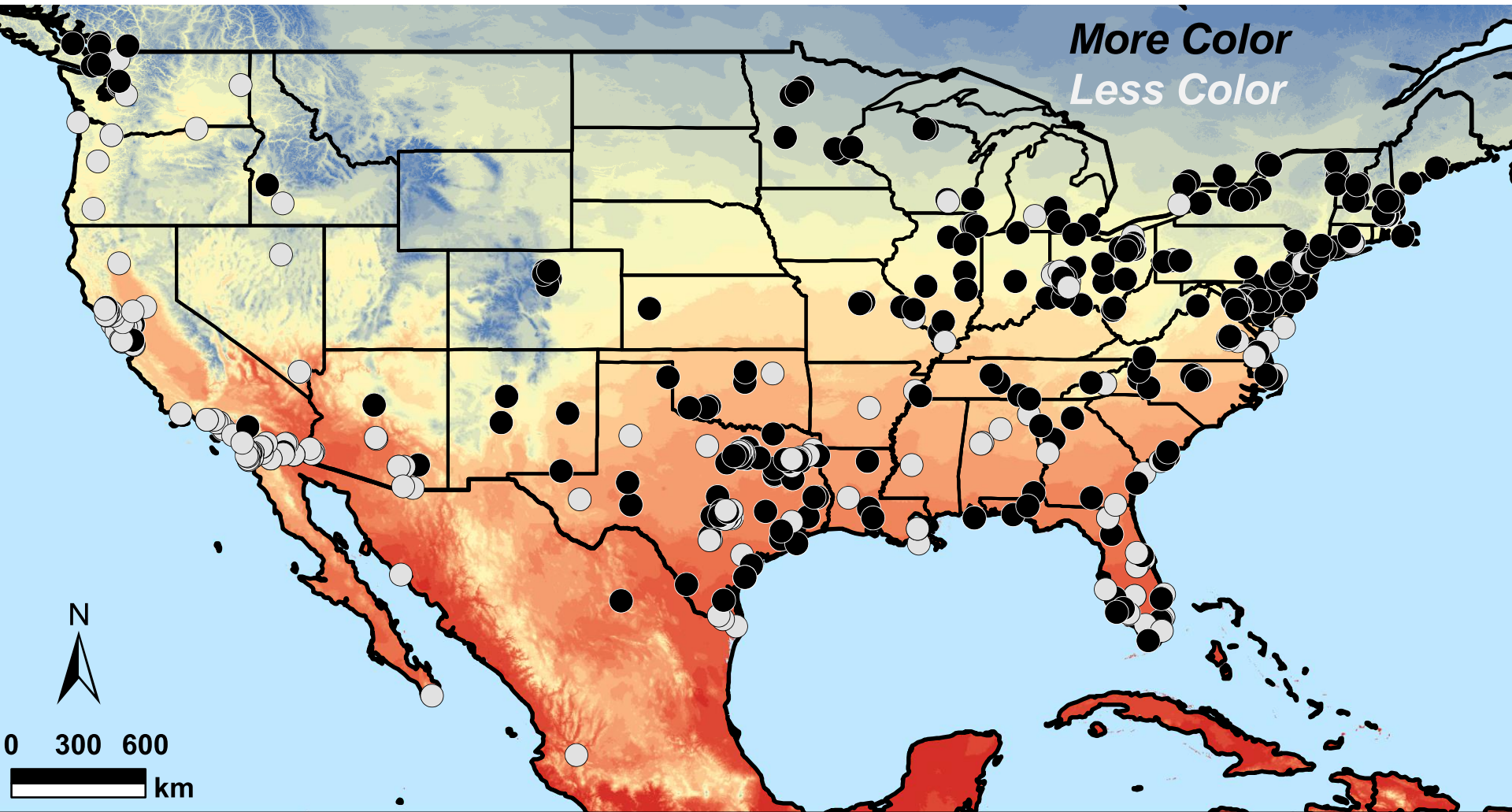


*540 geo-referenced photographs of males from iNaturalist*

*More vs Less Color*

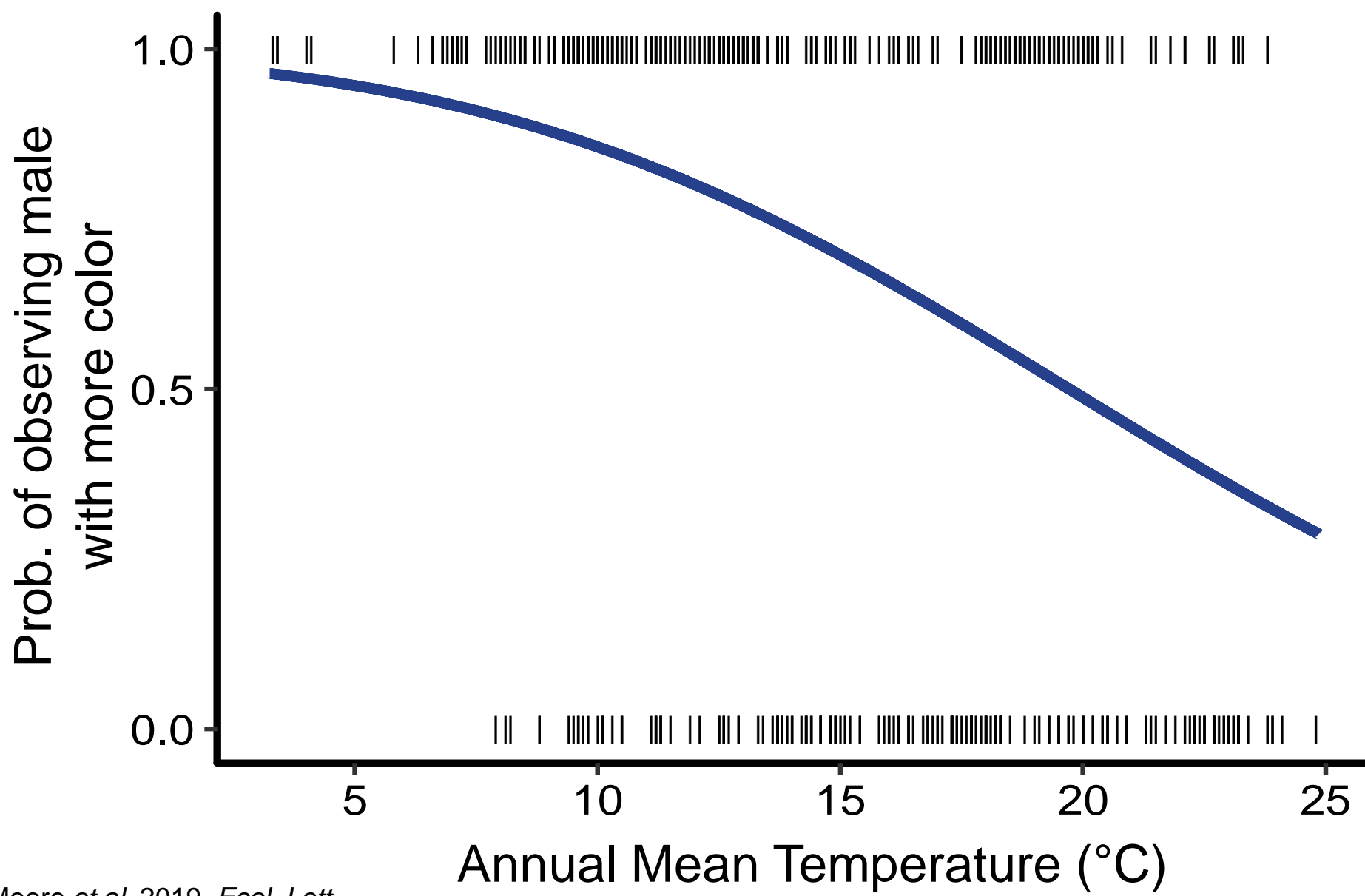


***Males almost always have extensive coloration in the northern and eastern portions of the range...***



***... but usually have greatly reduced coloration in western and southern regions!***

***Males tend to have more color in cool areas but usually have less color in the warmest regions***

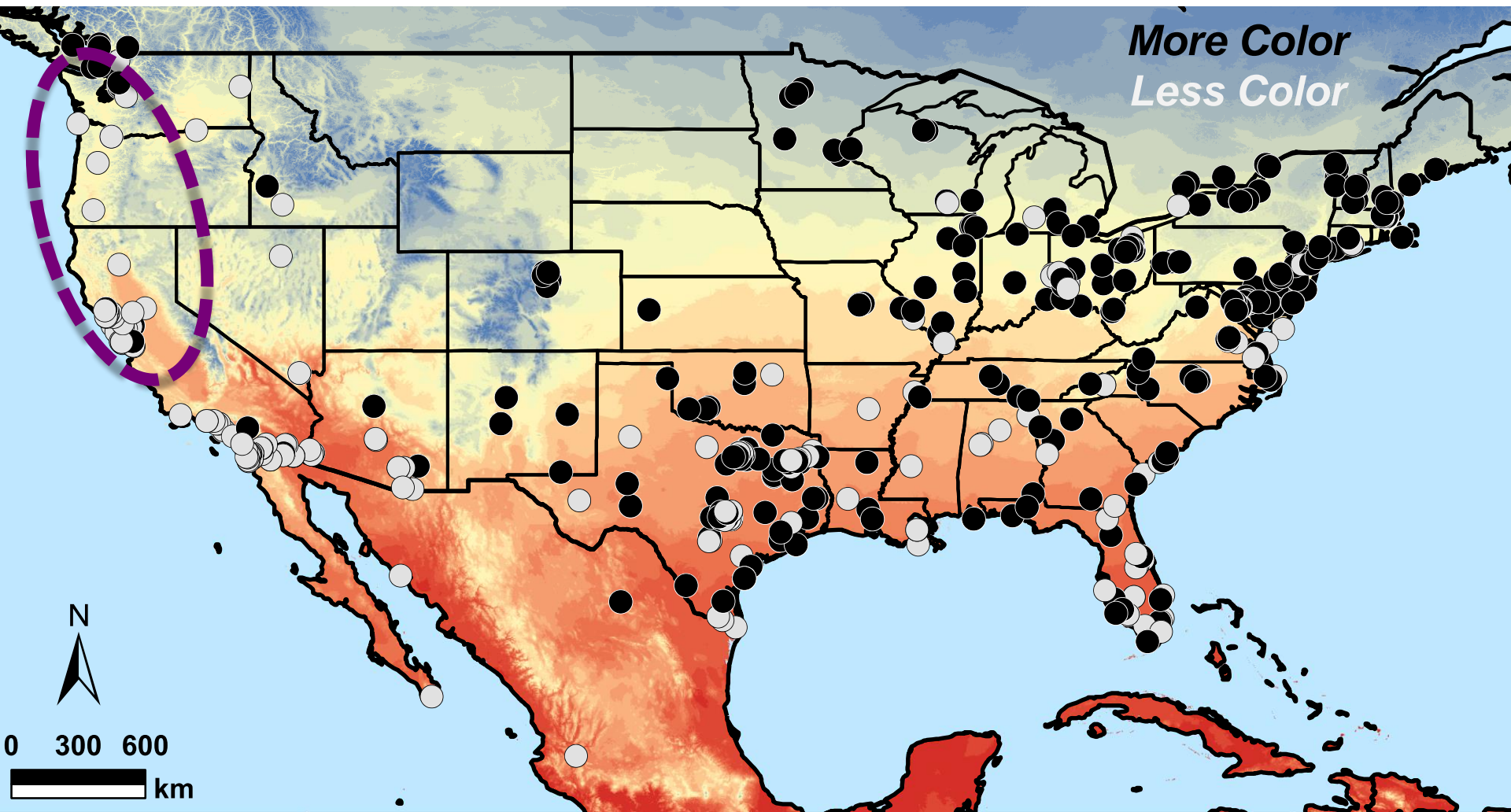


Moore et al. 2019, *Ecol. Lett.*

***Amount of wing color is associated with temperature across the species' range***

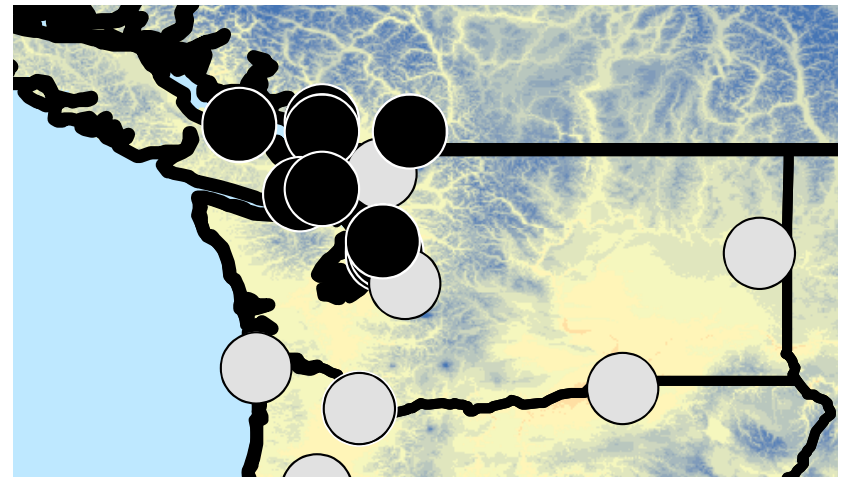
***Exactly what we'd expect if adapting to temperature causes wing color to diversify across North America***

***Geographic pattern more complicated than just adapting to different temperatures across North America***



***e.g. on the Pacific Coast, males don't get much wing color where it's cold enough that they could***

***Something weird is going on on the Pacific Northwest. Have wing color in BC, but not in WA***



Seattle, WA



Vancouver, BC



***Overall, probably lots of factors involved in the geographic differences of male wing color, but adapting to temperature is almost certainly one of them***

# Could **adapting** to different temperatures have caused geographic **diversification** in wing color?

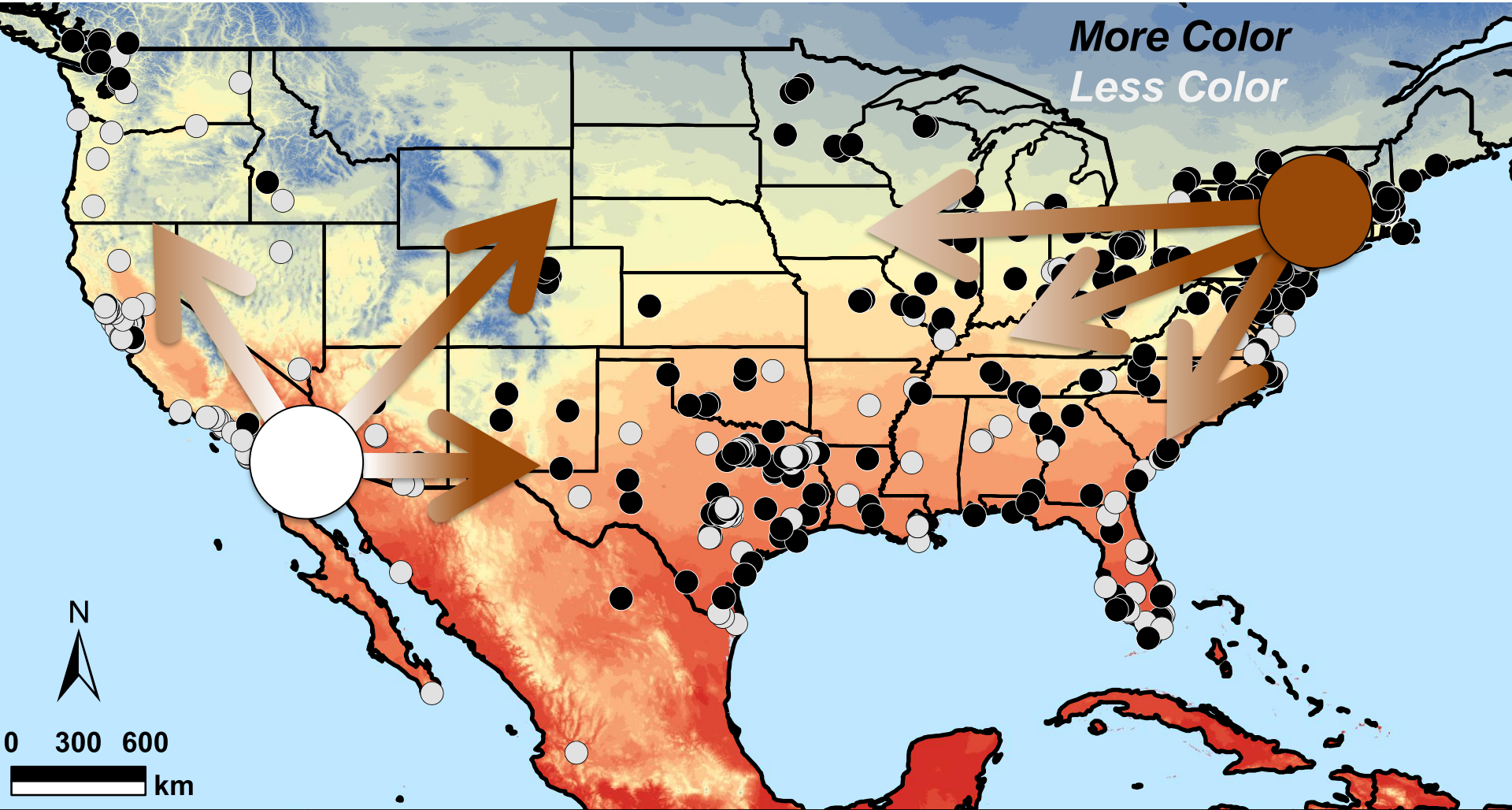
1. Does external temperature change the costs and benefits of male wing color? **YES**

2. Do males produce different amounts of wing color where it's hot versus where it's cold? **YES**

---

3. Did males gain wing color or lose it?

4. How will wing color adapt and diversify as the planet continues to warm?



*Did they GAIN wing color as they moved from cold regions to warm ones?*

*Did they LOSE wing color as they moved from warm regions to cold ones?*



***Recall that North America was covered in glaciers until 20,000 years ago***



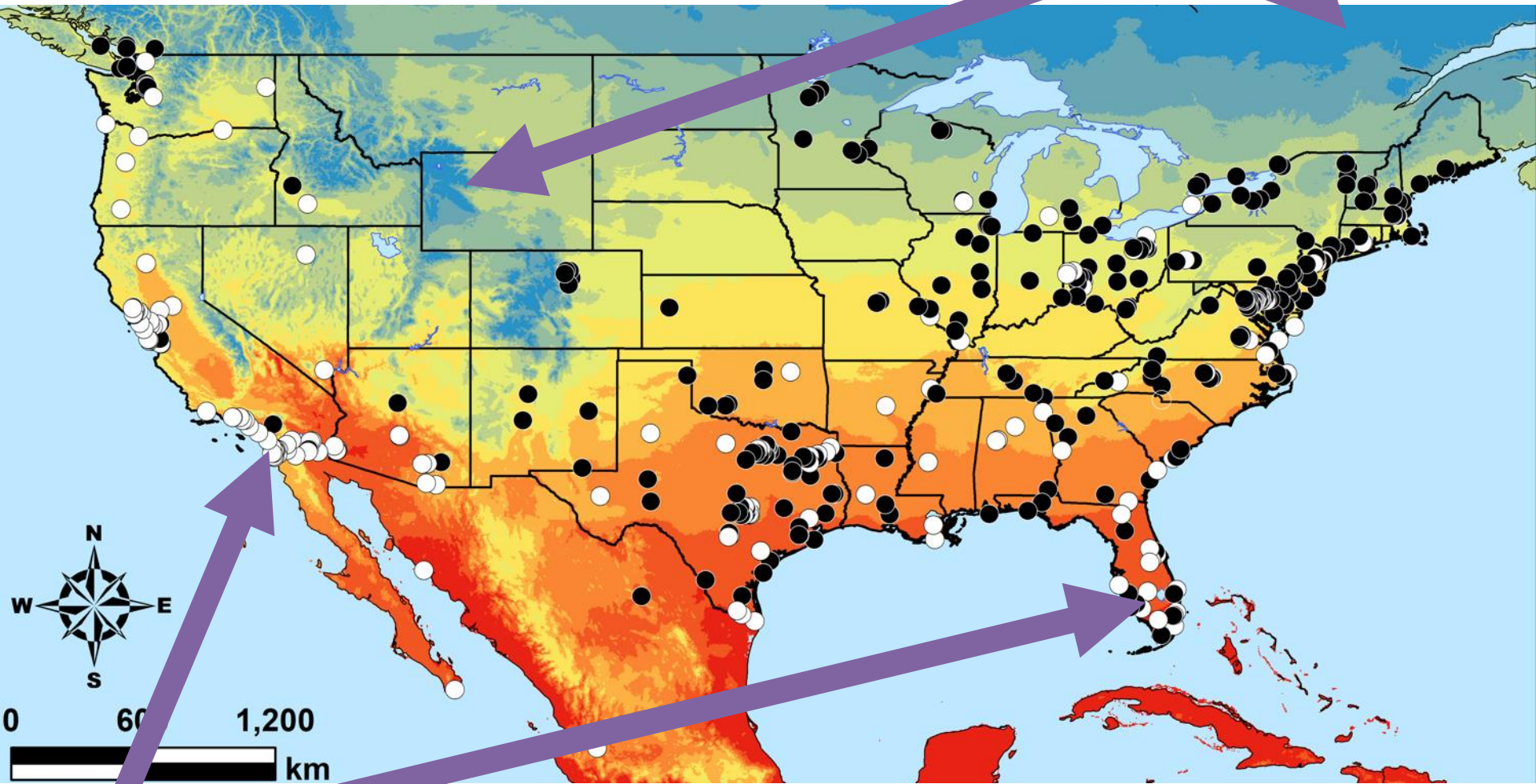
*Where were blue dashers likely to be living?*

*Was it hot or cold there?*

# Where were they living?

Compare to where they live today

Don't live where it's very cold

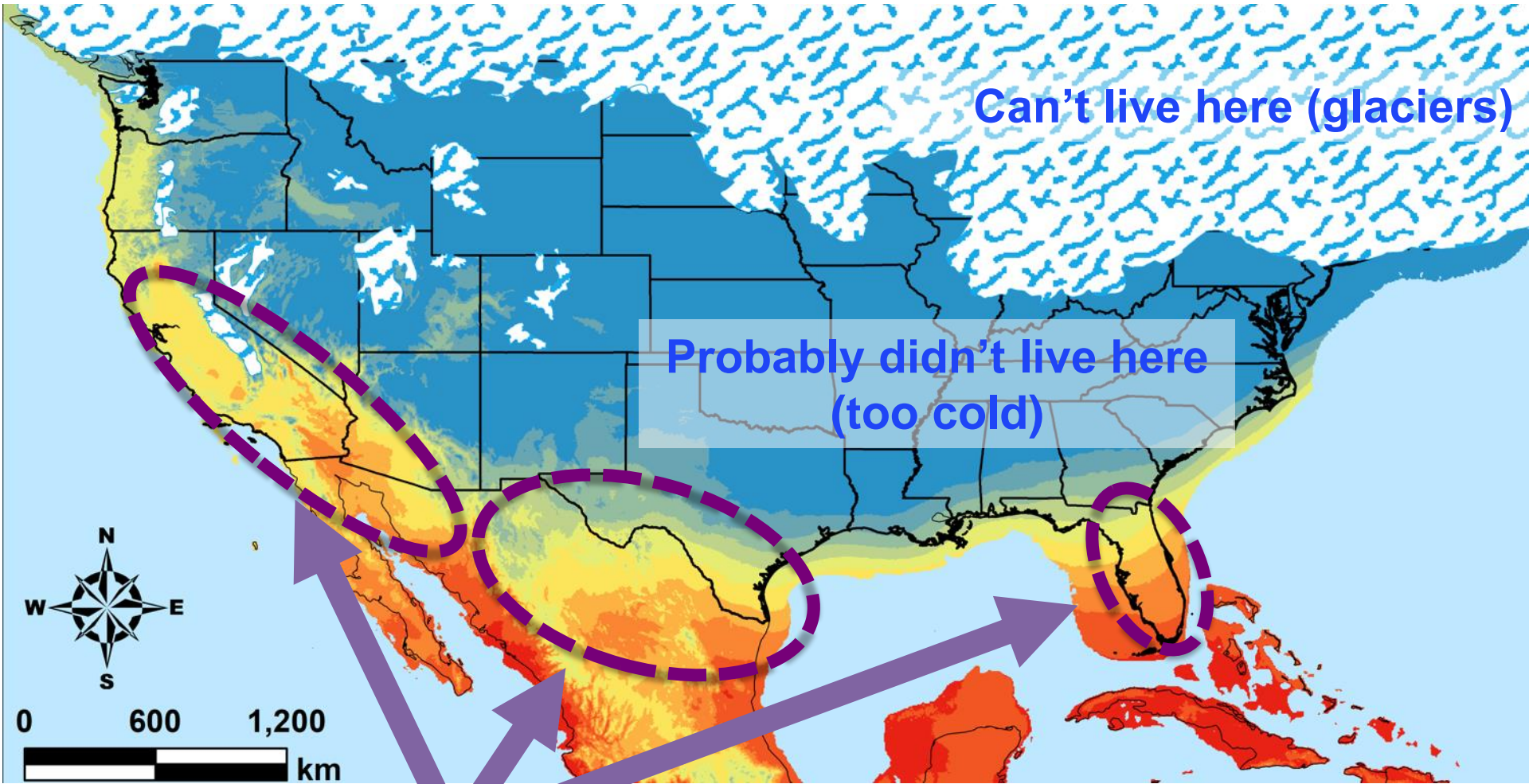


Typically have less color where it's warm

Was it hot or cold there?  
What temperatures do they have color in today

# 25,000 Years Ago

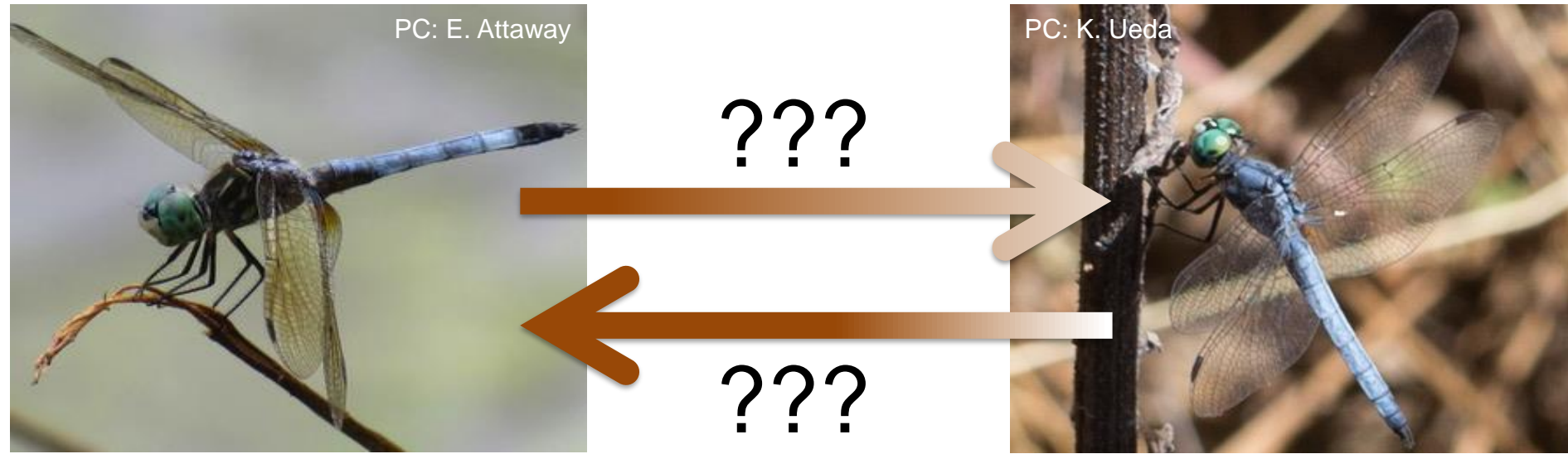
Where were they living?



Was it cold where they were living?

Still pretty hot where they could live;  
usually don't have much color when living in those temperature today

# As blue dashers adapted to the climate, which came first?



We cannot say for certain right now

*P. longipennis* was likely living in regions that were fairly warm during the last ice age

Males in warm regions tend not to have much wing coloration today  
Seems likely that they would not have had wing coloration then

Probably started without much wing color, then, as the glaciers melted, gained color as the species moved north

# Could **adapting** to different temperatures have caused geographic **diversification** in wing color?

1. Does external temperature change the costs and benefits of male wing color? **YES**

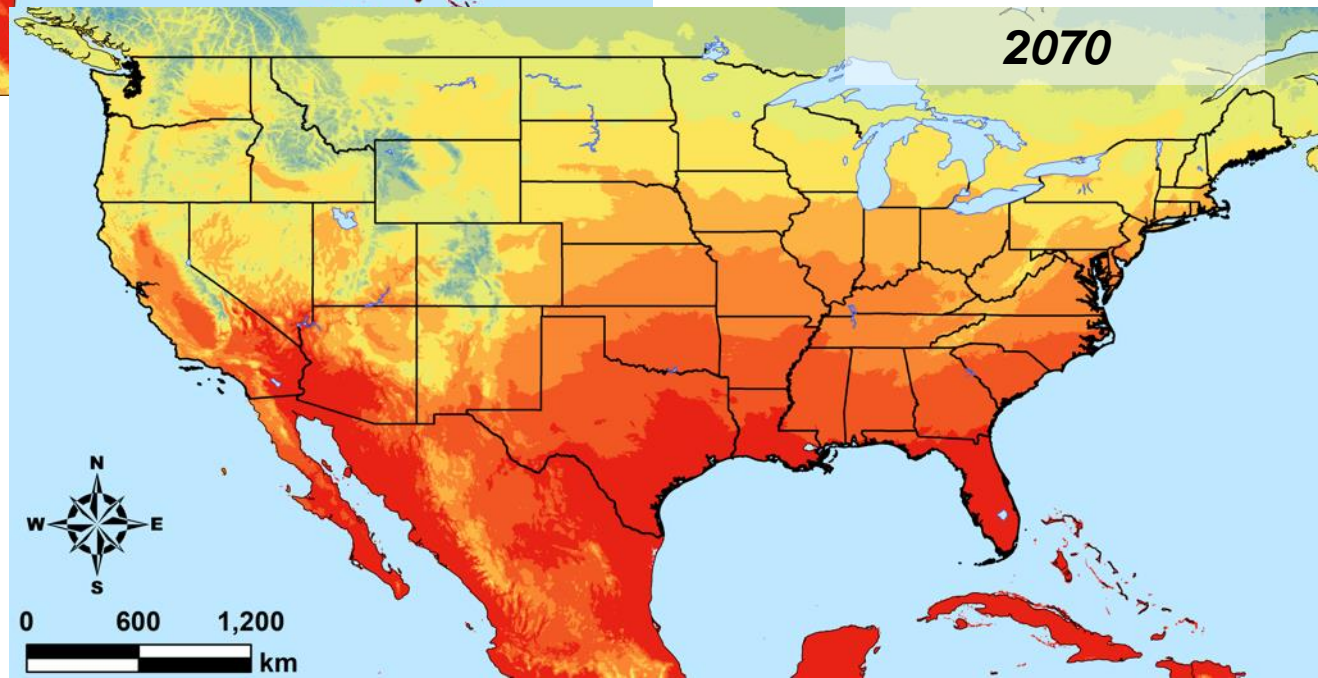
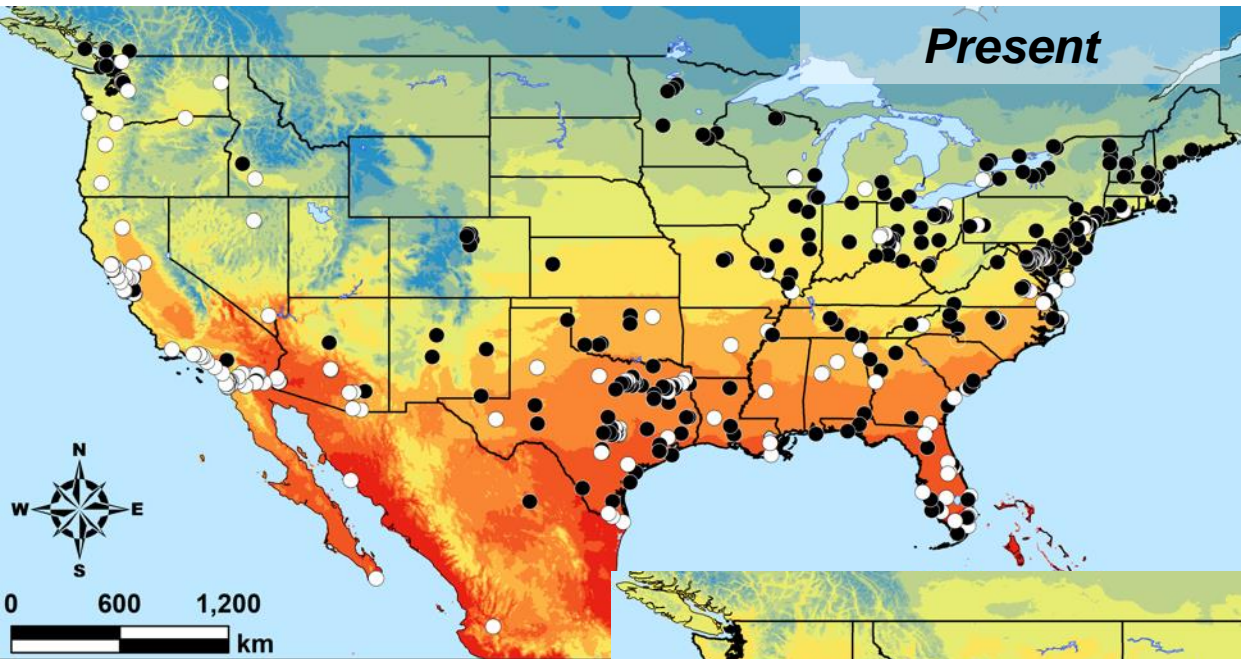
2. Do males produce different amounts of wing color where it's hot versus where it's cold? **YES**

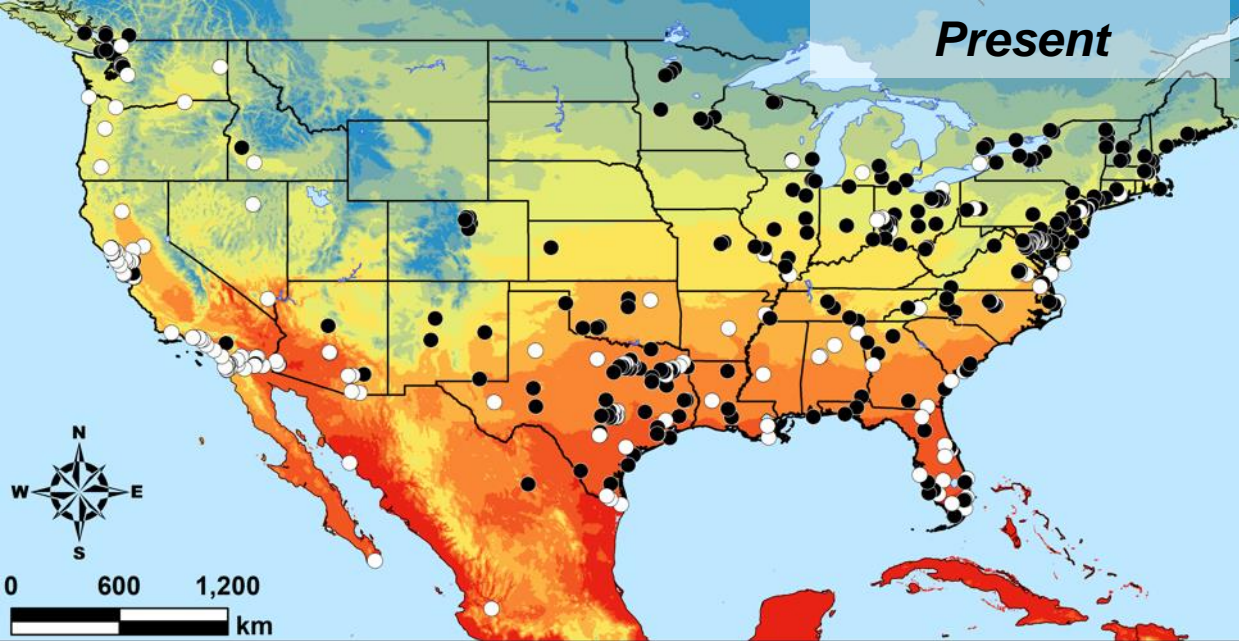
---

3. Did males gain wing color or lose it? **PROBABLY GAIN**

4. How will wing color adapt and diversify as the planet continues to warm?

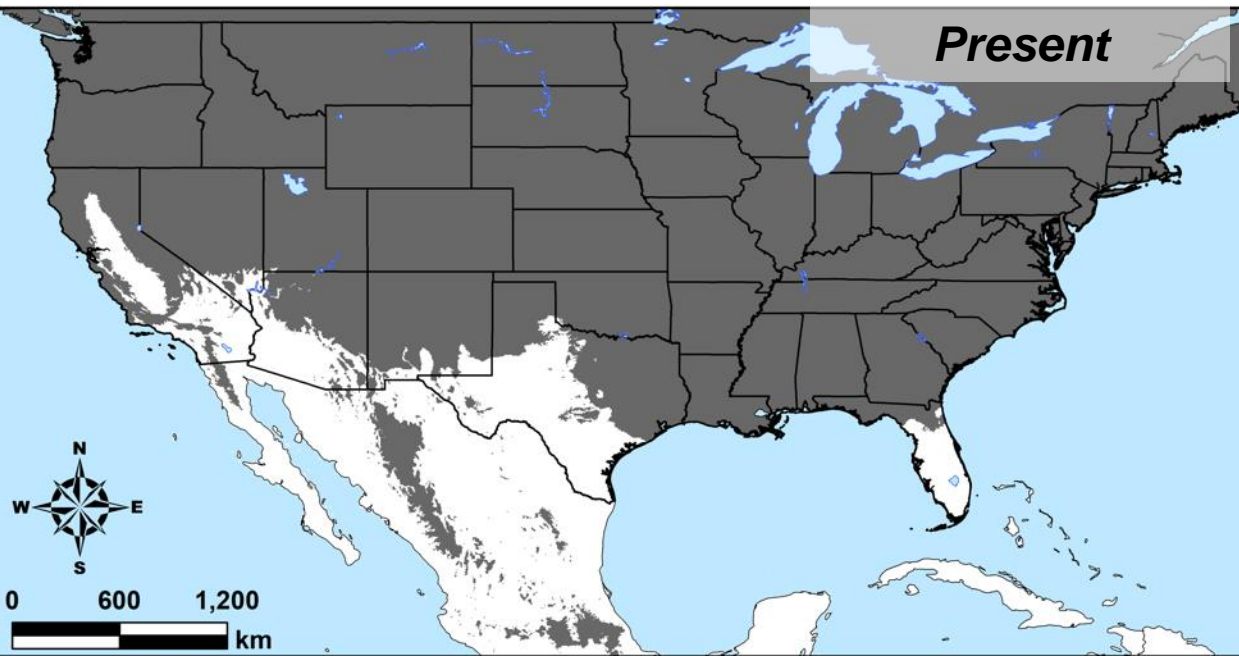
***We can use the current geographic pattern to consider what might happen in the future***





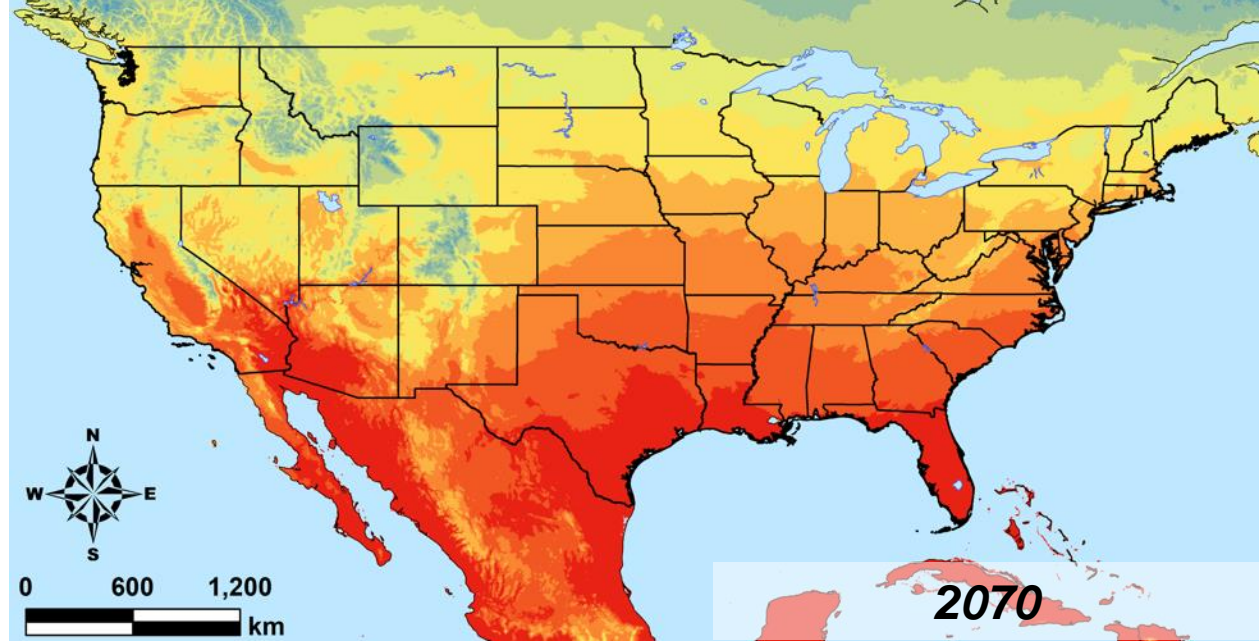
What temperatures do we usually find males without color?

Call regions where it's too hot: "Unsuitable"

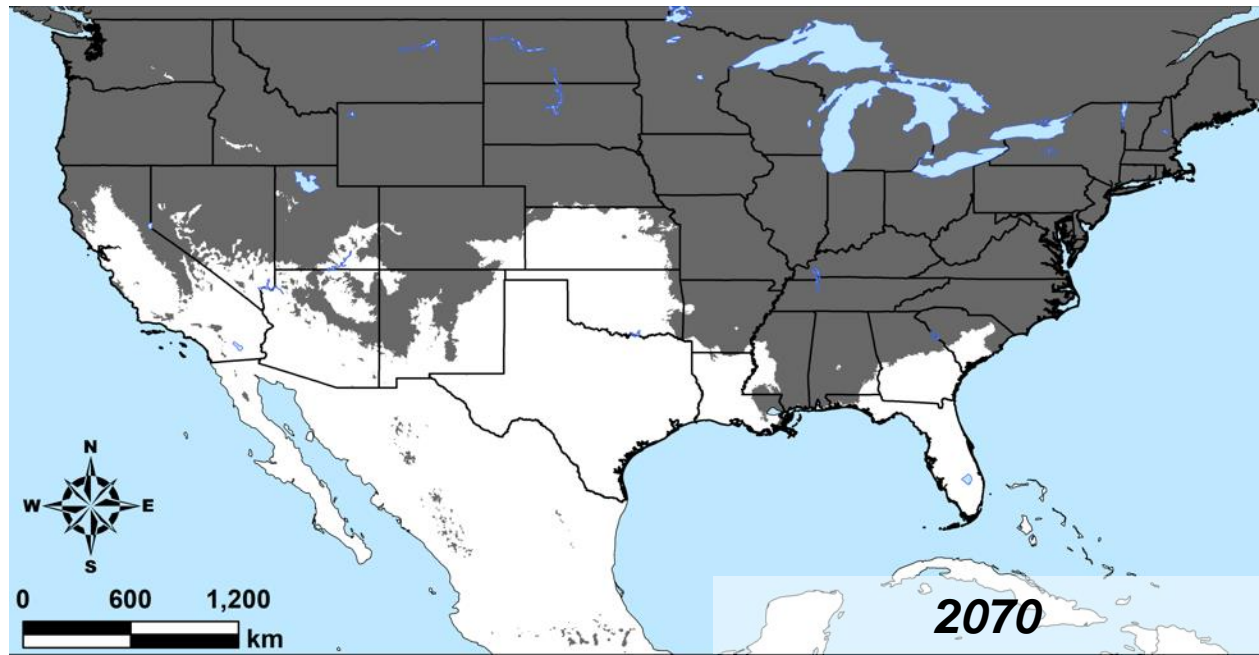


Map currently unsuitable (white) and suitable areas (grey)

Map out temperatures  
forecasted for 2070



Map regions predicted  
to be unsuitable based  
on climate

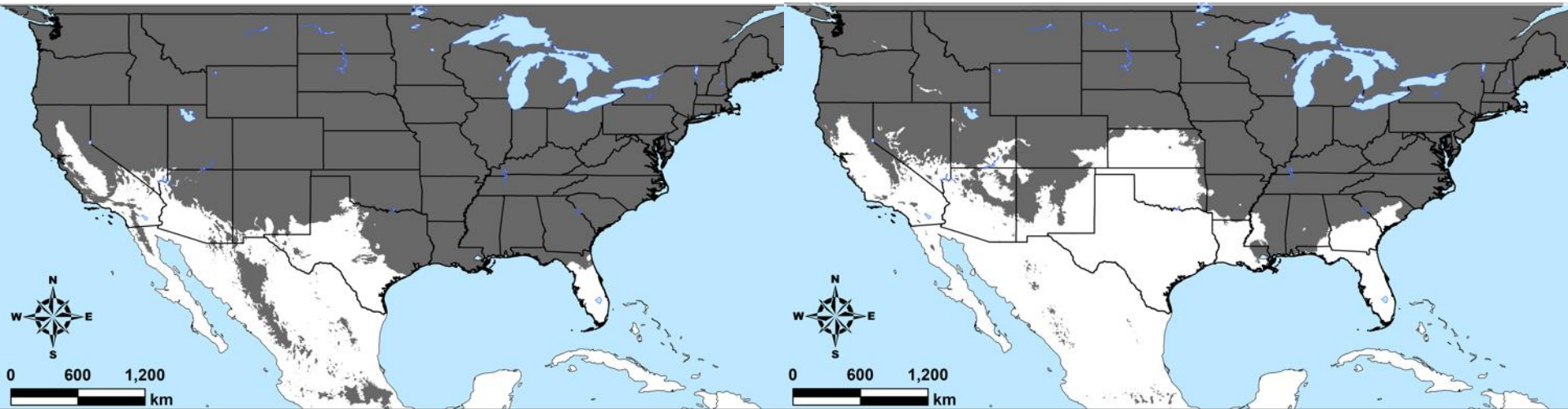




***Much more of the southern US and Plains will be unsuitable for males with wing coloration in 50 years***

*Present*

*2070*



***Adapting to a warming climate MIGHT cause males to lose wing coloration across most of the southern part of the range***

# Could **adapting** to different temperatures have caused geographic **diversification** in wing color?

1. Does external temperature change the costs and benefits of male wing color? **YES**

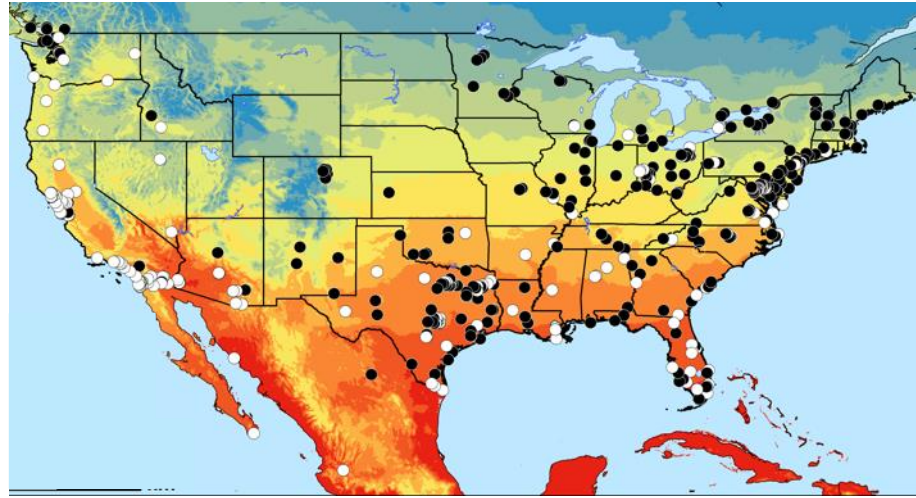
2. Do males produce different amounts of wing color where it's hot versus where it's cold? **YES**

---

3. Did males gain wing color or lose it? **PROBABLY GAIN**

4. How will wing color adapt and diversify as the planet continues to warm? **LOSE IT IN MANY PLACES**

# Color & Climate in Blue Dashers



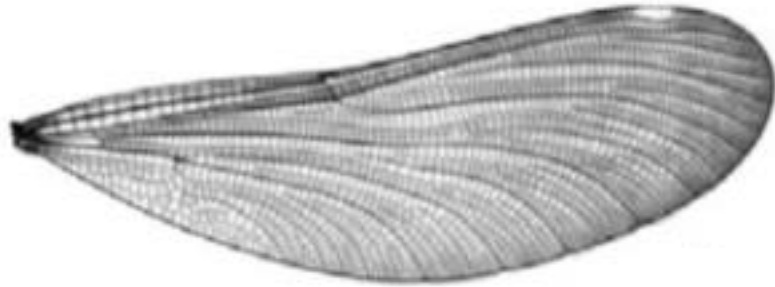
Color differences across North America probably reflect, in part, adaptation to differences in temperature

*P. longipennis* probably gained wing color in the last 20,000 years

In the next 50 years, there will be strong pressure for them to lose wing color in some parts of the range

# ***Has wing color adapted to climactic differences in other odonates?***

*Southern latitude female*



*Northern latitude female*

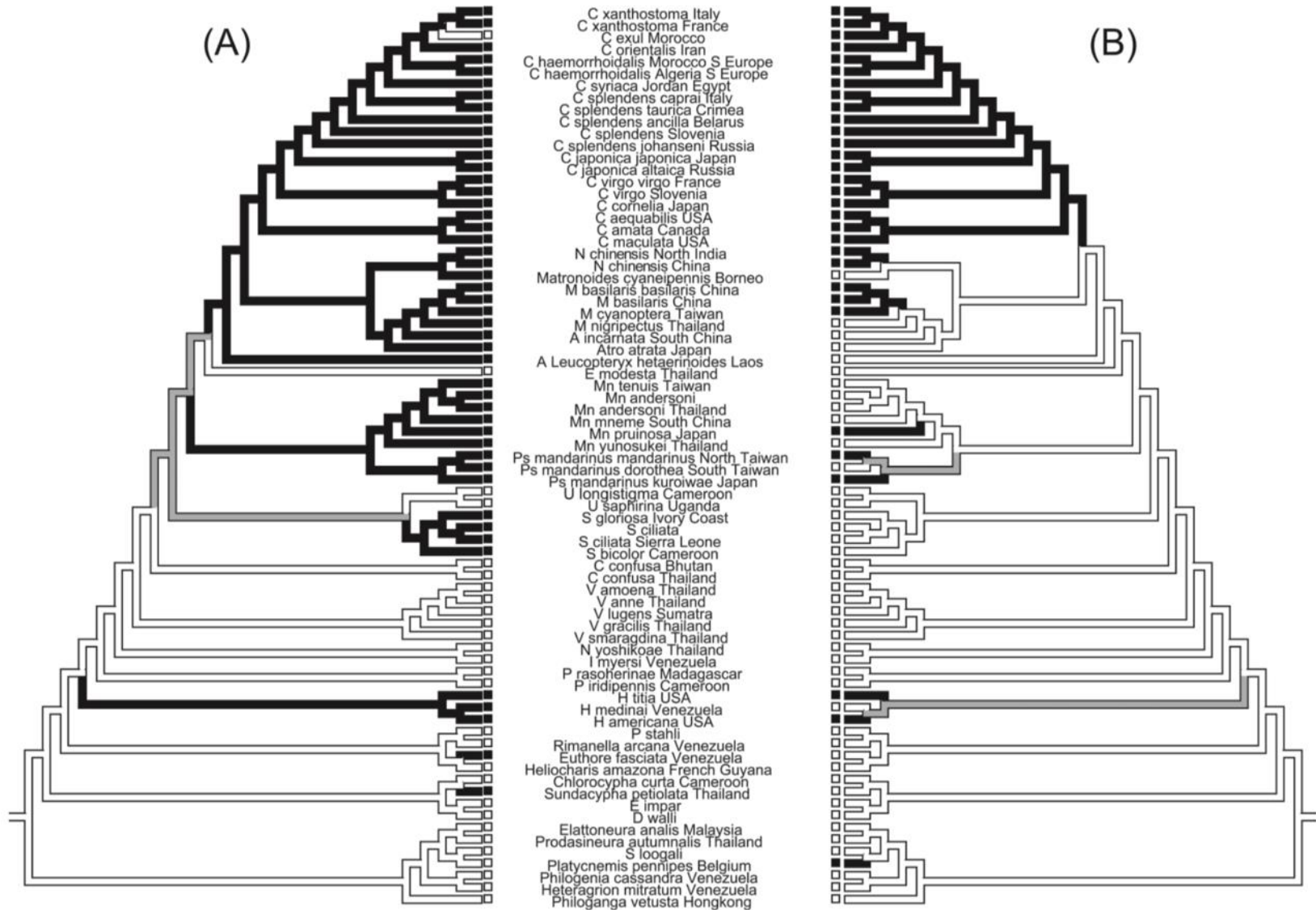


Otomuro & Ocharan 2011, *Biol. J. Linn. Soc.*

Beautiful demoiselles (*Calopteryx virgo*) produce more wing coloration at colder, more Northern latitudes in Europe

**Wing color? (Black = Yes)**

**Northern Latitude? (Black = Yes)**



Svensson & Waller 2013, *Am. Nat.*

**Damselfly species with wing coloration typically live in colder, more northerly latitudes**

***Adaptation to temperature can  
generate wing color diversification  
within and between species!***

# ***Some evidence that temperature can affect the costs and benefits of breeding colors in other animals***

African  
Lions



Ambush  
Bugs



Collared  
Flycatchers

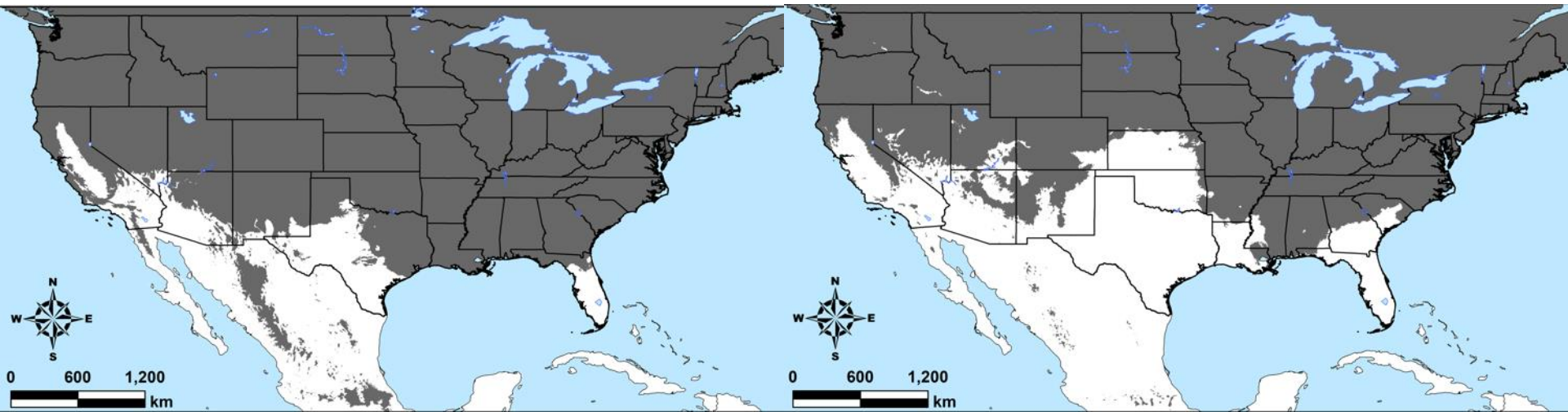


***Adapting*** to different temperatures may be a common reason that breeding colors ***diversify***

***Plants and animals (and fungi! and microbes!) are going to have to find ways to adapt to a warming planet***

Present

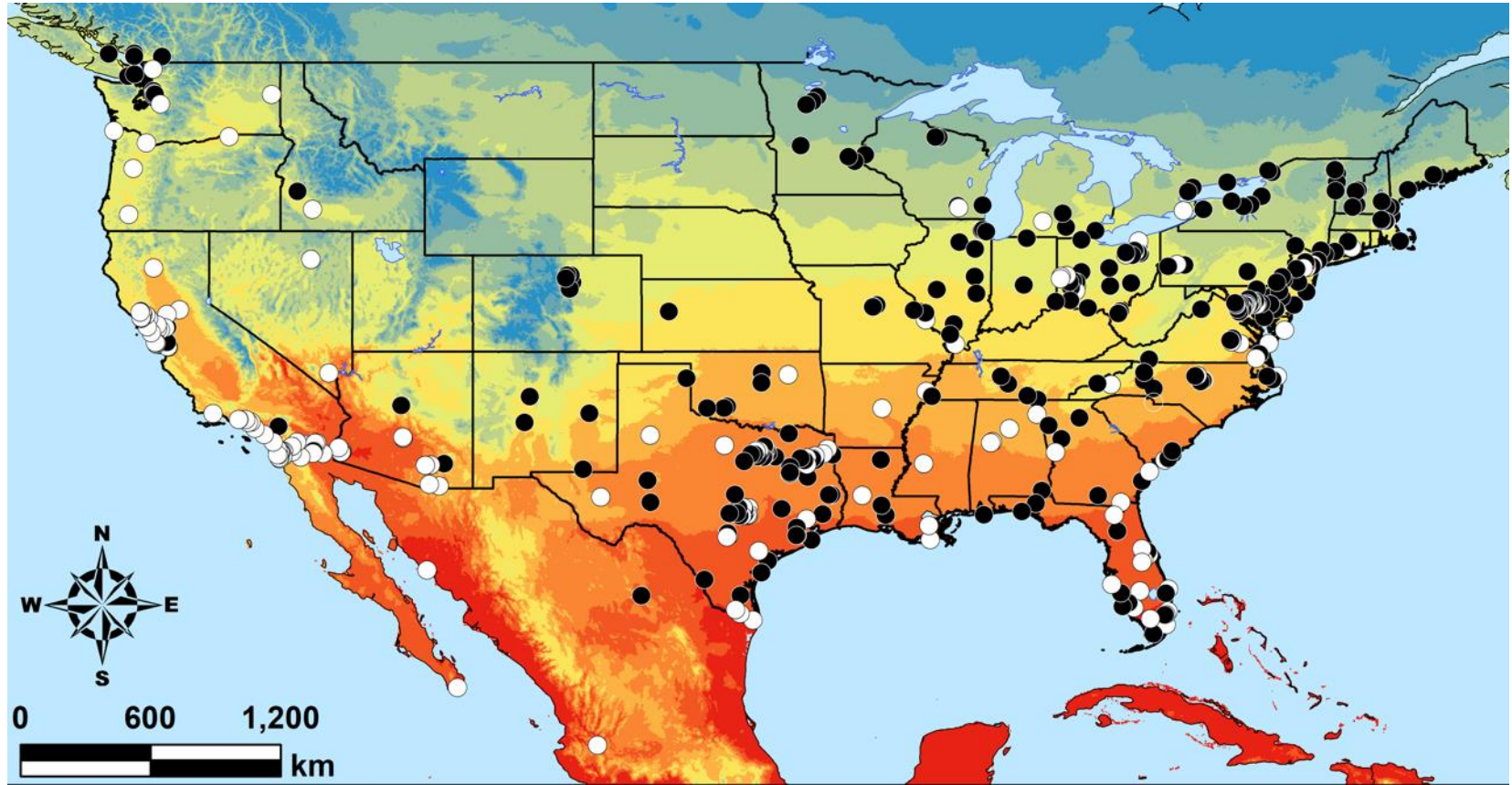
2070?



***Platforms like iNaturalist have IMMENSE potential for studying how organisms make these adjustments***



***This project started with me looking at iNaturalist pictures on the couch during the winter***



*Dedicated naturalists are the vanguard for documenting how organisms are (or aren't) adapting to their rapidly changing planet*

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AMERICAN MUSEUM  
& NATURAL HISTORY

HathawayBrown 



CASE WESTERN RESERVE  
UNIVERSITY EST. 1826

# ECOLOGY LETTERS

*Ecology Letters*, (2018)

doi: 10.1111/ele.13200

**LETTER**

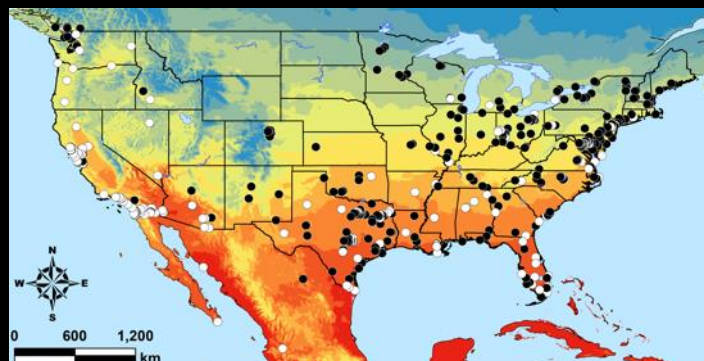
**Temperature shapes the costs, benefits and geographic diversification of sexual coloration in a dragonfly**

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Legally prohibited from posting a public version until November

Contact me for a “private” copy that I can share –  
mpm116@case.edu

# Too hot to trot? Climate & color adaptation in dragonflies



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