Joshua M. Hall[1] and Daniel A. Warner[1]

[1]Department of Biological Sciences, Auburn University, Auburn, AL

jmh0131@auburn.edu

Embryo development and global change: how do reptile embryos respond to ecologically relevant thermal stress?

Abstract

Two components of global change, climate change and urbanization, contribute to increased ambient temperatures that cause heat stress or mortality in animals. Many animals can respond to harmful temperatures behaviorally; however, embryos of ectotherms which develop inside eggs in the ground and receive little or no parental care cannot respond this way. This early life stage is more vulnerable to harmful temperatures, yet, the effects of ecologically relevant thermal stress on these embryos has received little attention. We measured ground temperatures in an urban landscape where lizards (*Anolis sagrei* and *Anolis cristatellus*) nest and exposed eggs to extreme nest temperatures in the lab. We determined the critical thermal maximum for embryos of each species and assessed how thermal tolerance might change through development. Our results show that the thermal tolerance of reptile embryos can differ widely among closely related species, and thermal tolerance can change through development.

Embryo development and global change: how do reptile embryos respond to ecologically relevant thermal stress?

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Daniel A Warner

Evolution • Ecology • Behavior • Physiology
WARNER LAB

AUBURN UNIVERSITY

Embryos…

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- Are particularly **sensitive to environmental** disturbance

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- Are unable to **behaviorally compensate** for adverse conditions (can't run away)

Embryos…

- Are particularly **sensitive to environmental** disturbance
- Are unable to **behaviorally compensate** for adverse conditions (can't run away)
- Influence population dynamics and **species distributions and persistence**

Pike. 2014. Glob Chang Biol 20: 7−15

Ecologically relevant thermal stress

- <u>Not</u> Ecologically relevant

Ecologically relevant thermal stress

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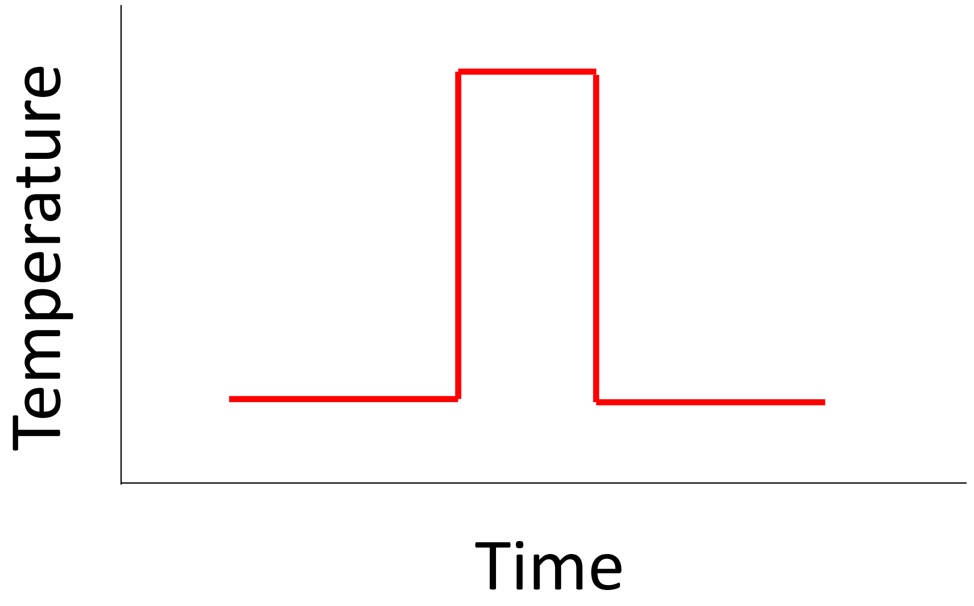
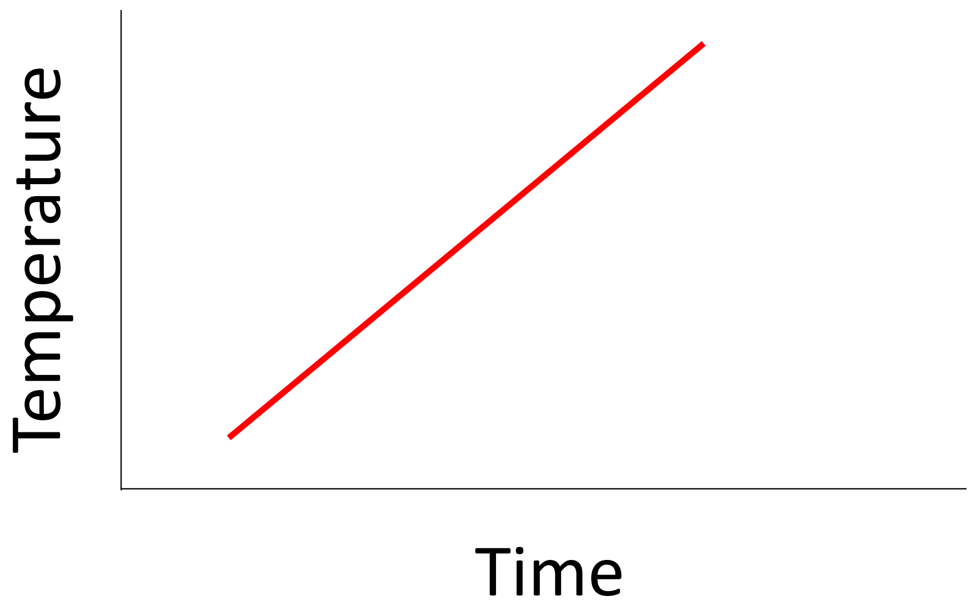
  - Heat shocks



Ecologically relevant thermal stress

- Not Ecologically relevant
  - Heat shocks
  - Steady increase



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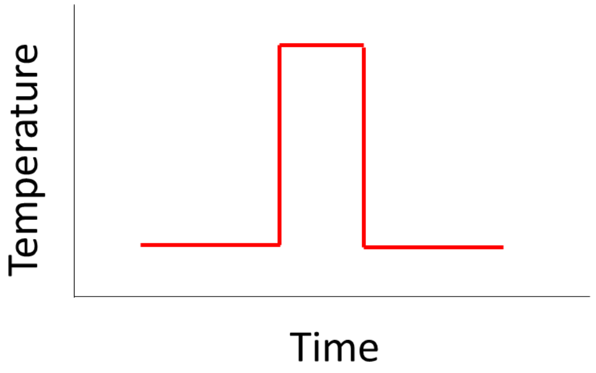

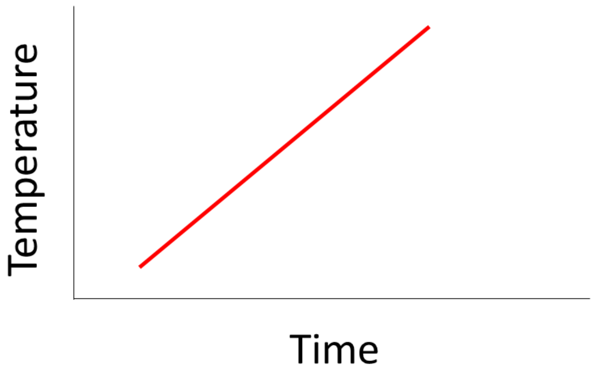

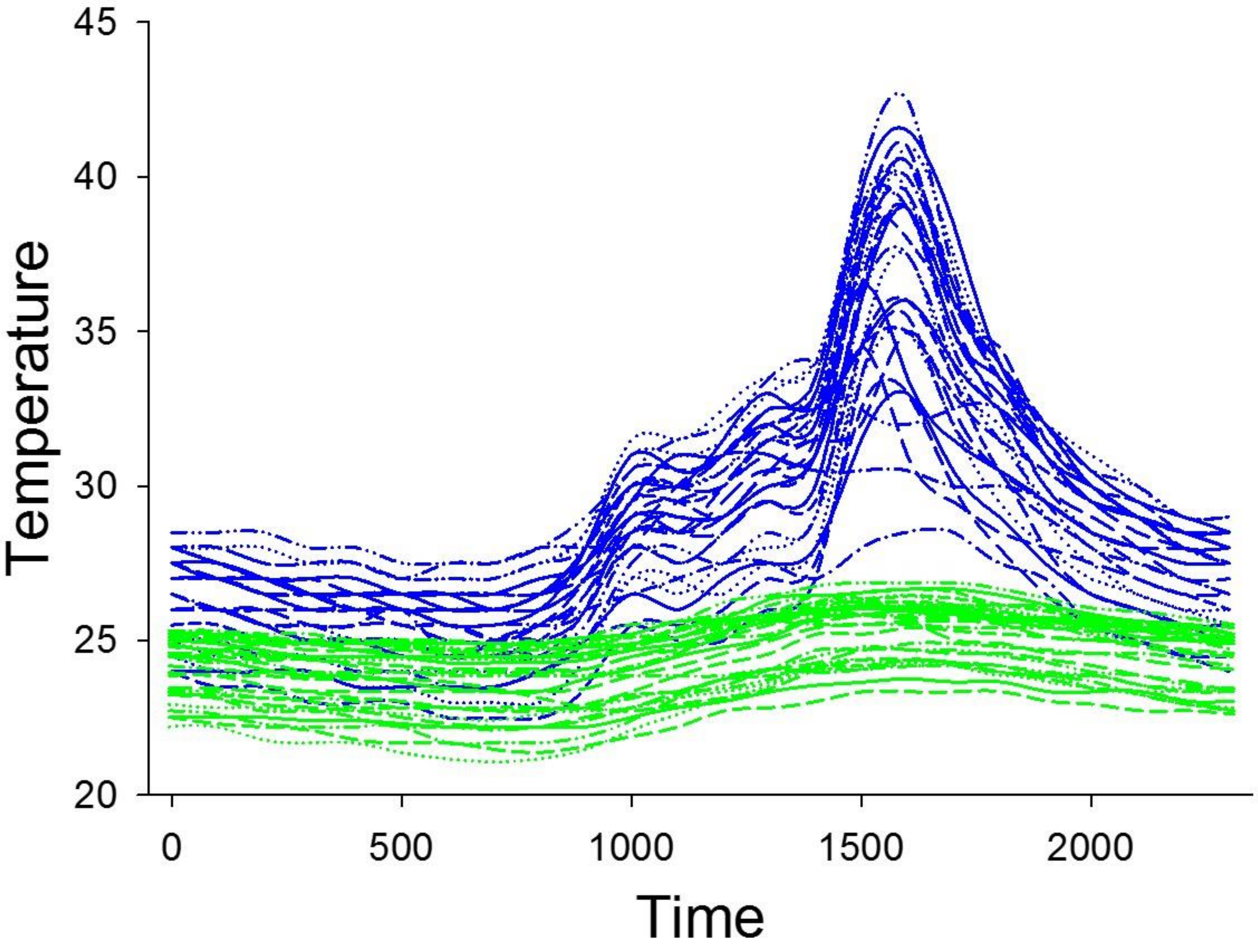

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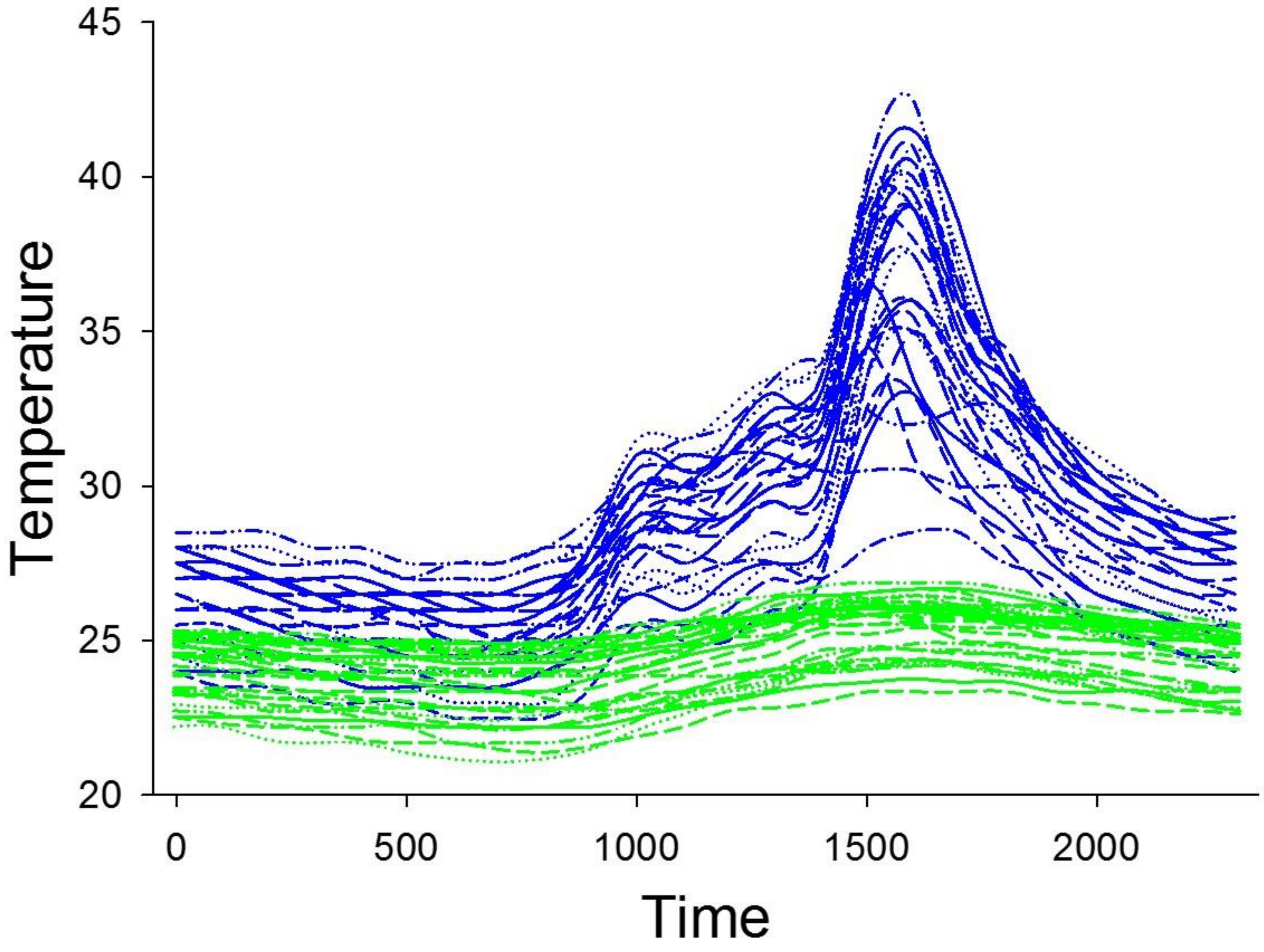
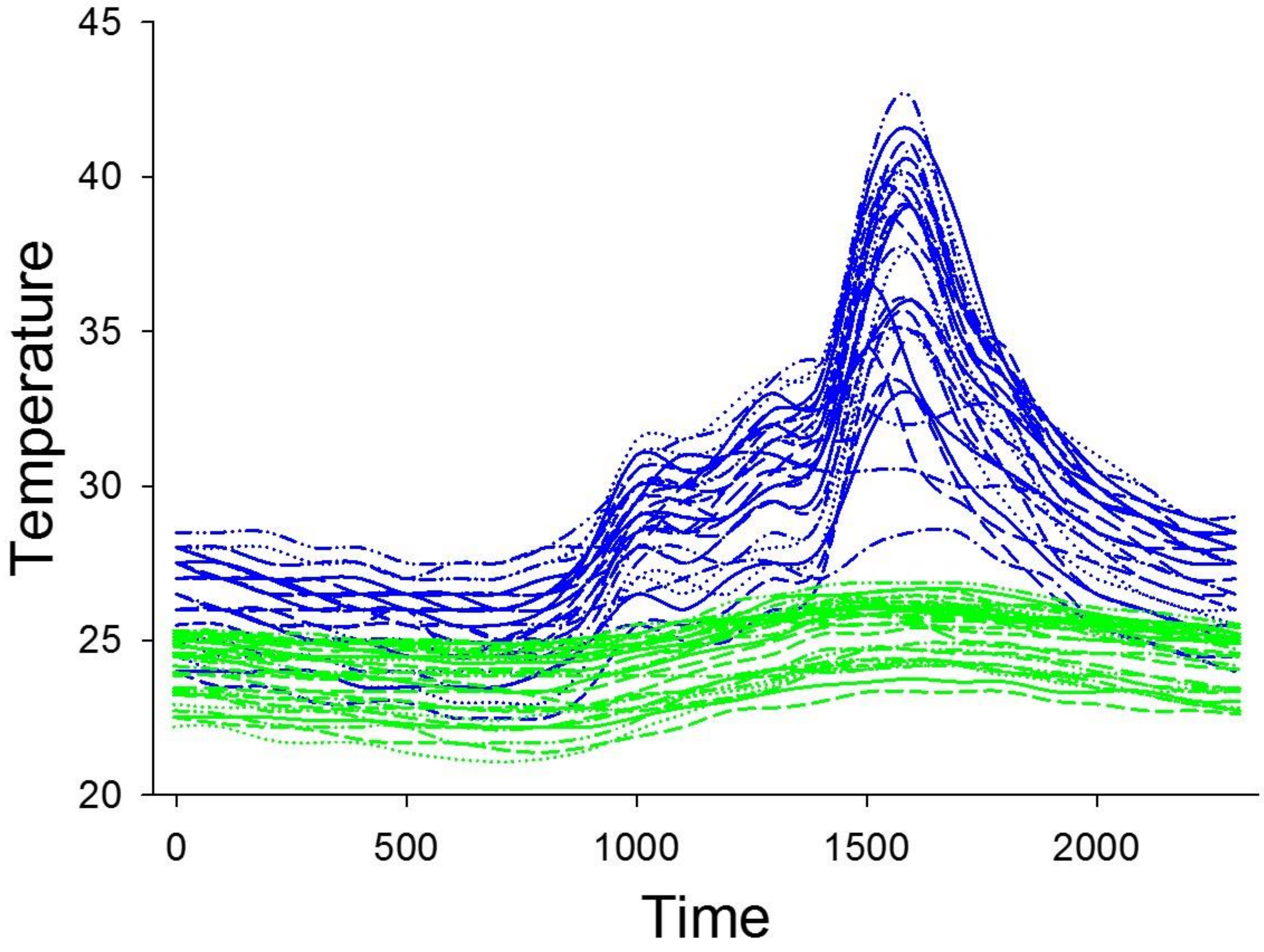


Ecologically relevant thermal stress

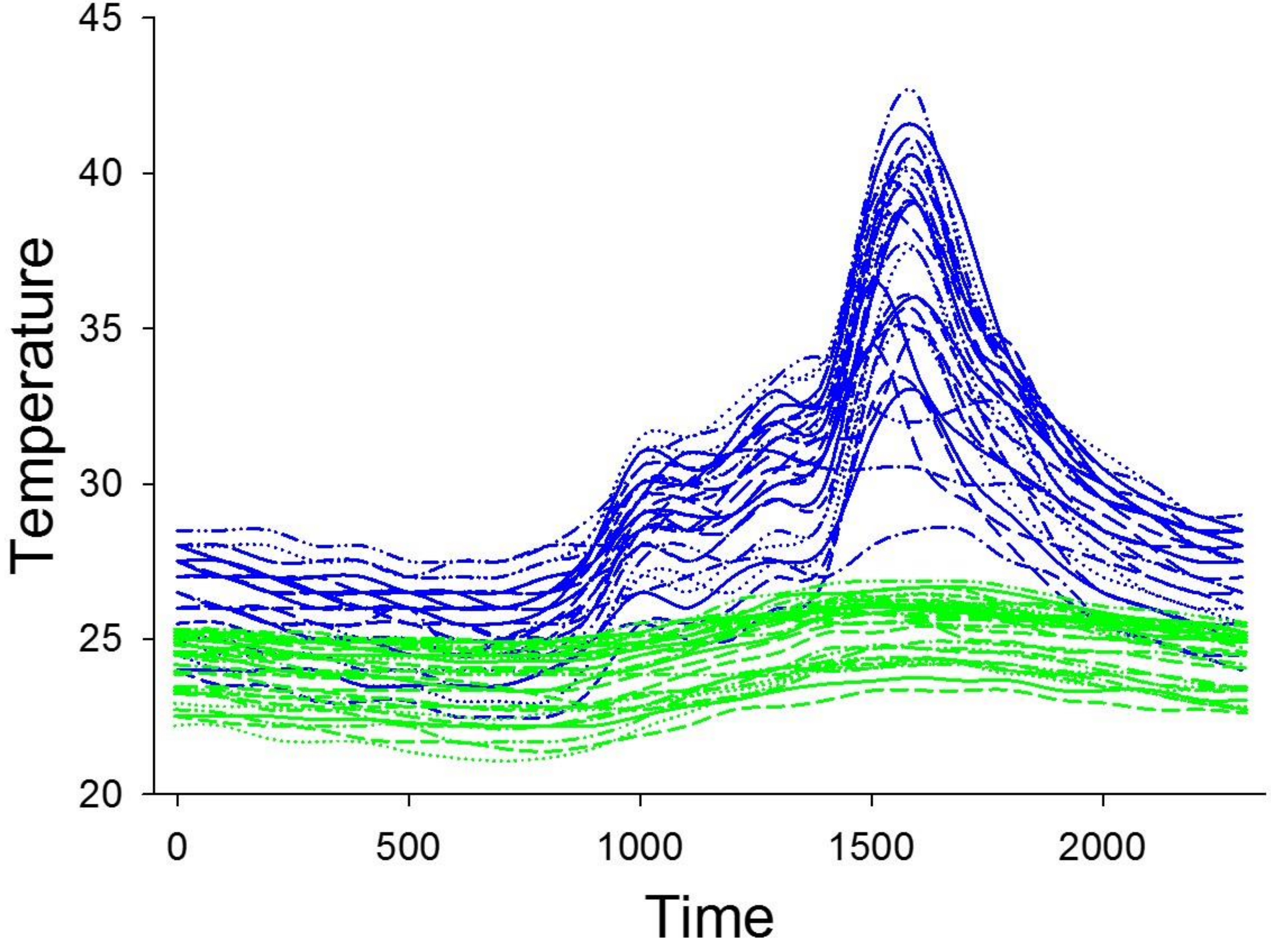
- <u>Not</u> Ecologically relevant
  - Heat shocks
  - Steady increase

Reduce egg survival by ~ 20%

Hall & Warner. 2018. J Exp Biol

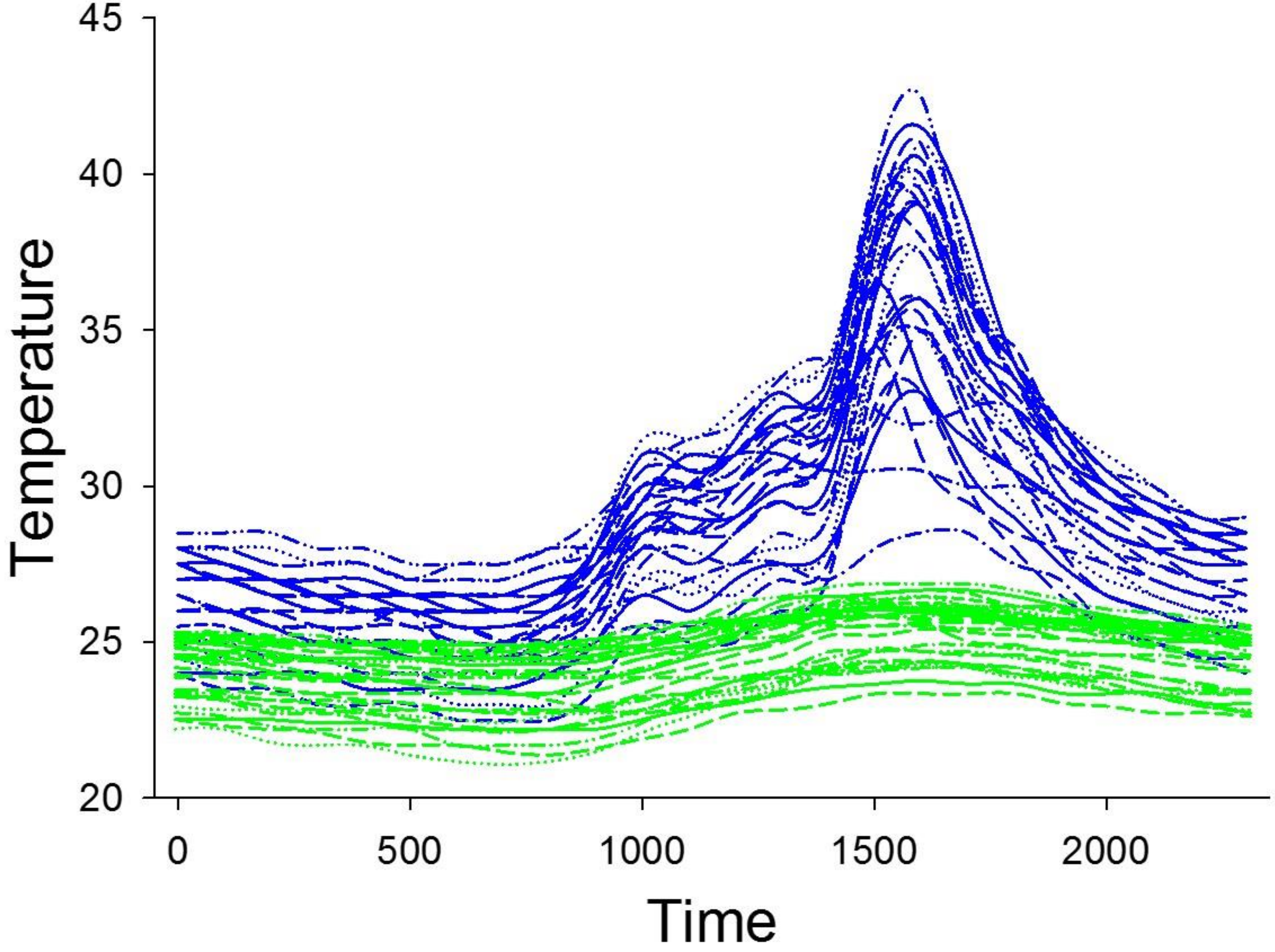


Ecologically relevant thermal stress



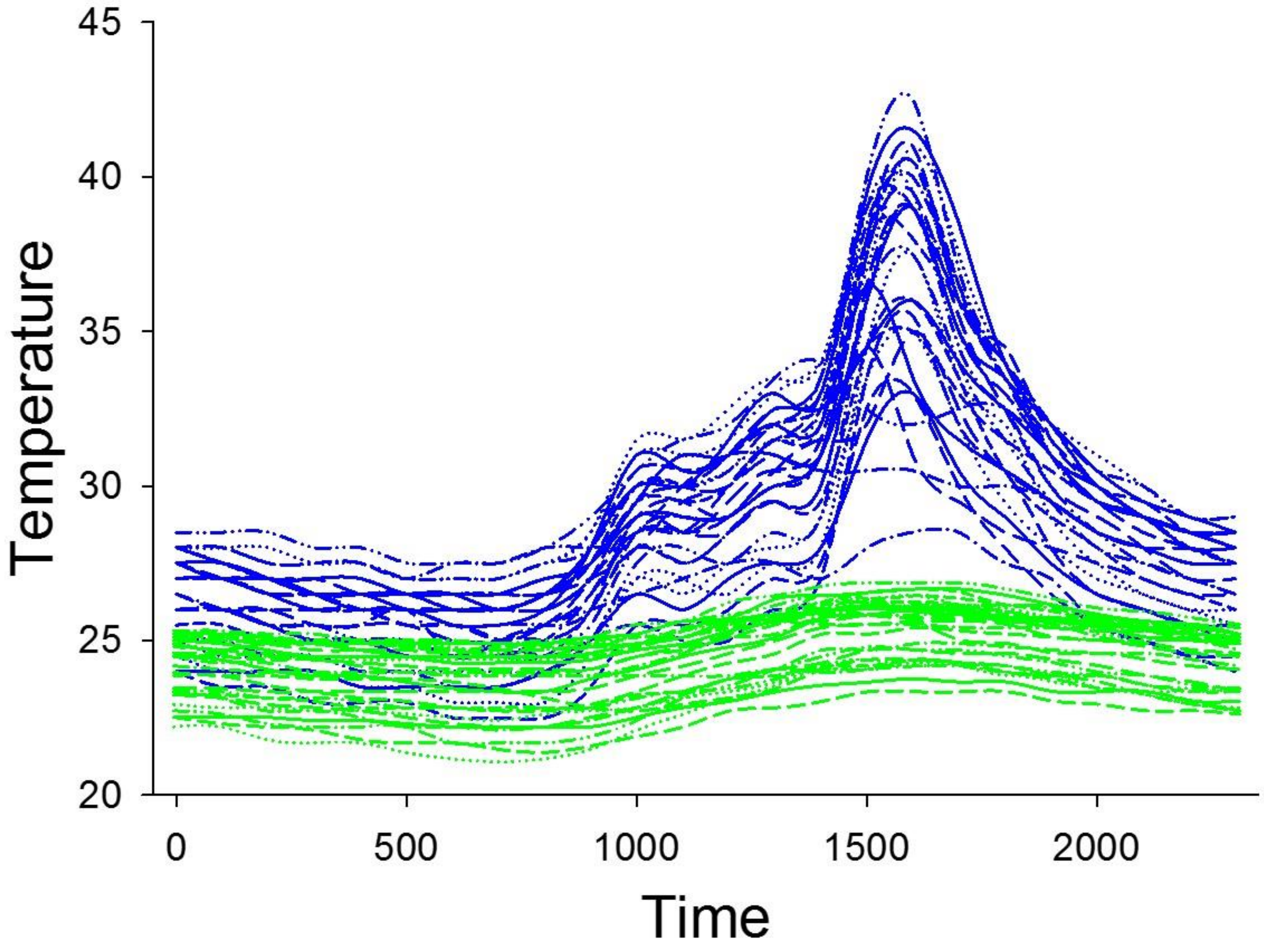
Ecologically relevant thermal stress

- Magnitude (how hot?)



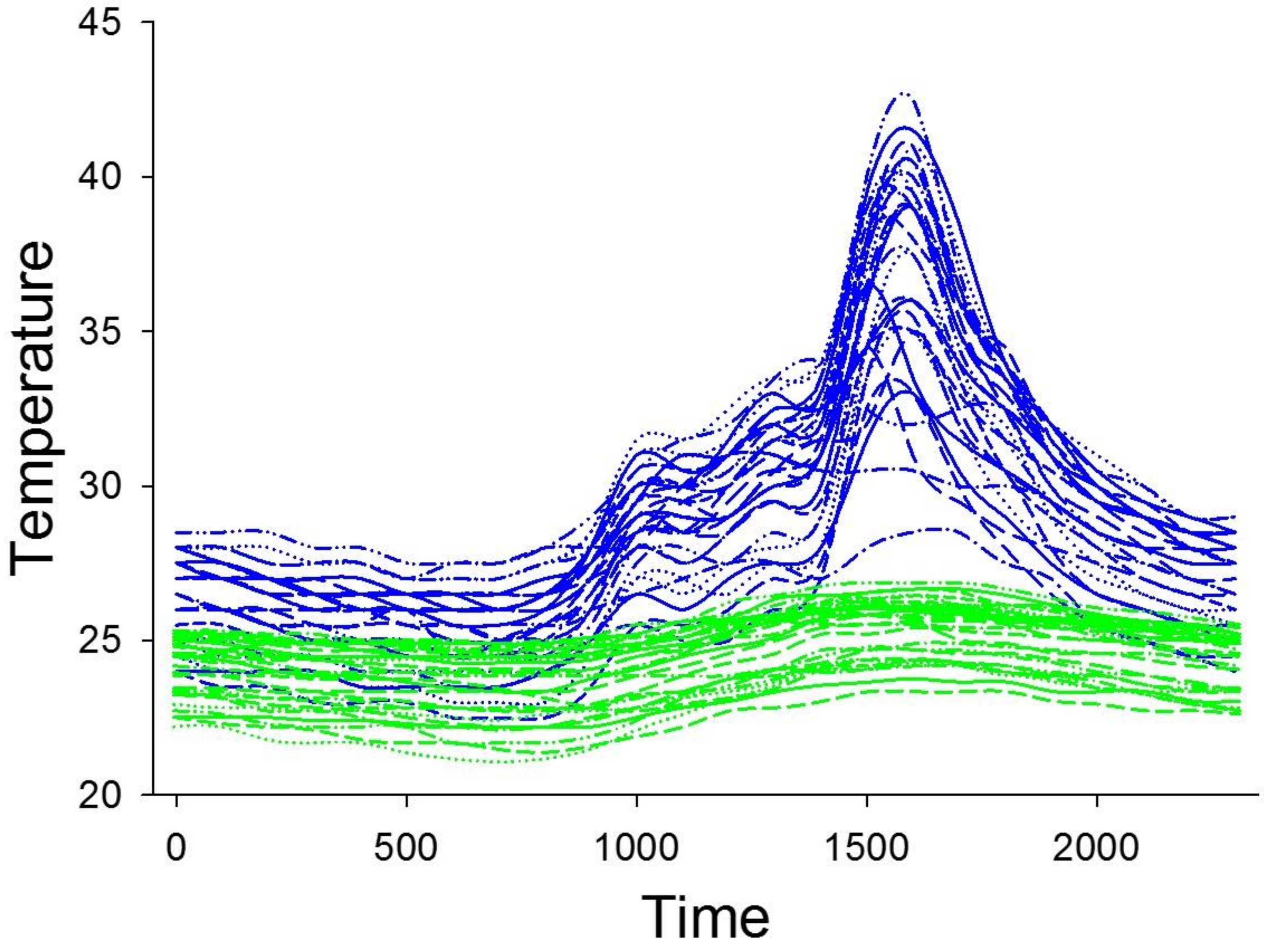
Ecologically relevant thermal stress

- Magnitude (how hot?)
- Frequency (how often?)



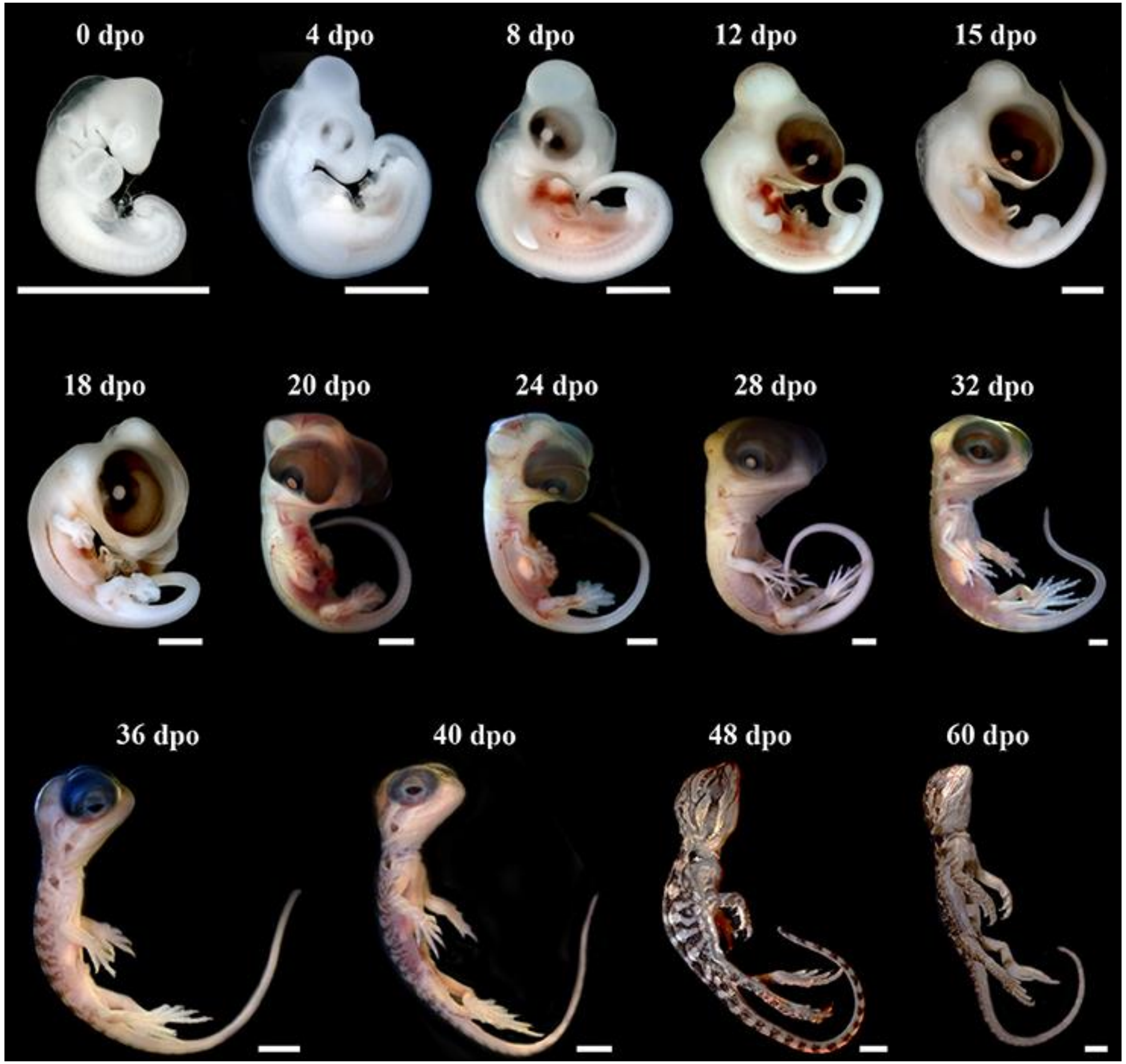
Ecologically relevant thermal stress

- Magnitude (how hot?)
- Frequency (how often?)
- Timing (how old?)



Ecologically relevant thermal stress

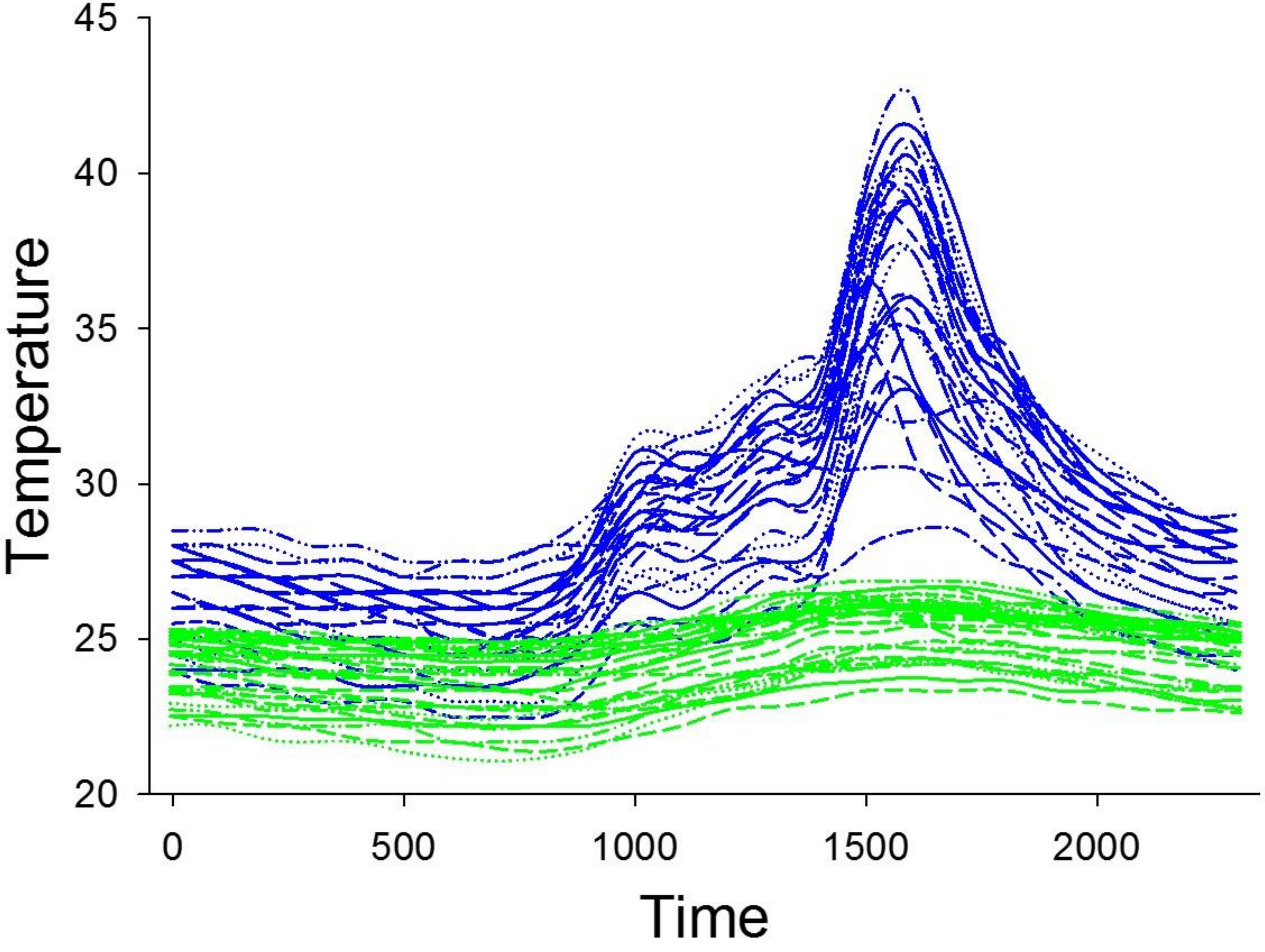
- Magnitude (how hot?)
- Frequency (how often?)
- Timing (how old?)



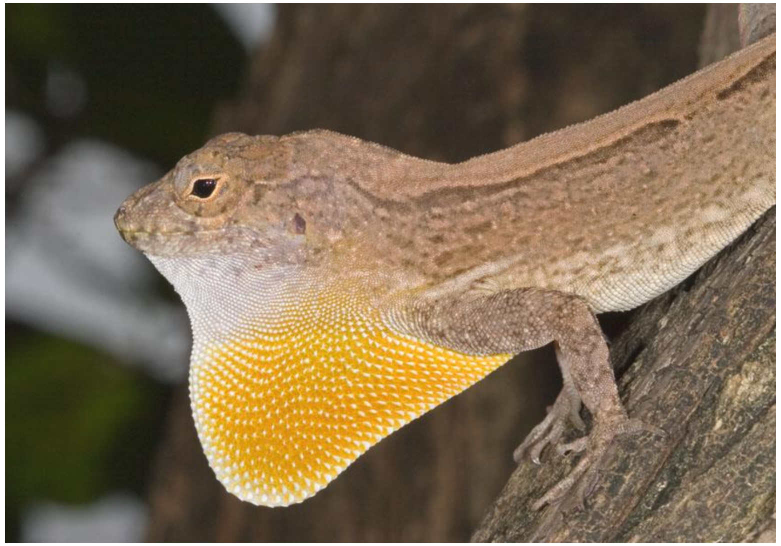
Ollonen et al. 2018. Front. Physiol.

Ecologically relevant thermal stress

- Magnitude (how hot?)
- Frequency (how often?)
- Timing (how old?)
- Species (how general?)



Experimental Design



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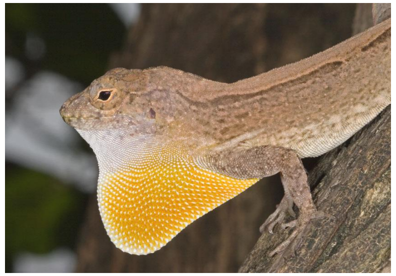

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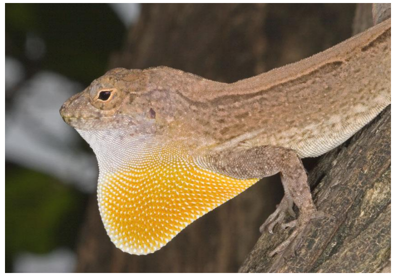

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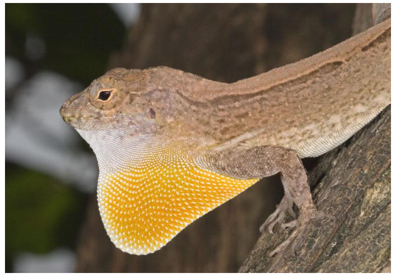

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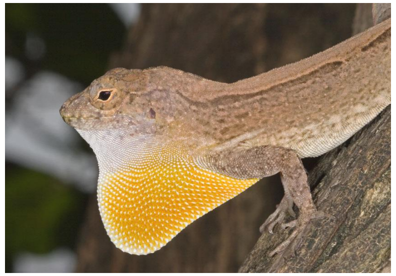


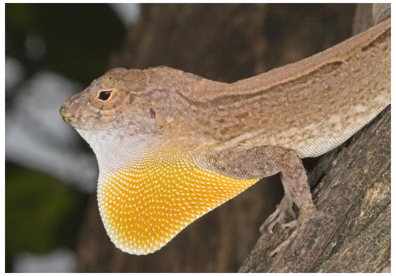
Crested anole nests: 36-39 °C

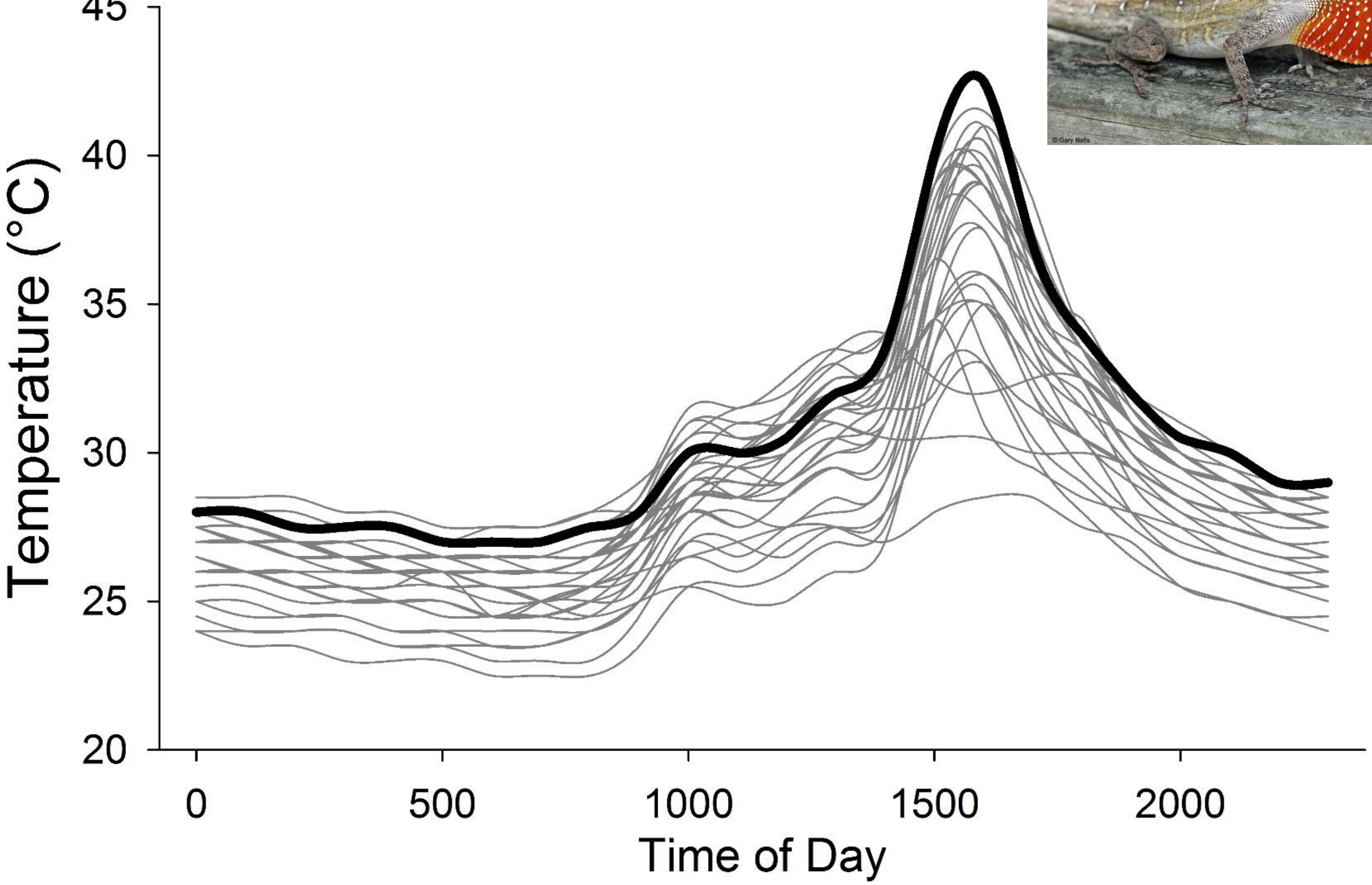
Tiatragul, **Hall**…et al. In Revision

Brown anole nests: 42-46 °C

Sanger et al. 2018. J Exp Zool

Experimental Design





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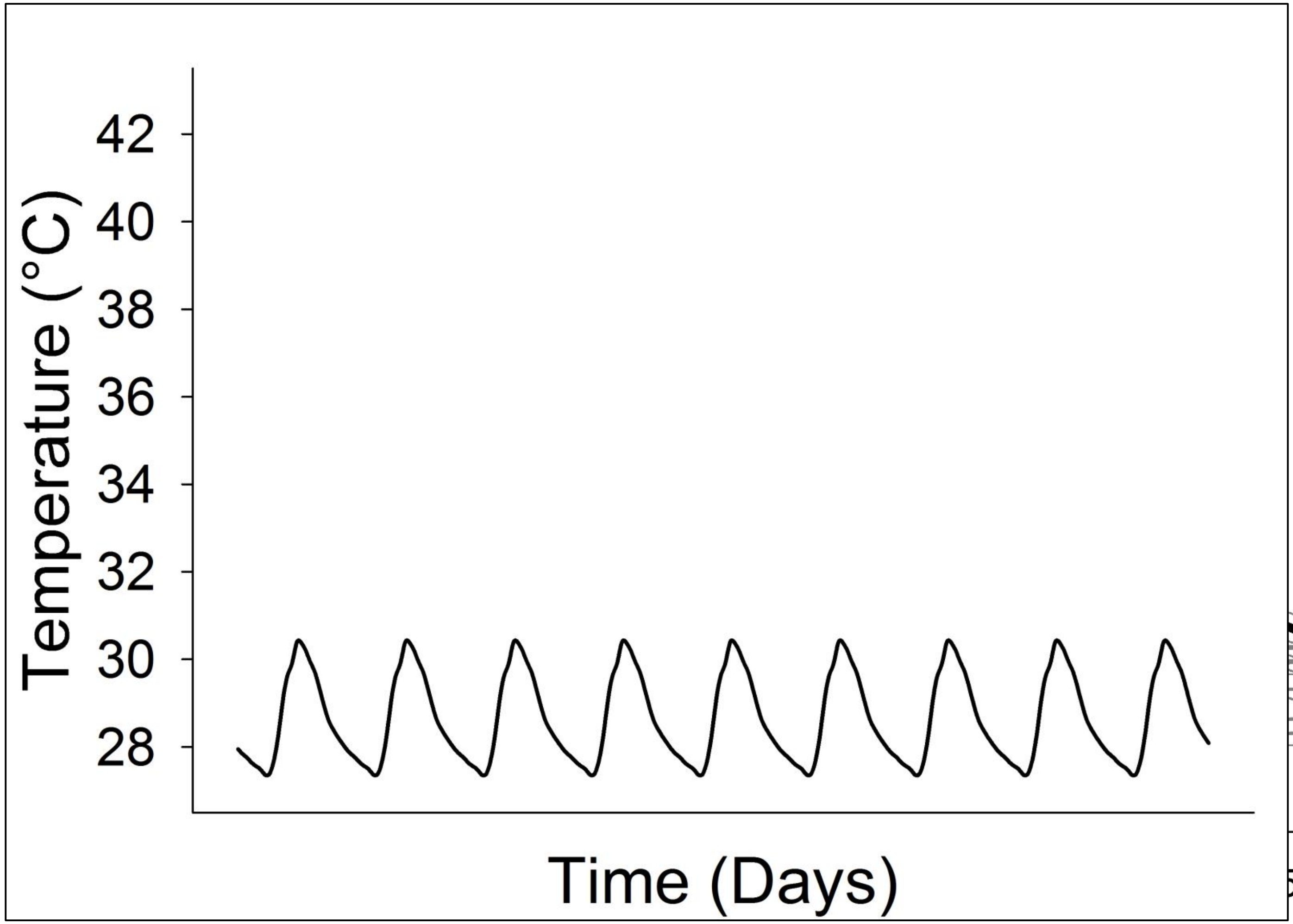

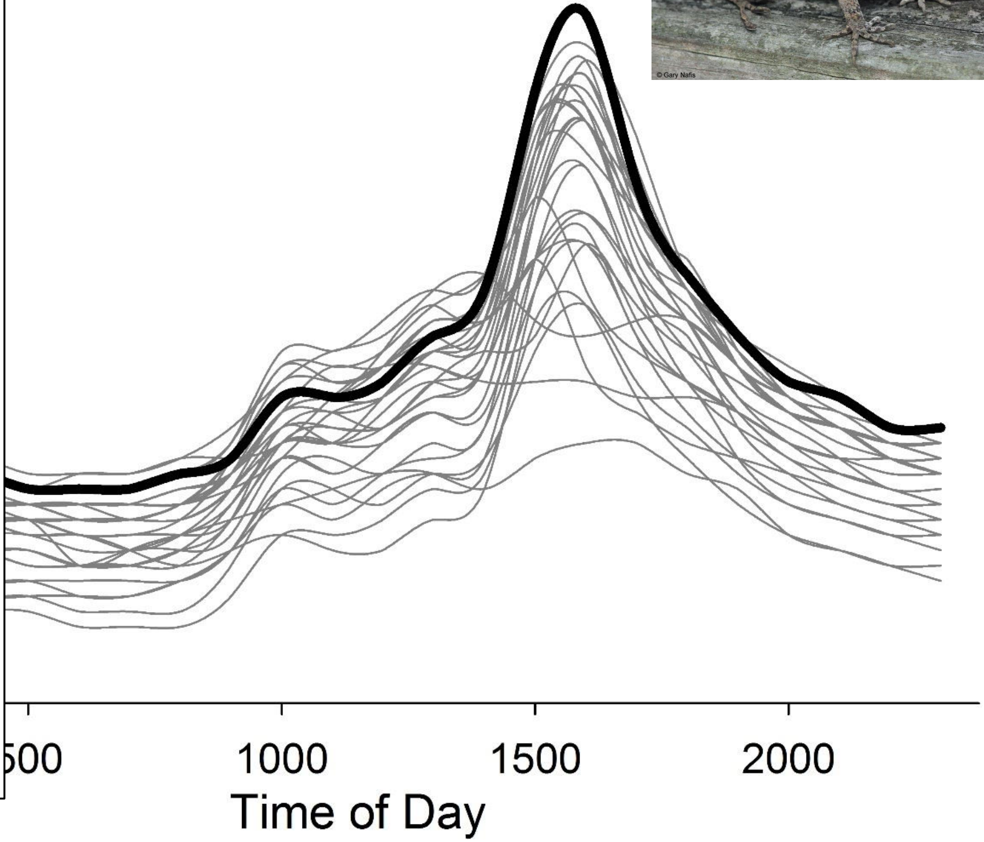

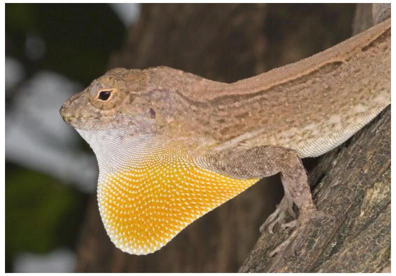

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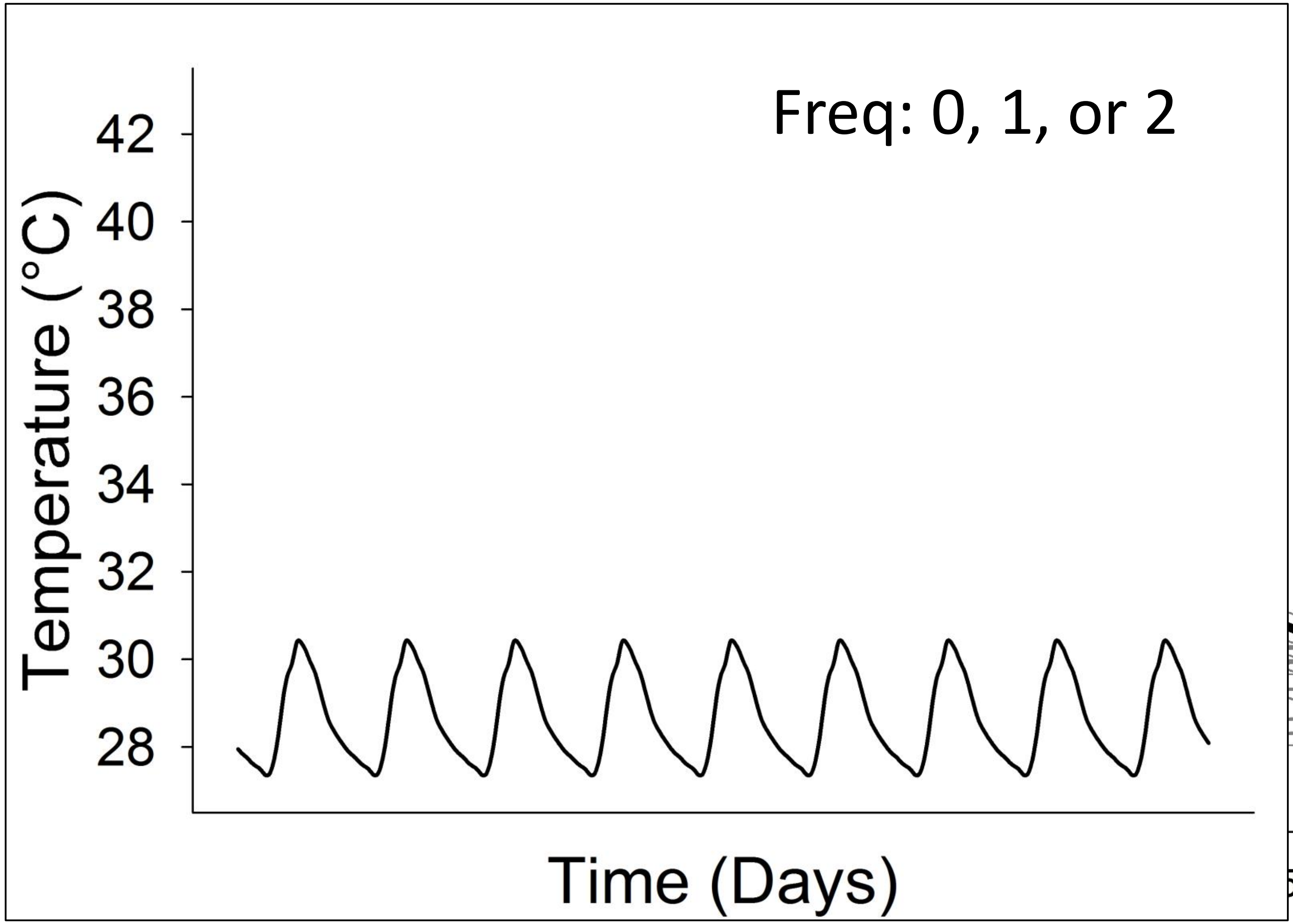

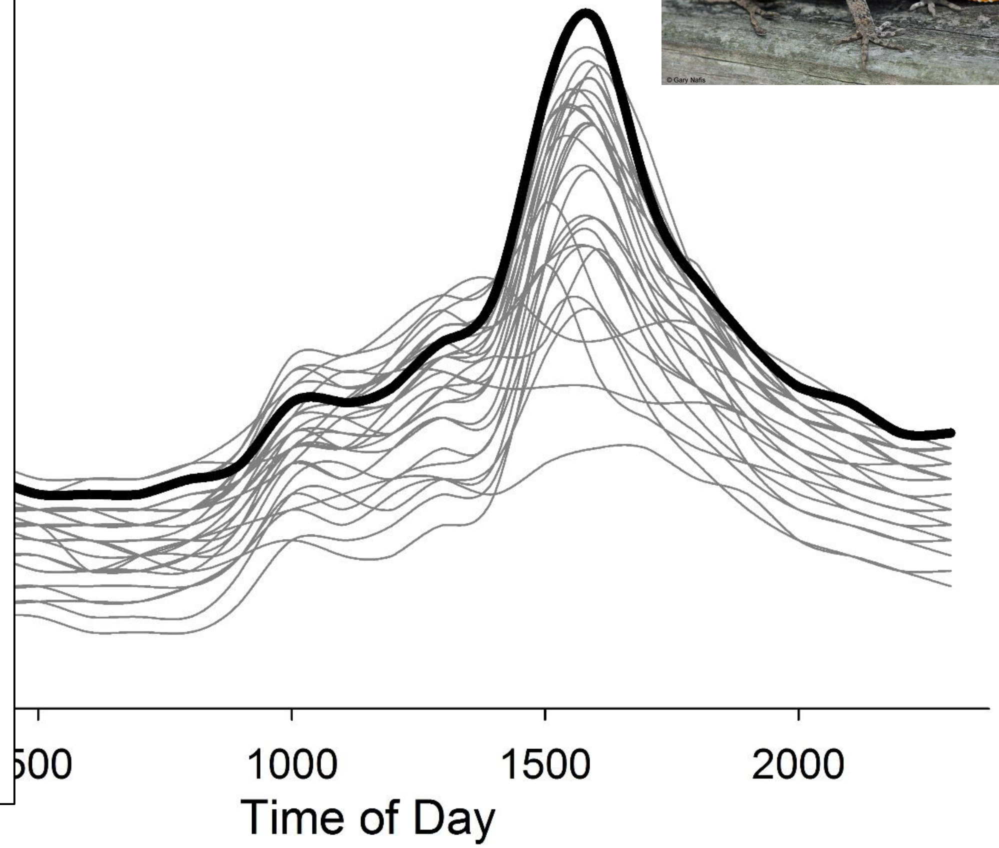

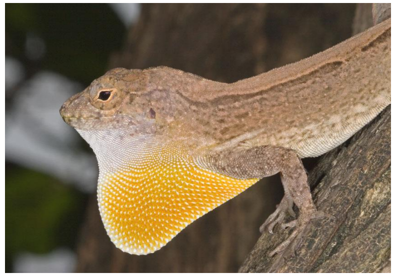

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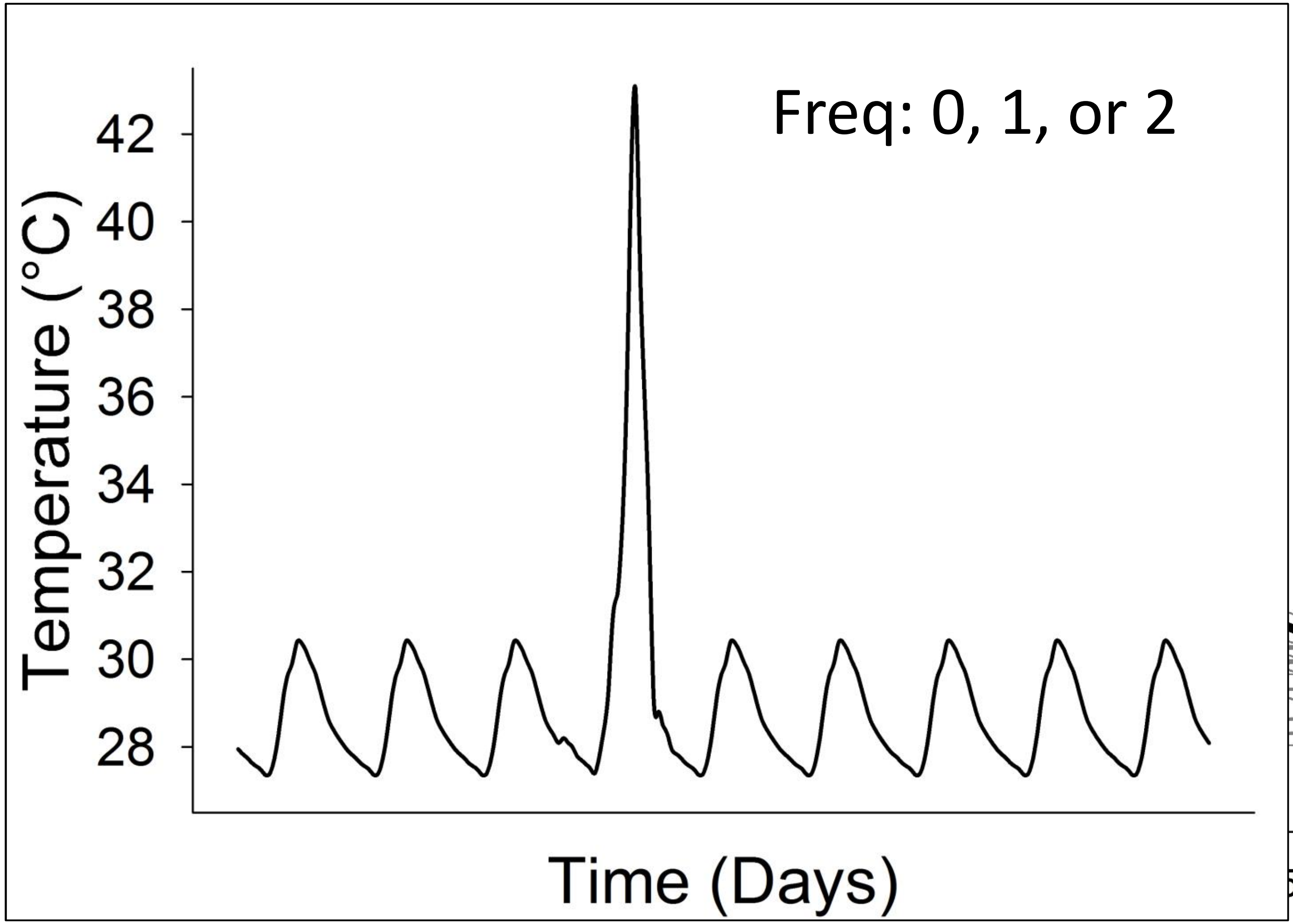

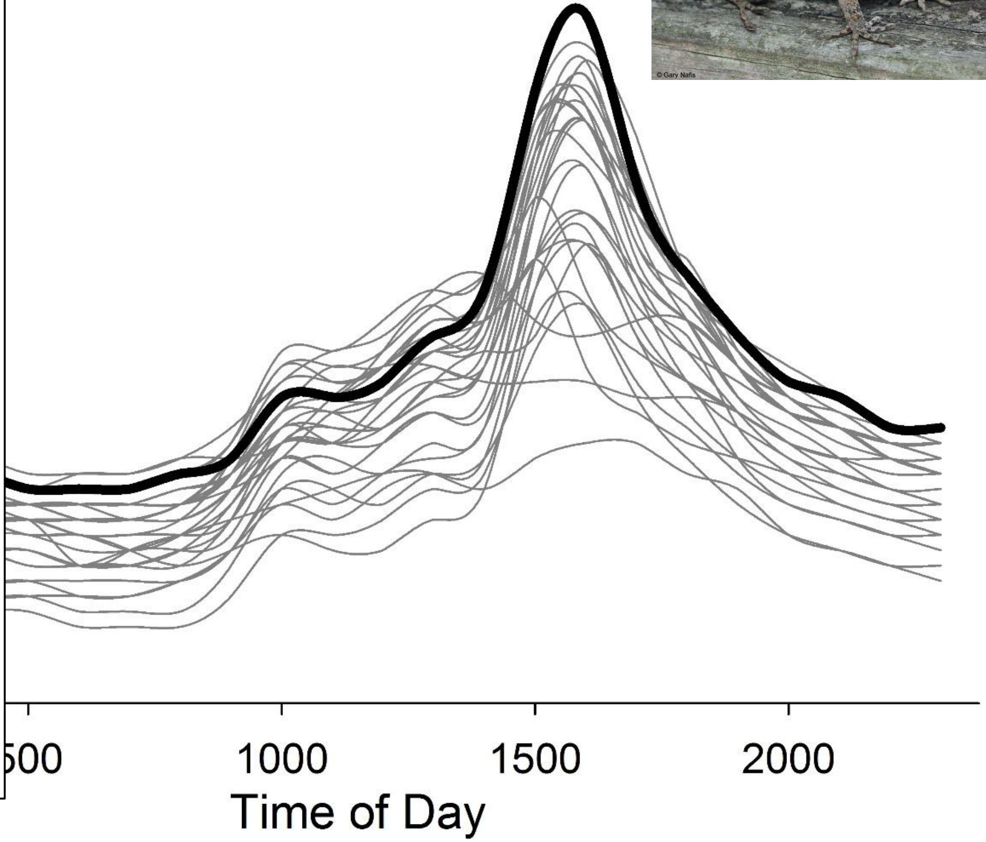

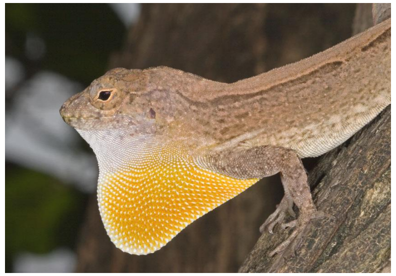

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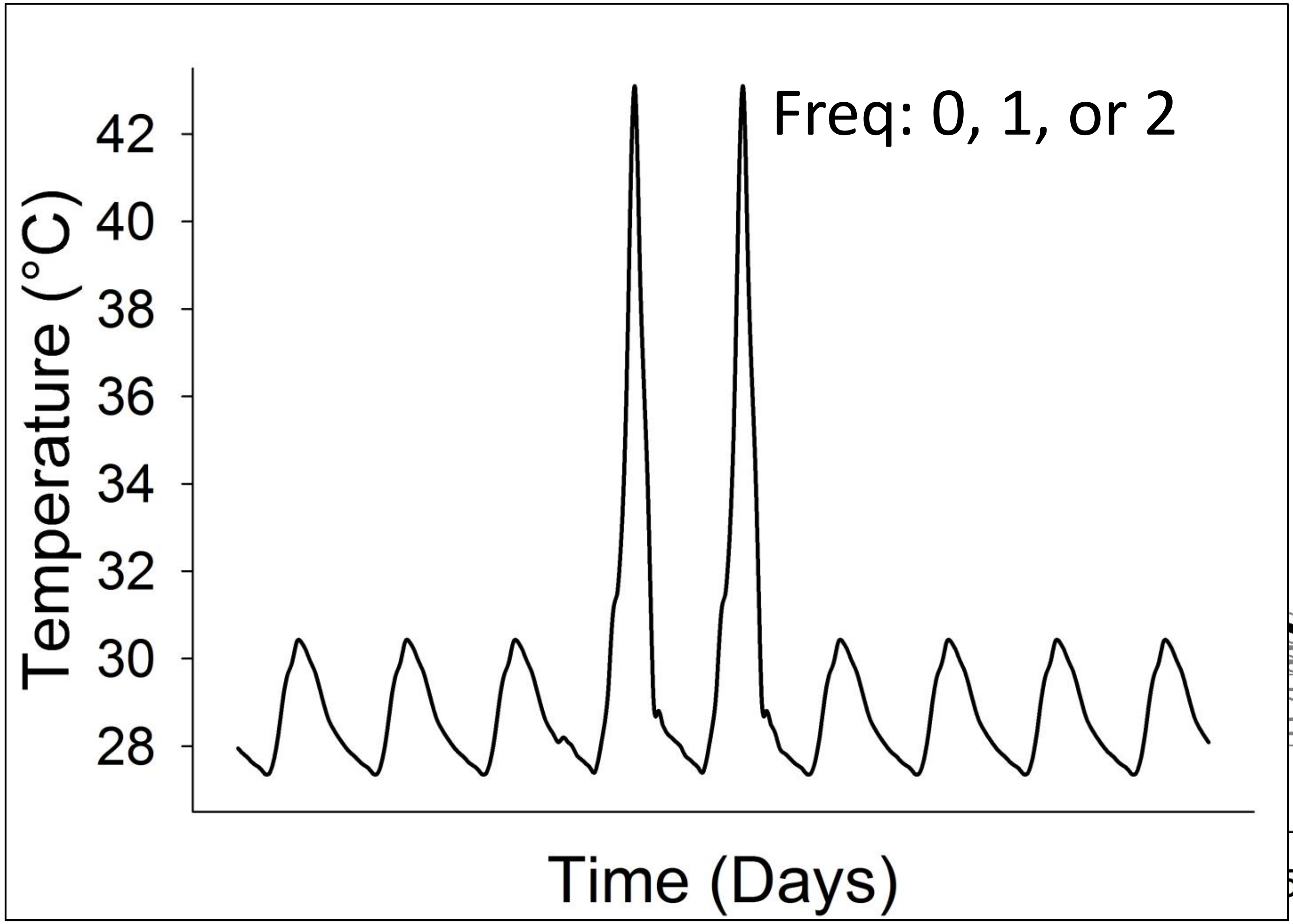

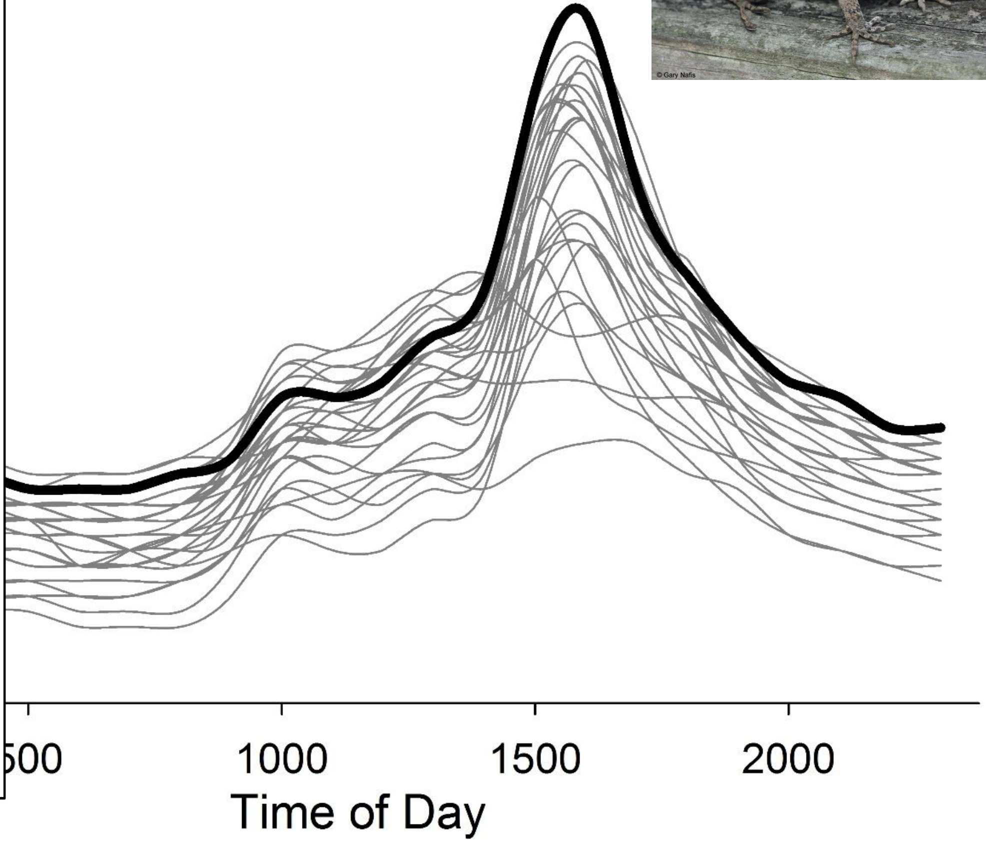

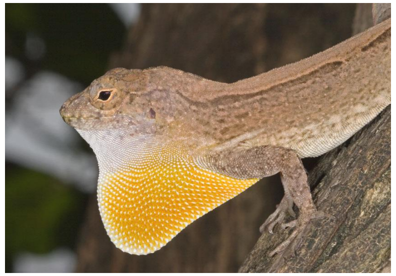

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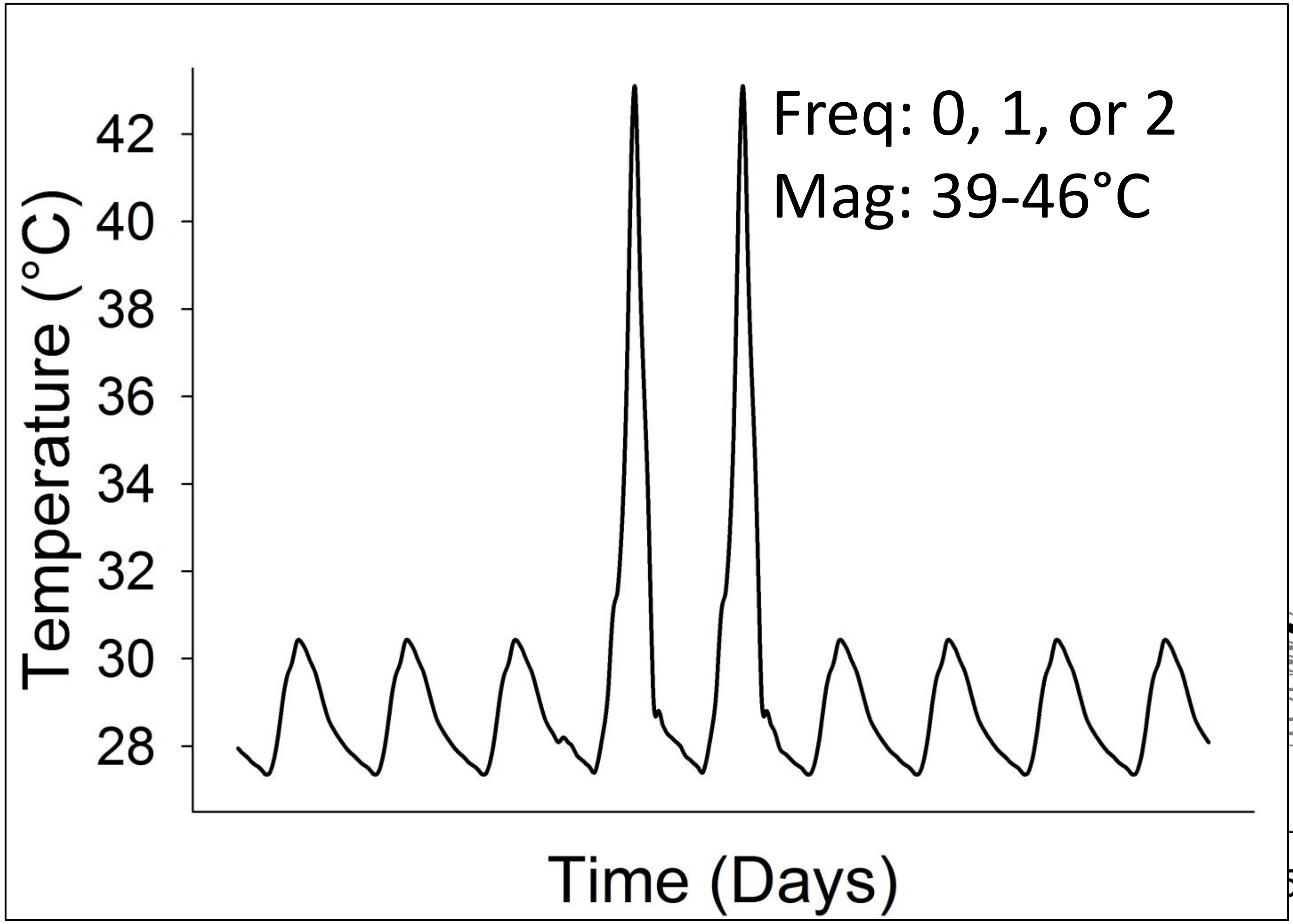

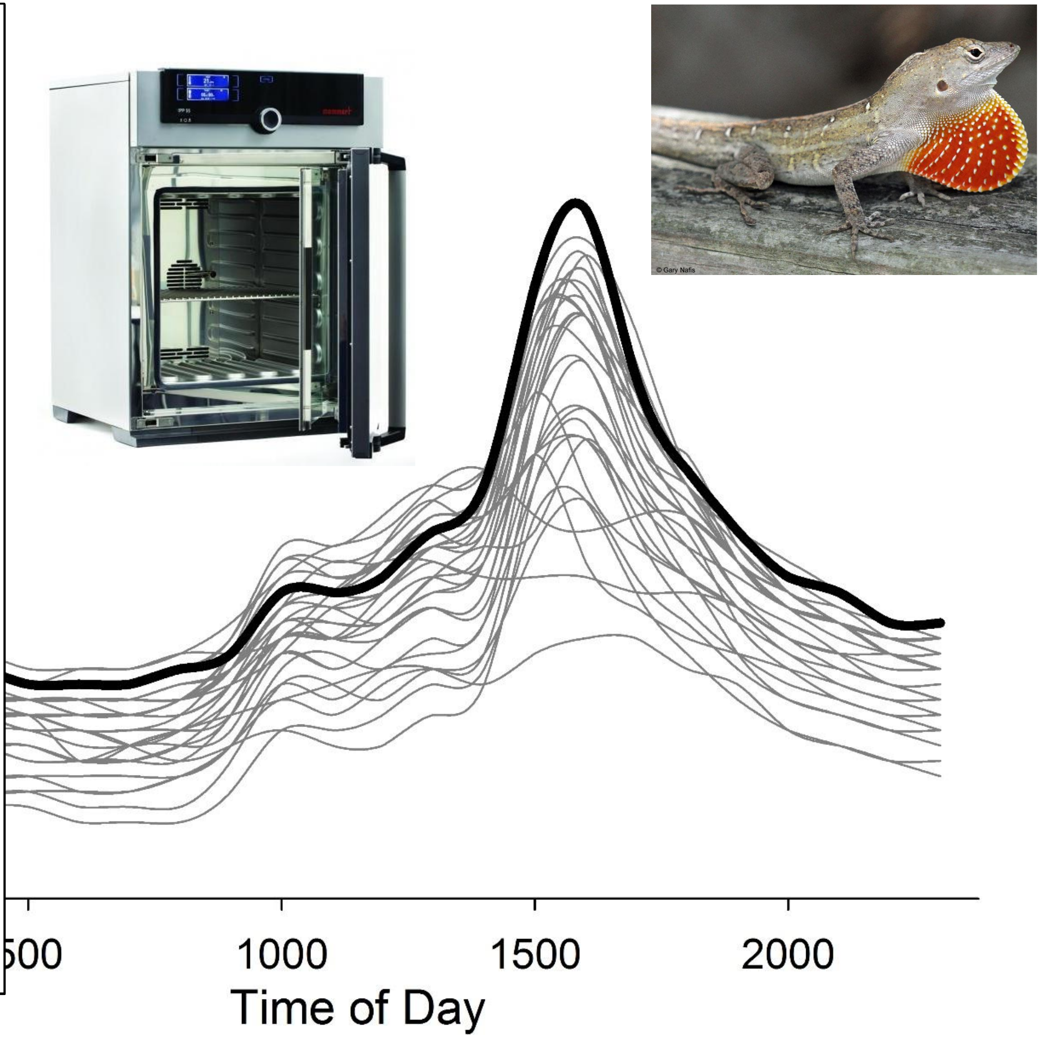

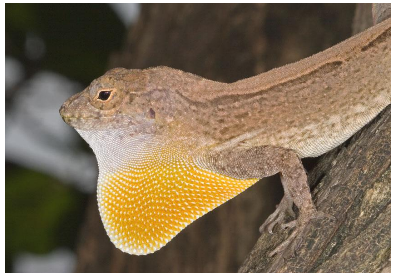

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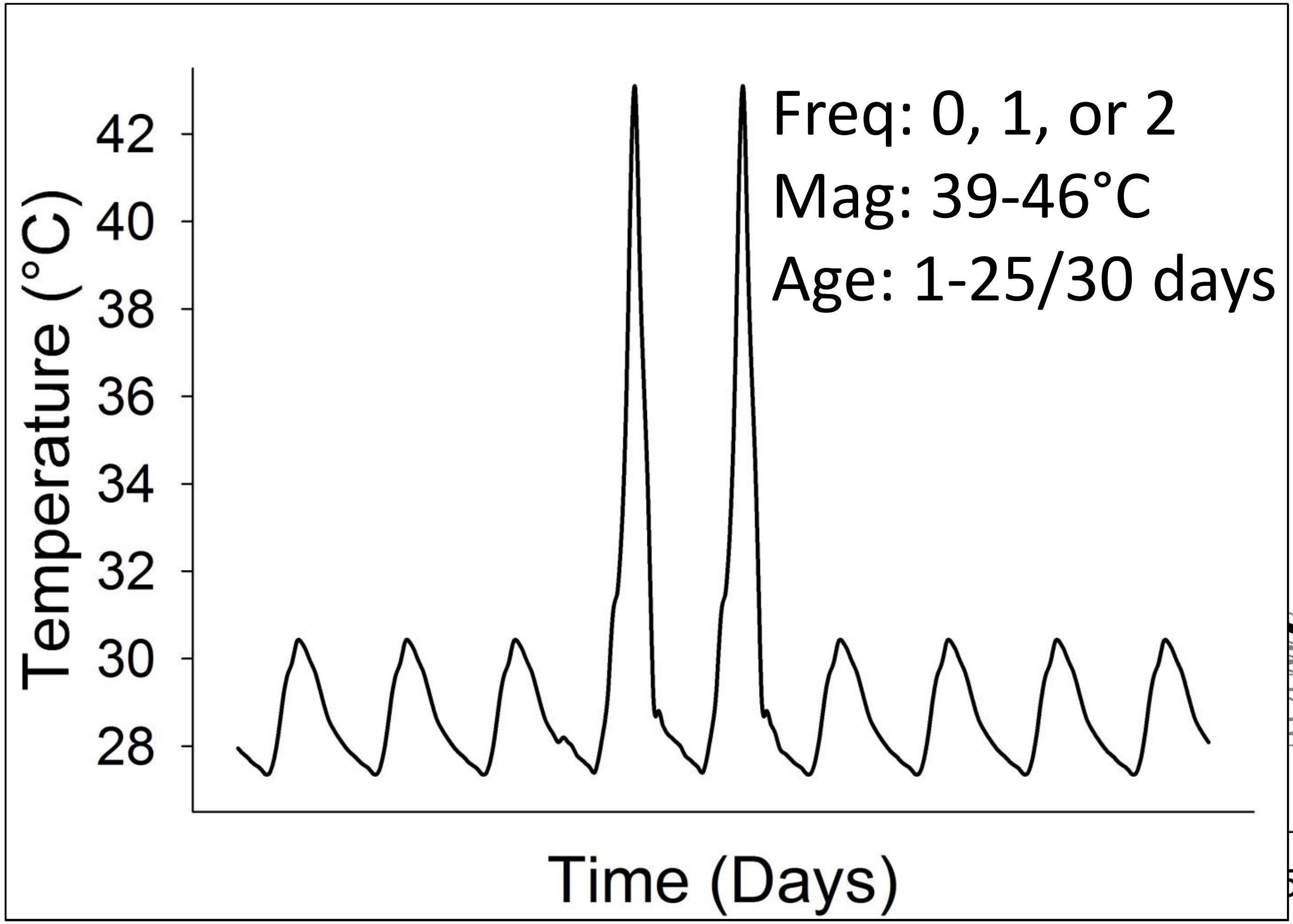

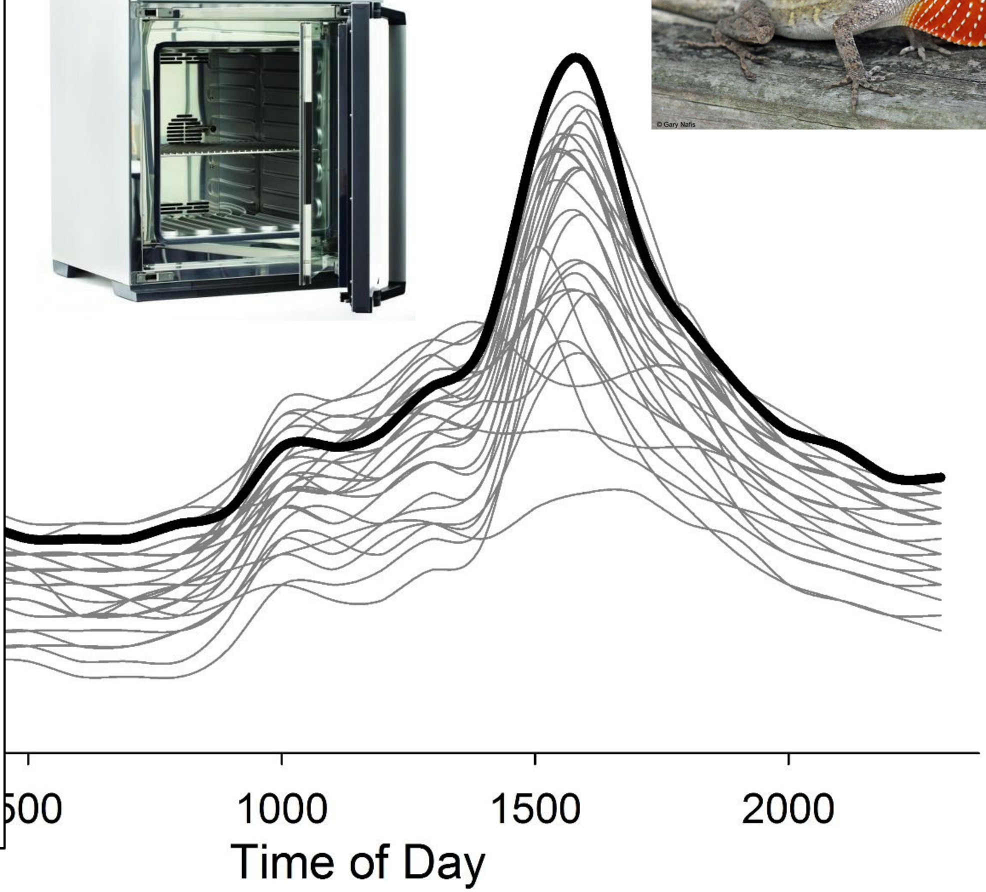

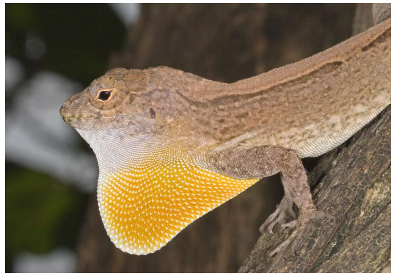

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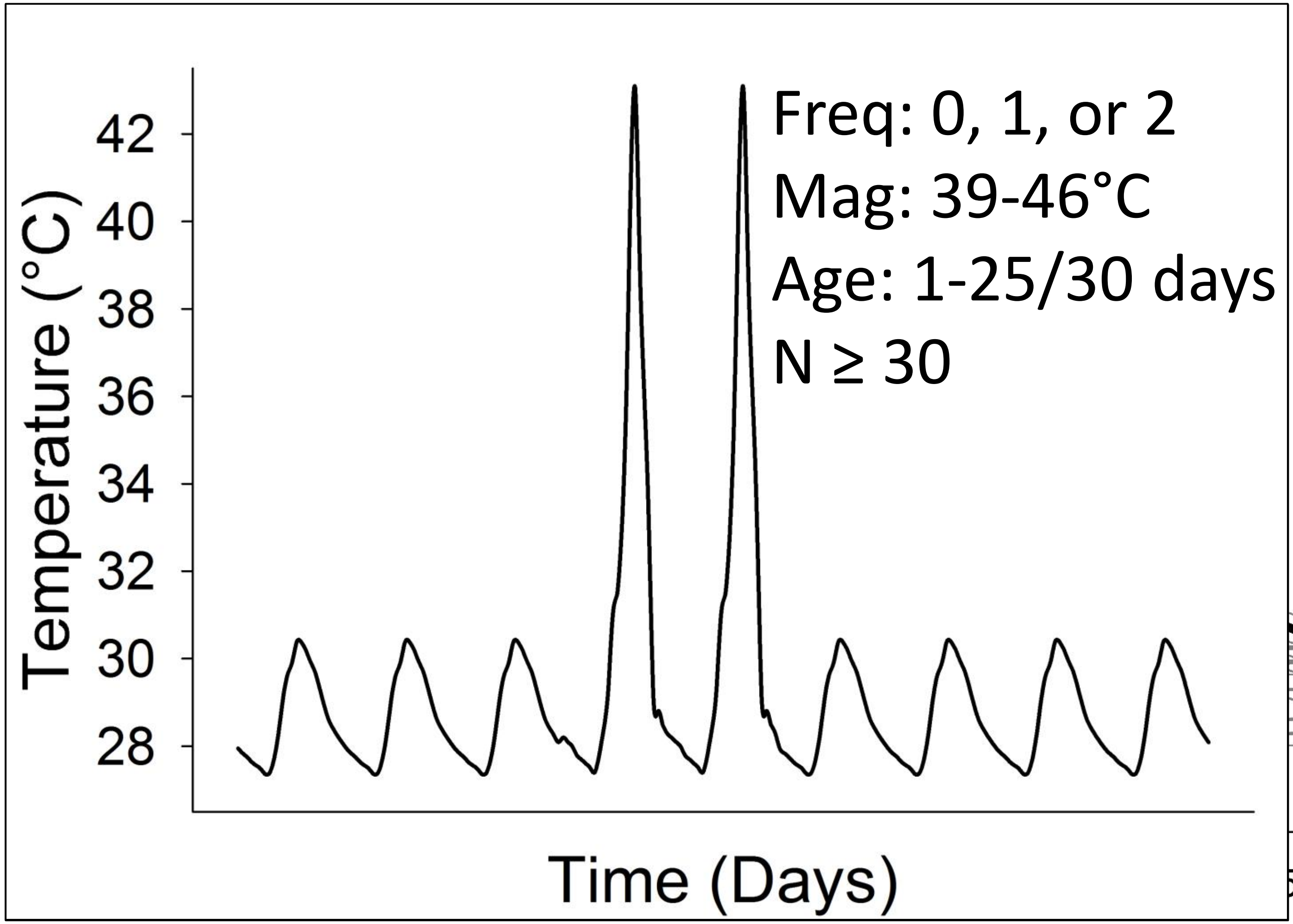
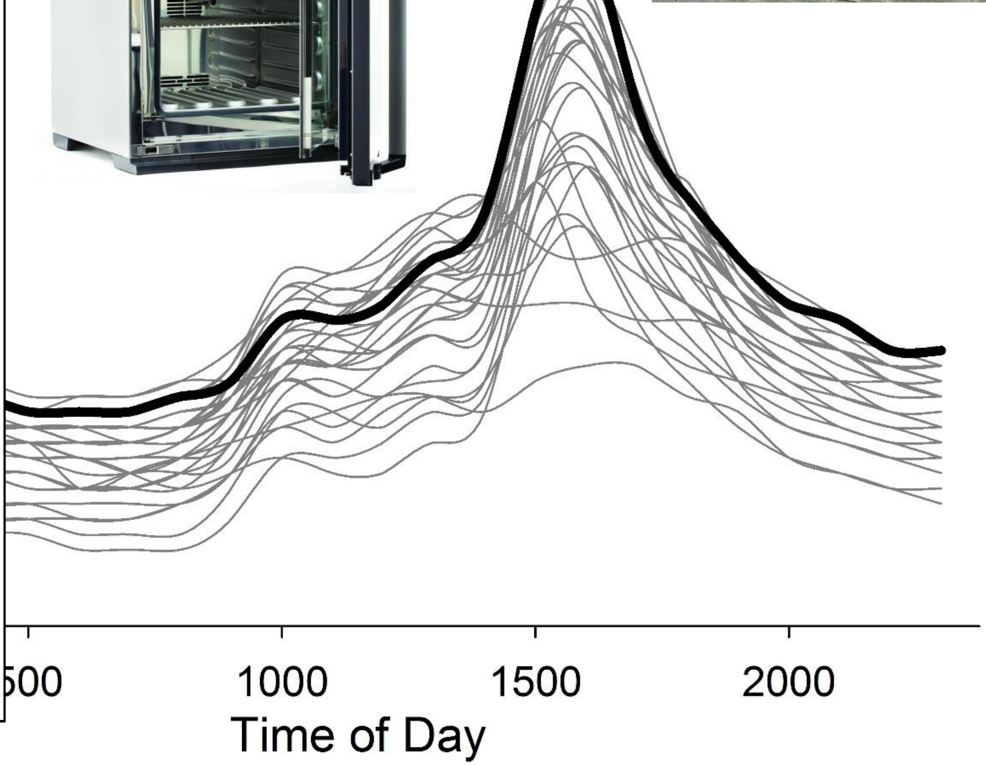
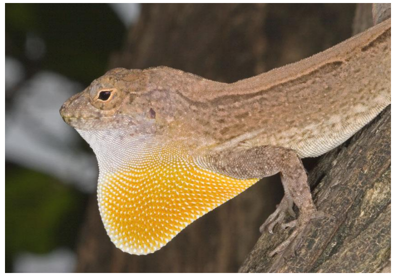


Freq: 0, 1, or 2
Mag: 39-46°C
Age: 1-25/30 days
N ≥ 30





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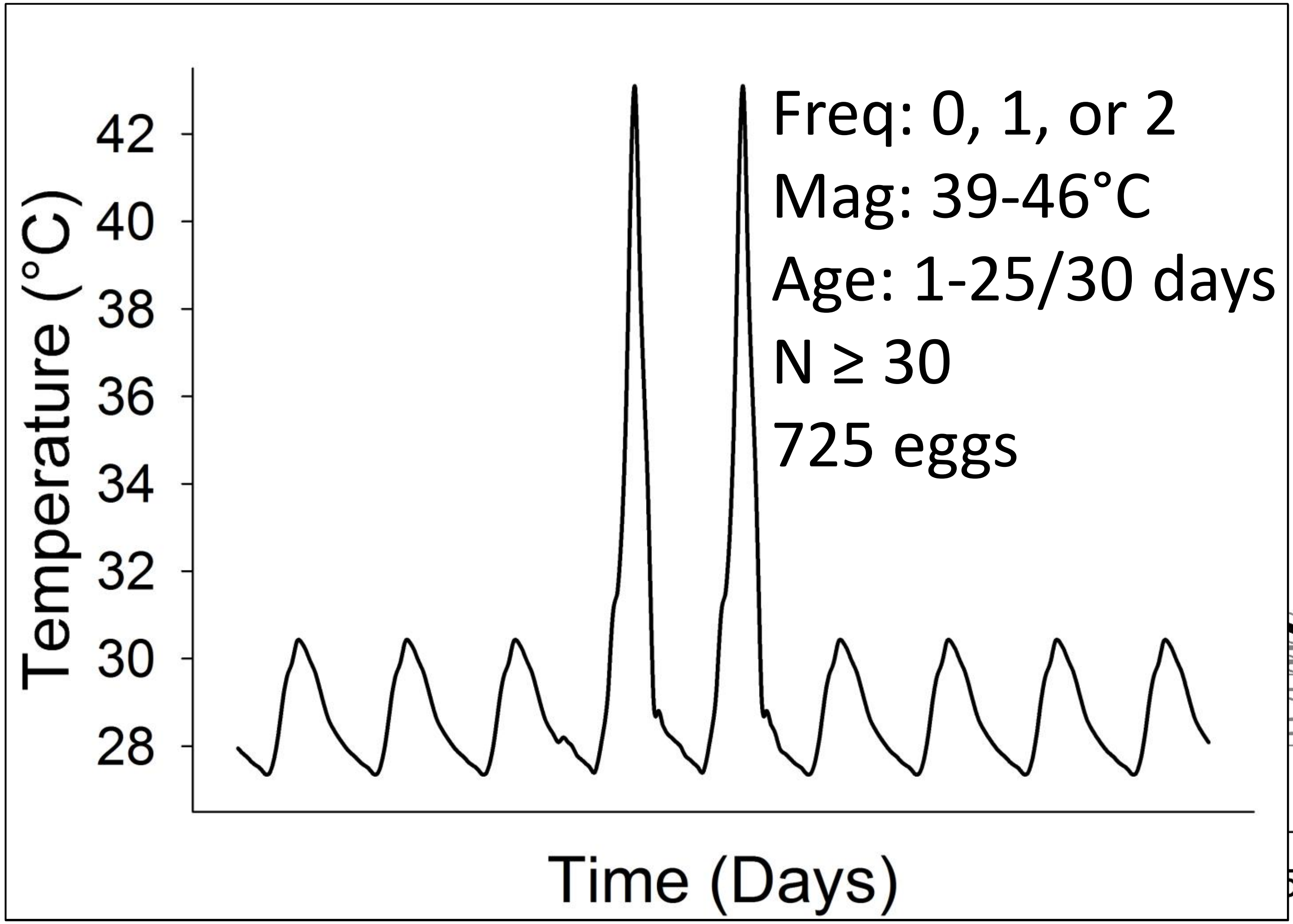
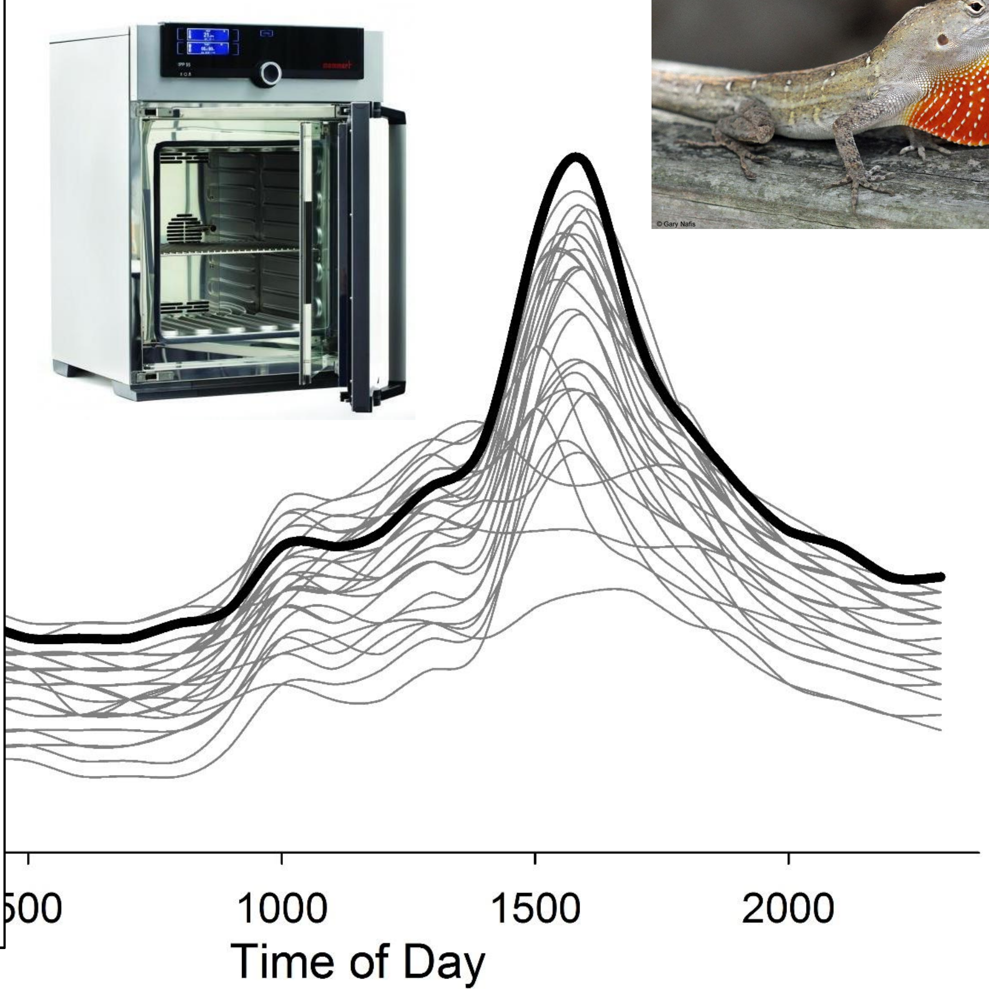
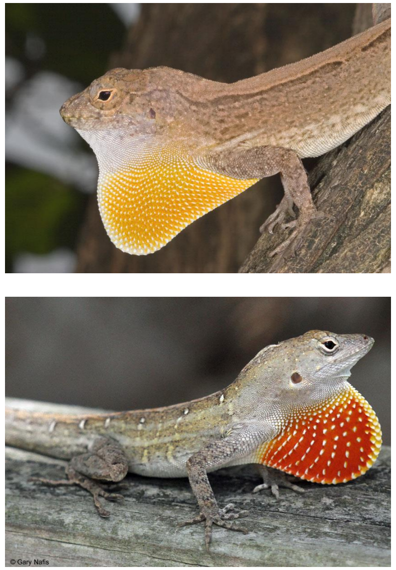


Freq: 0, 1, or 2
Mag: 39-46°C
Age: 1-25/30 days
N ≥ 30
725 eggs





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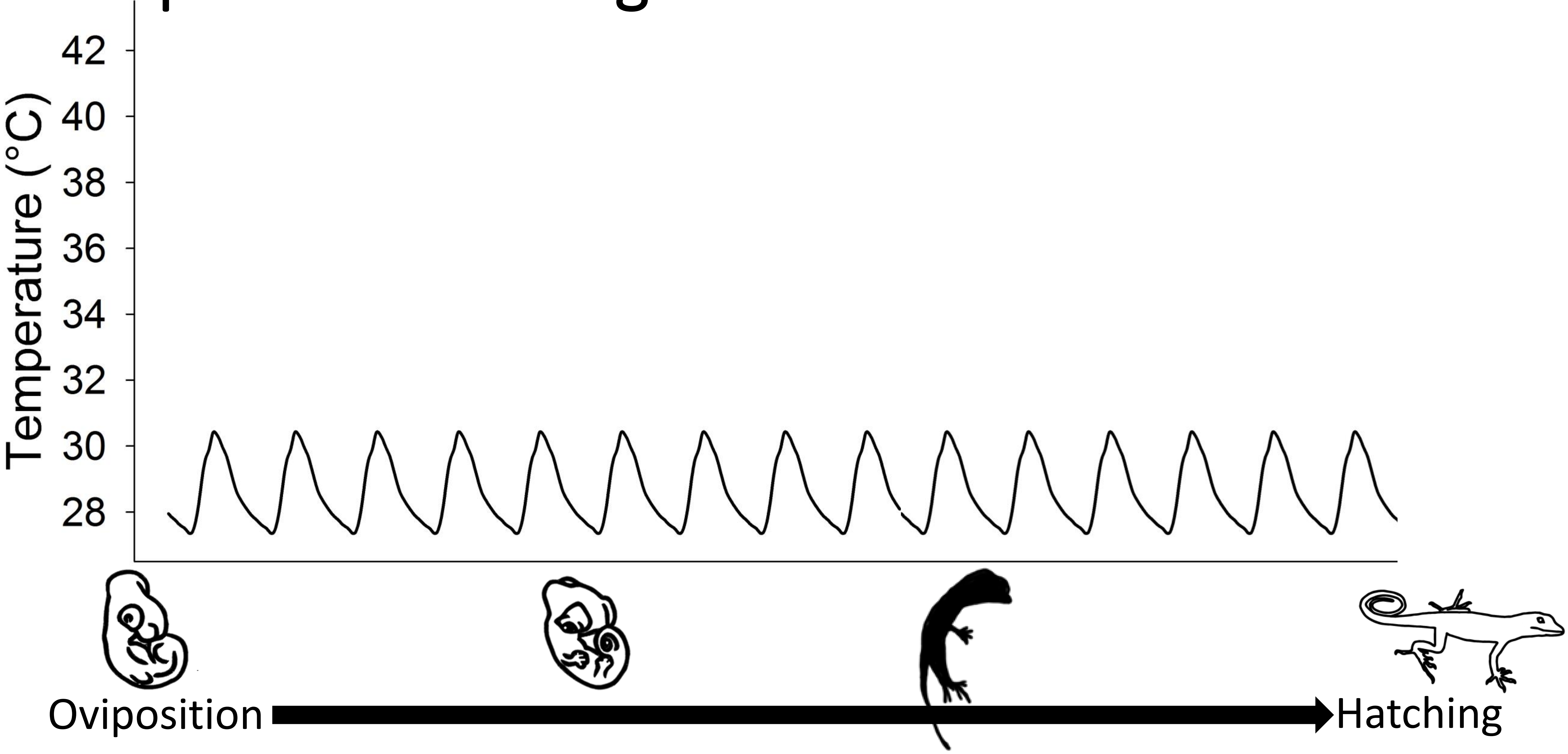

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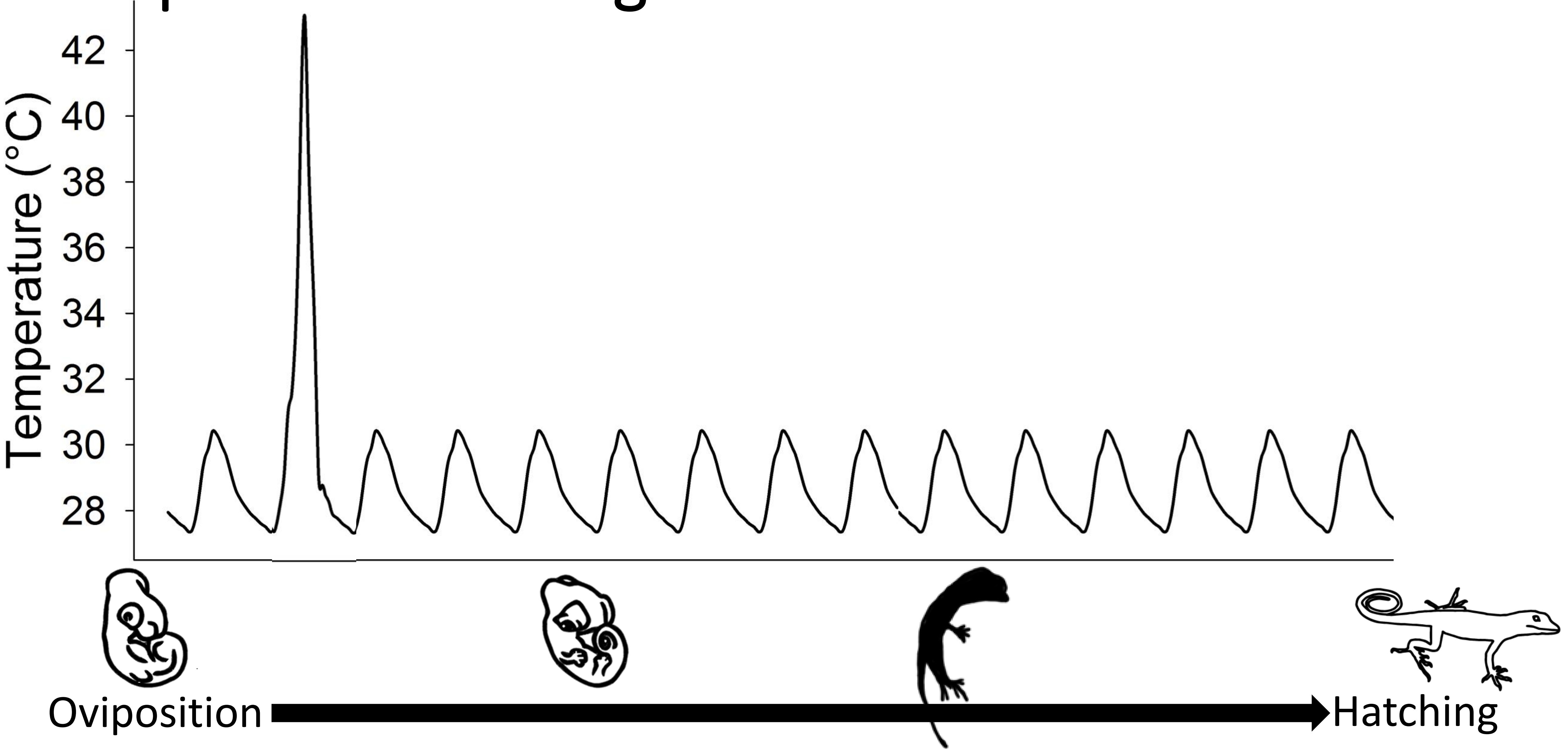

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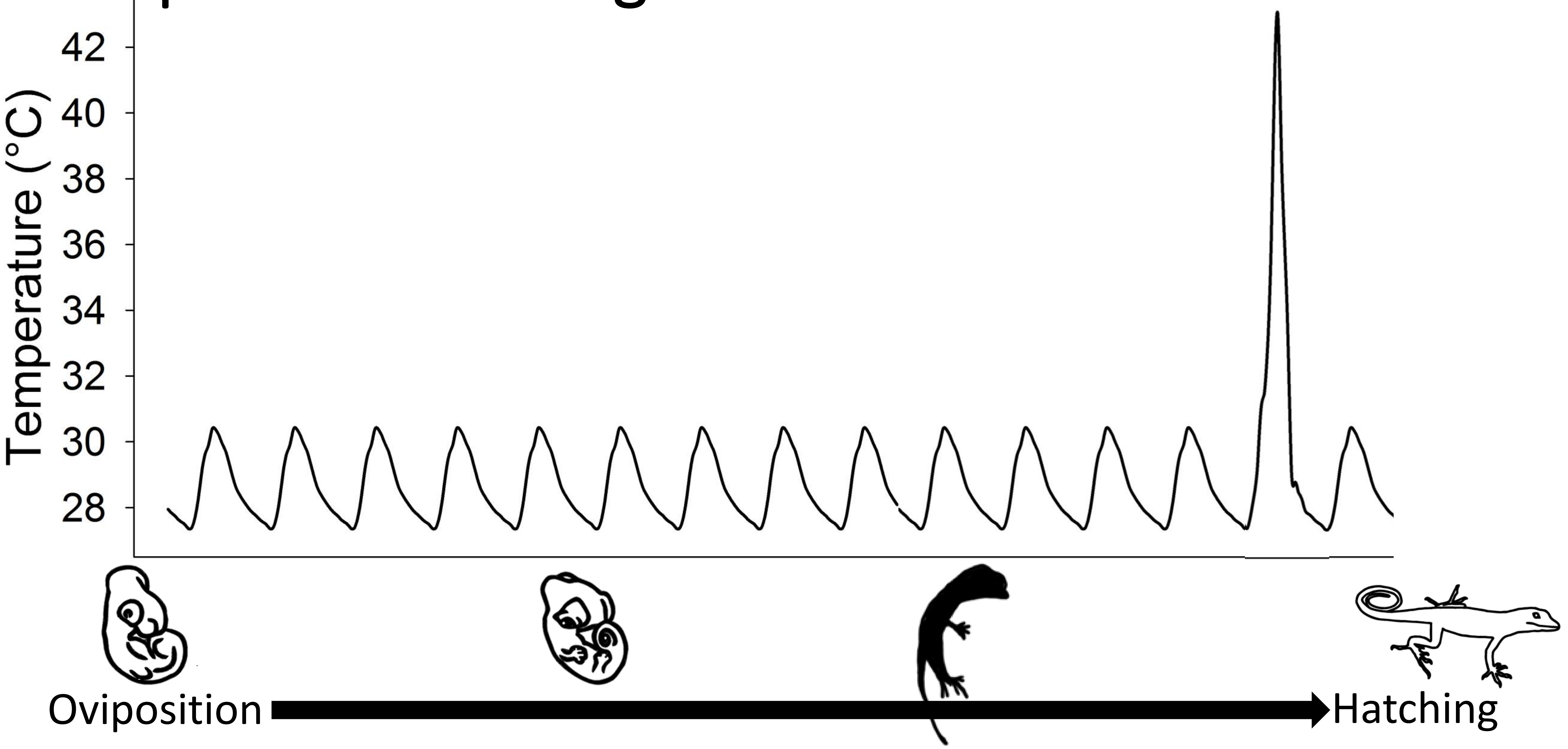

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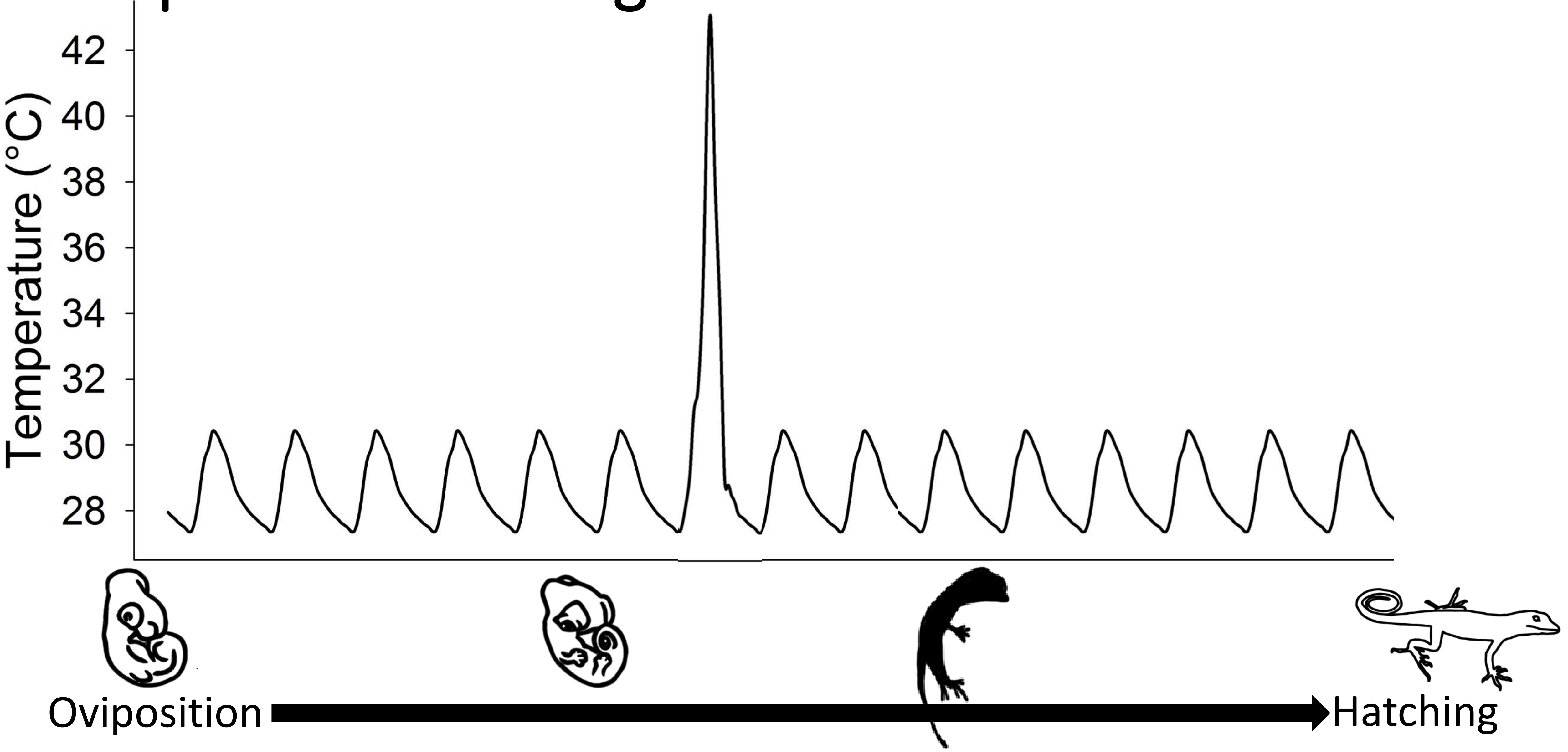

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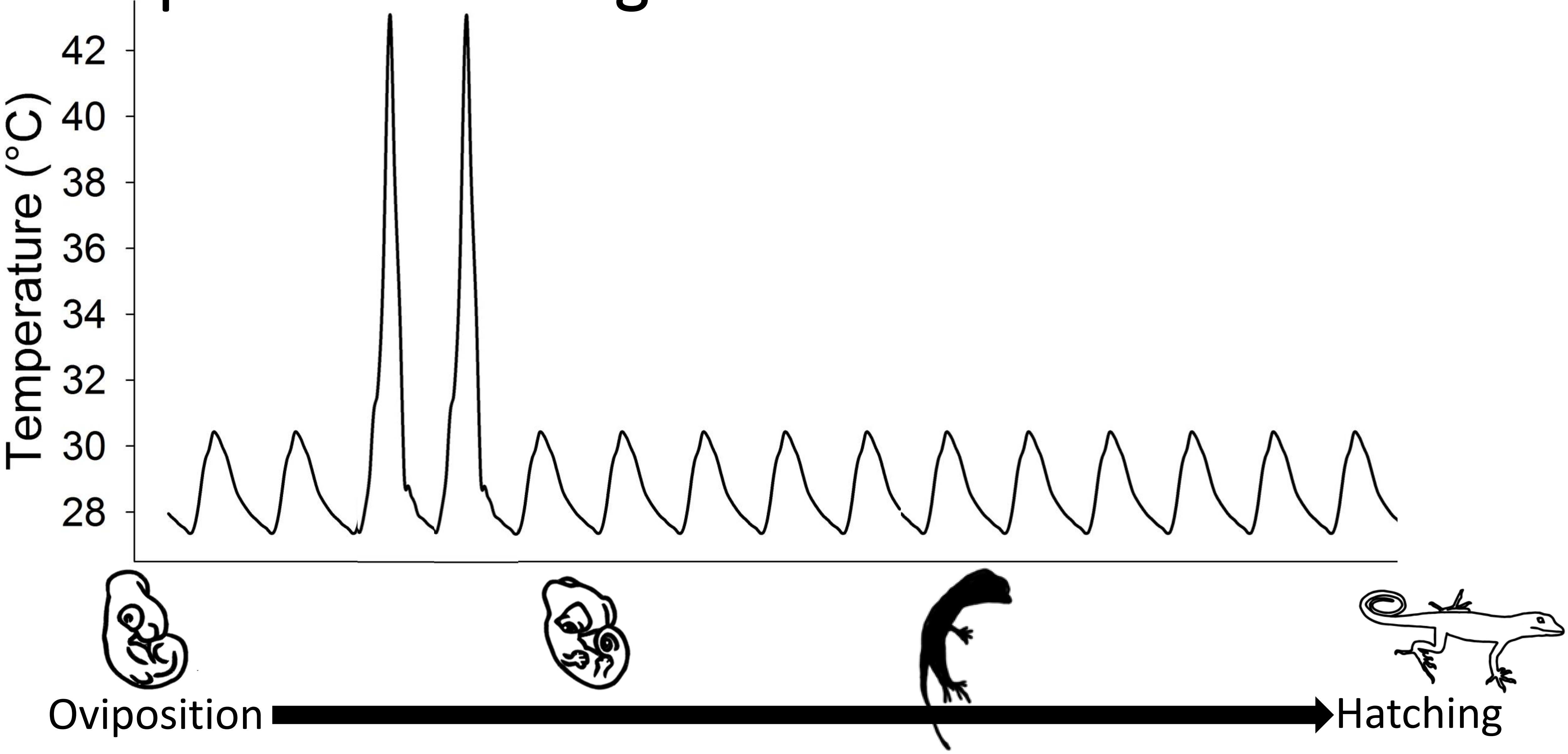

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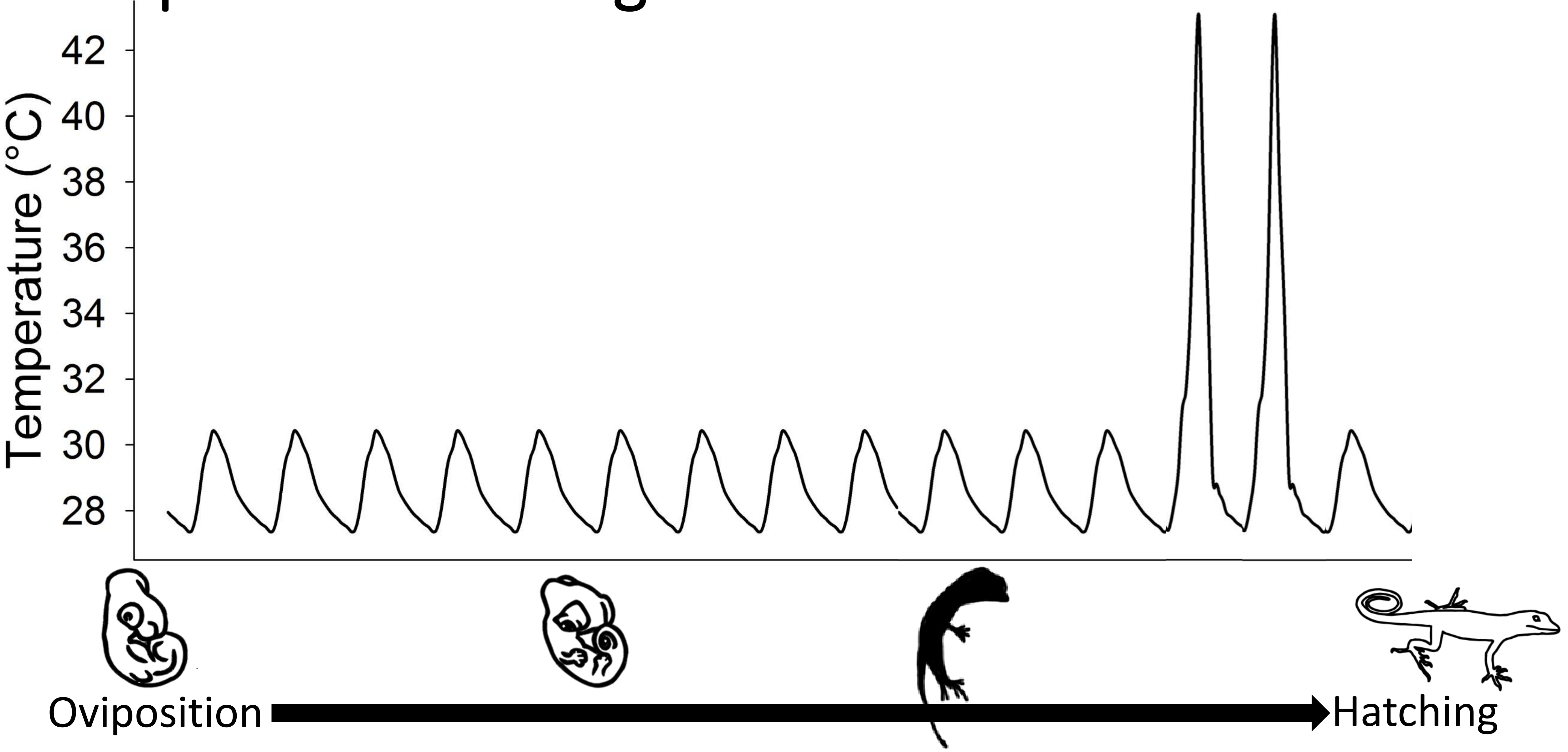
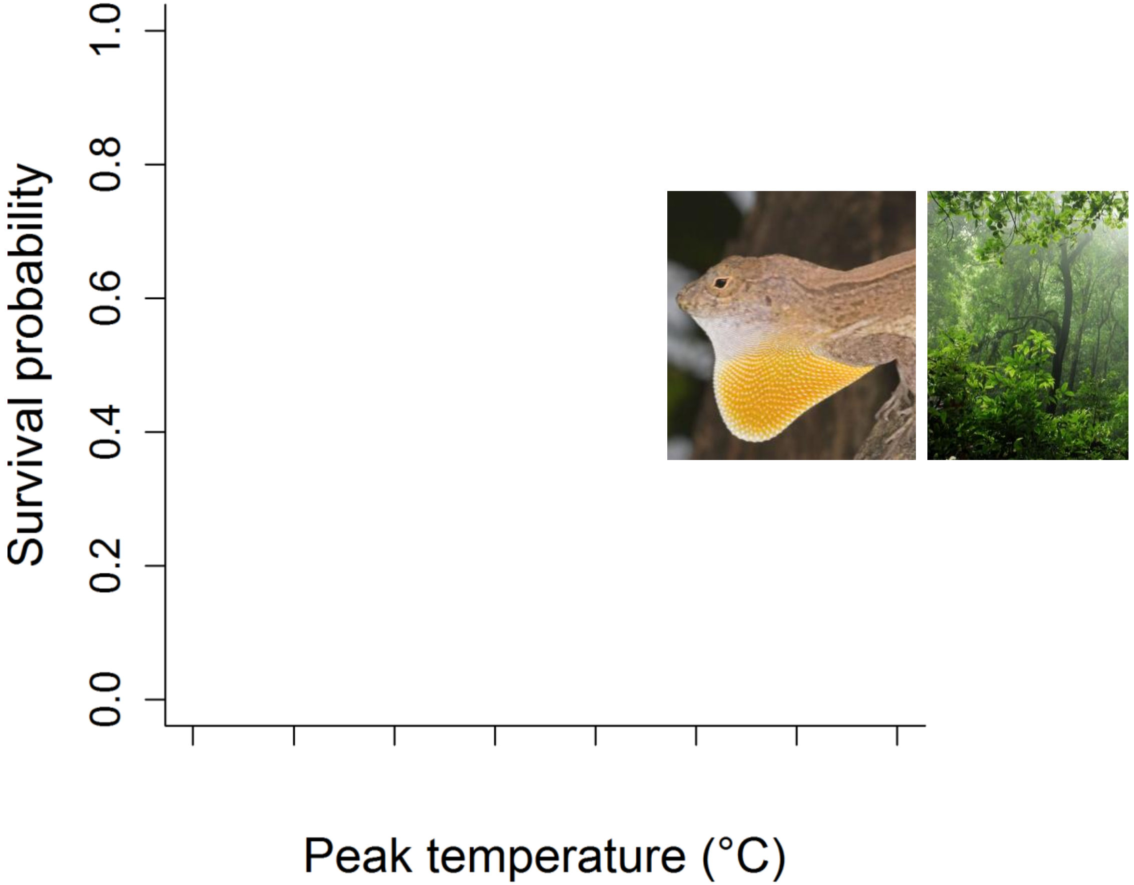
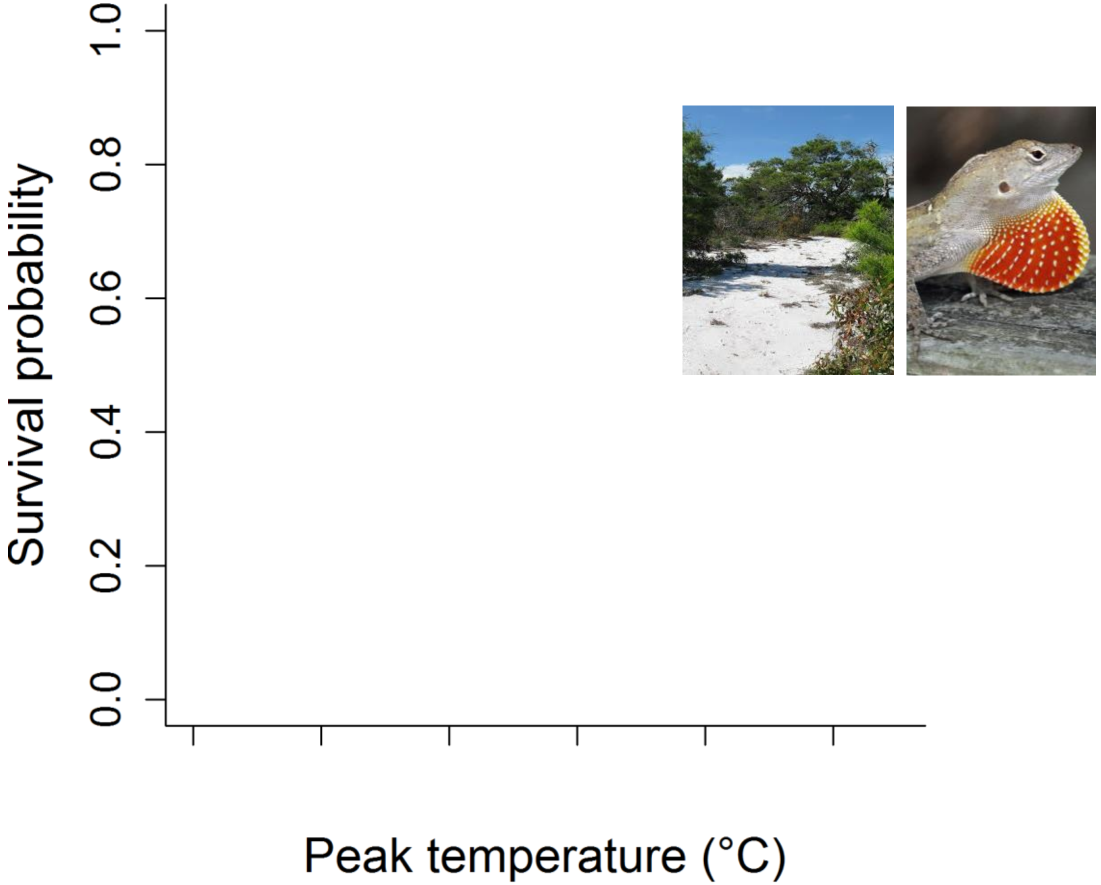
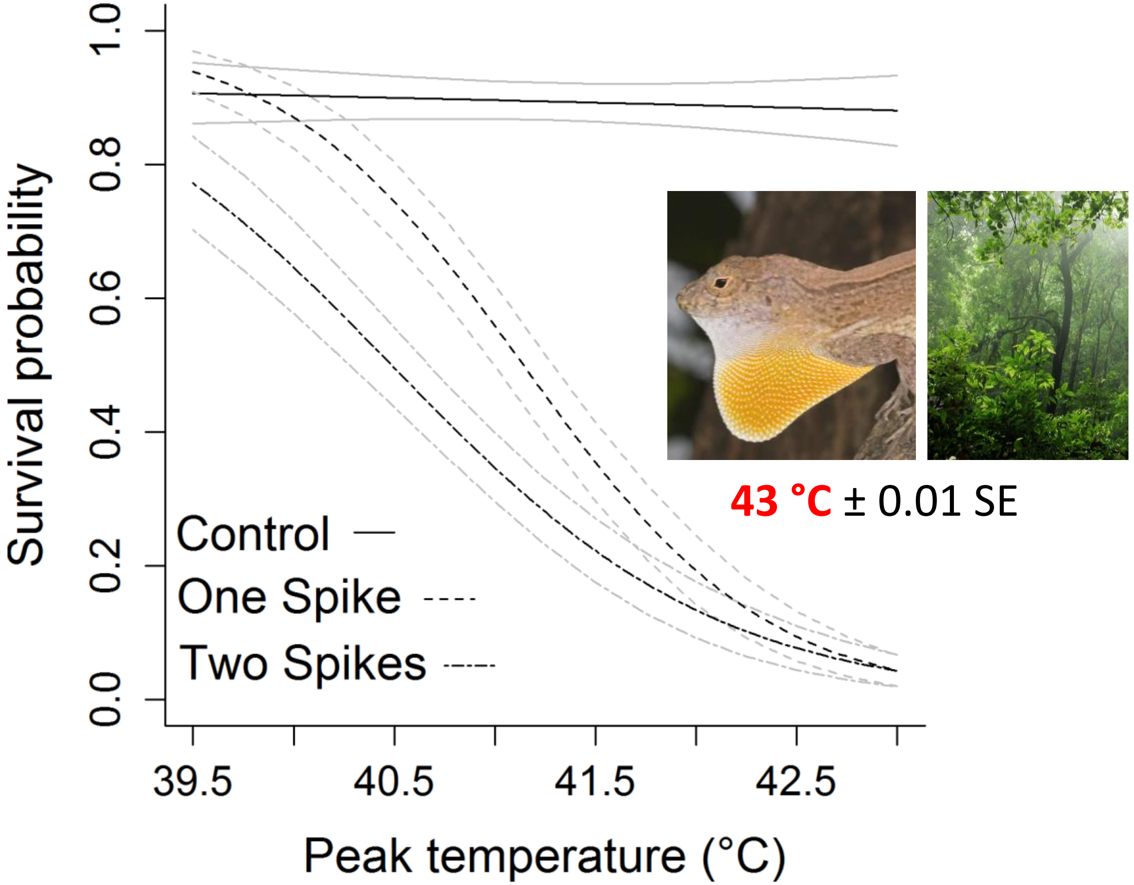


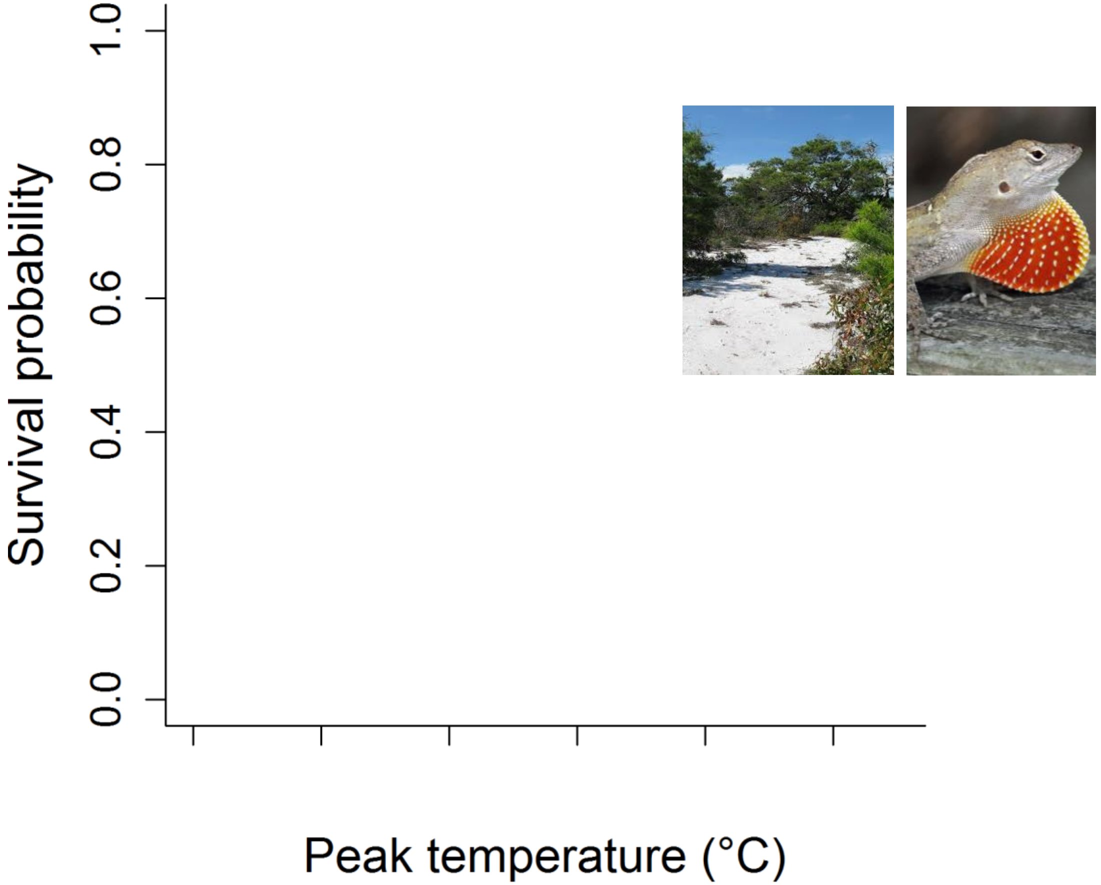
Embryo survival: Eco Relevant





Embryo survival: Eco Relevant

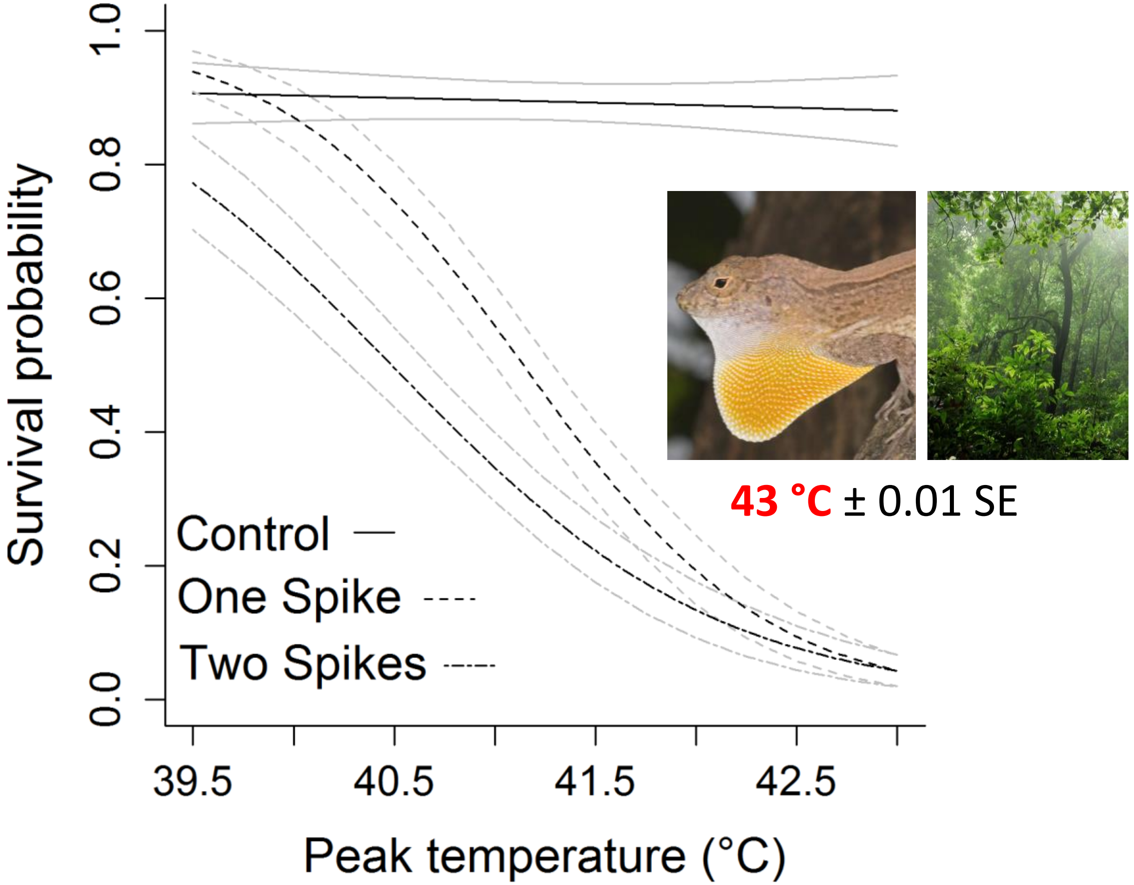


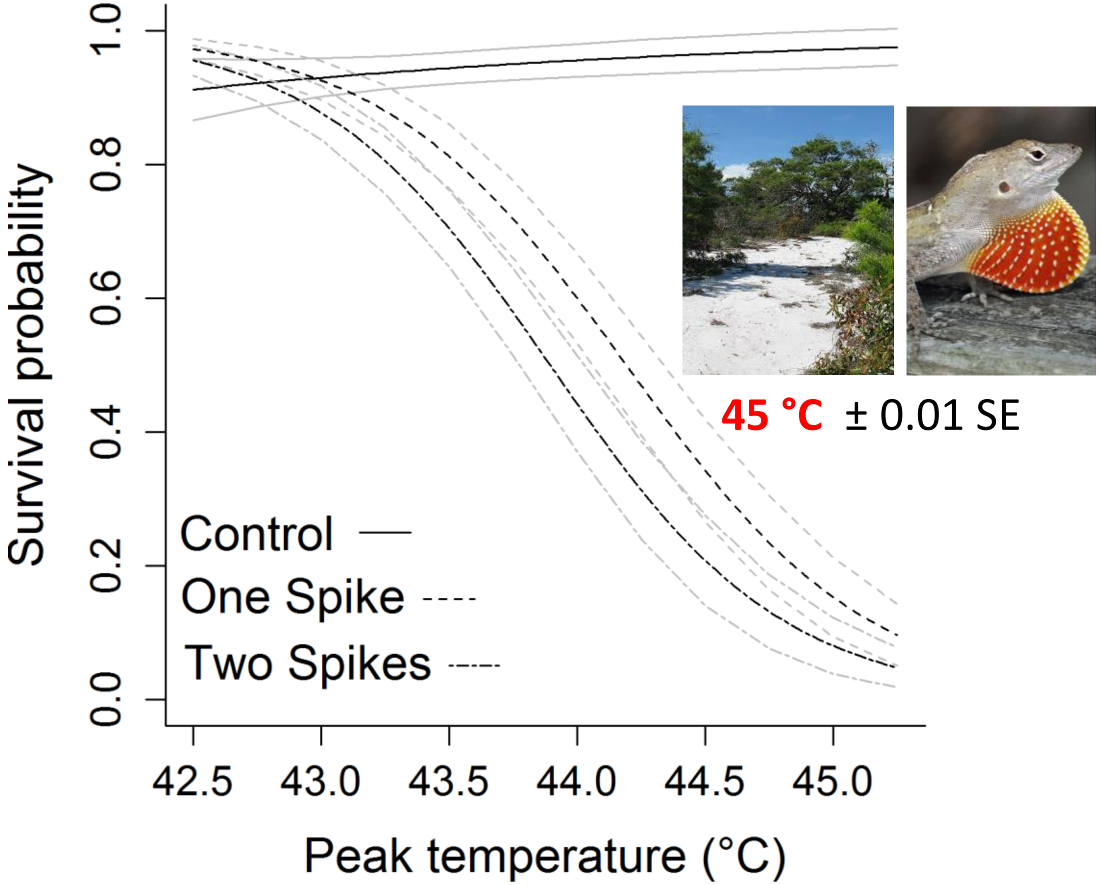


Treatment: χ^2_1=58.46; p<0.0001

Treatment by Temperature: χ^2_1=51.52; p<0.0001

Embryo survival: Eco Relevant





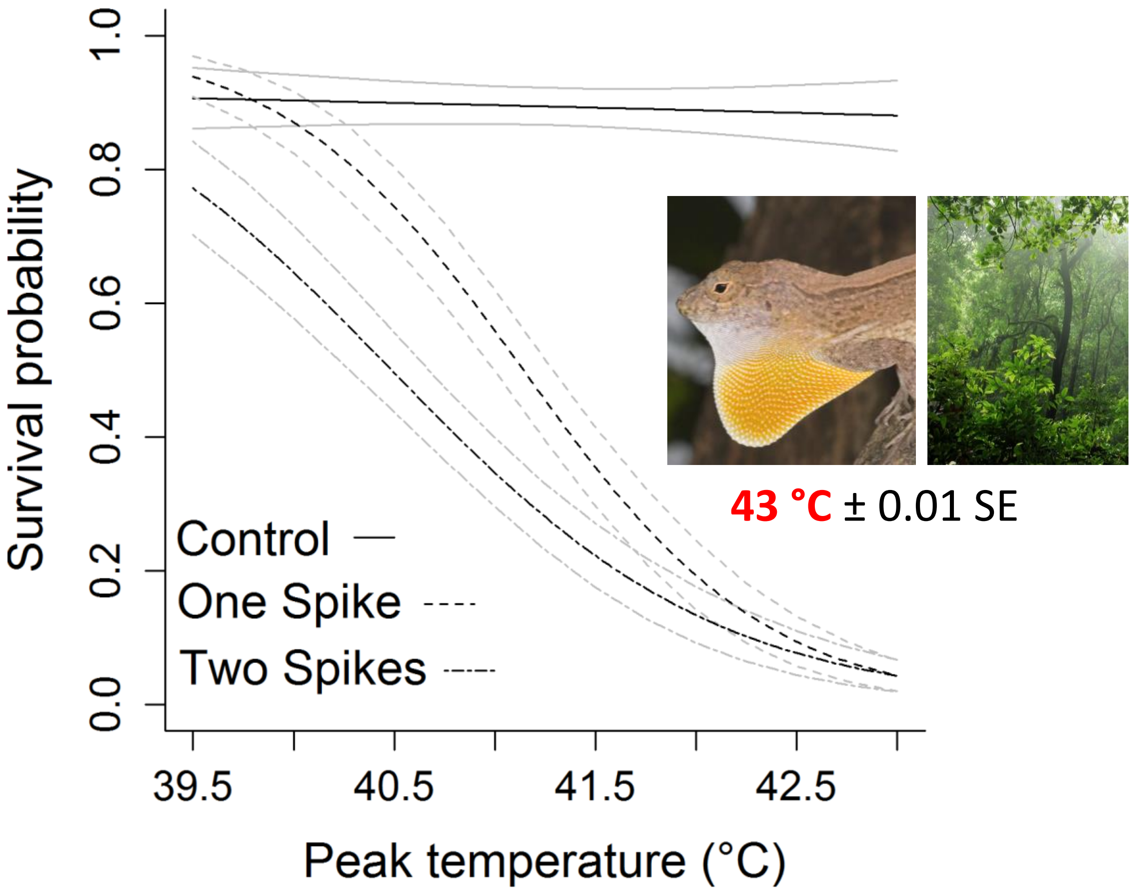
Treatment: χ^2_1=58.46; p<0.0001

Treatment by Temperature: χ^2_1=51.52; p<0.0001

Treatment: χ^2_1=20.45; p<0.0001

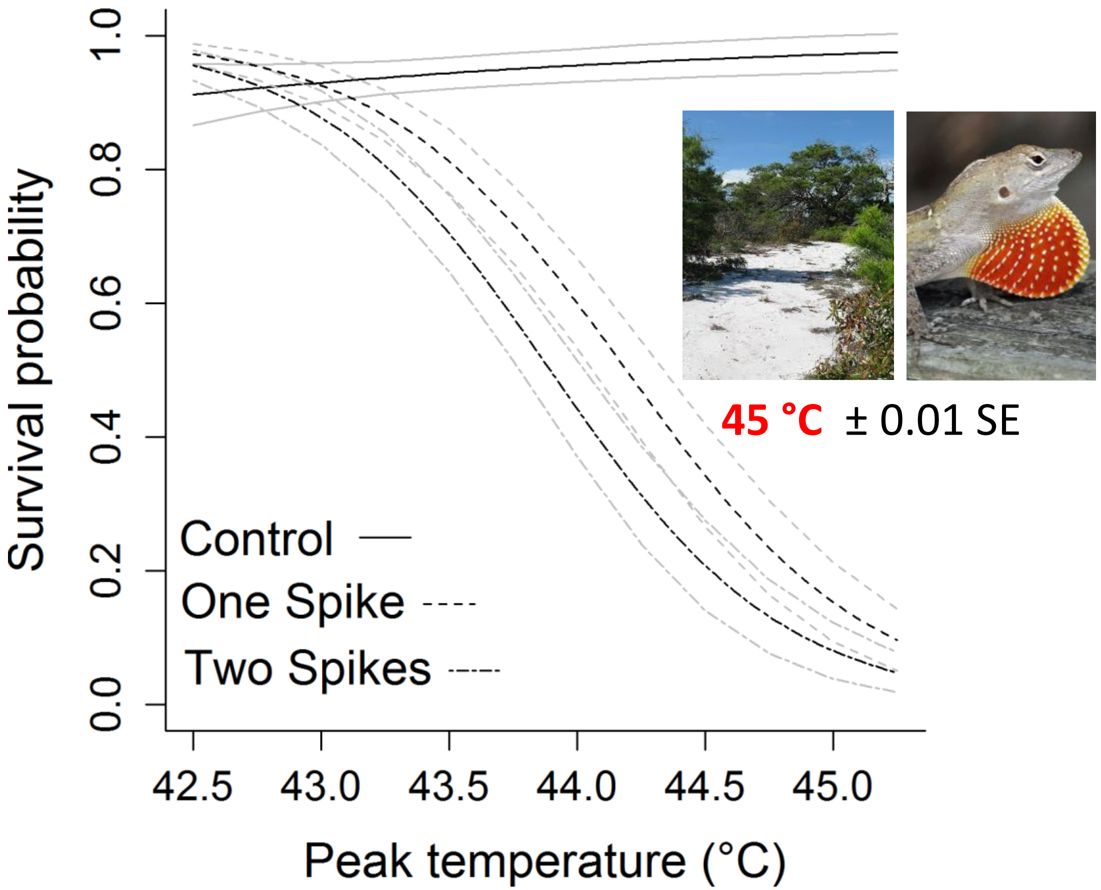
Treatment by Temperature: χ^2_1=62.7; p<0.0001

Effect of age?



Treatment: χ^2_1=58.46; p<0.0001

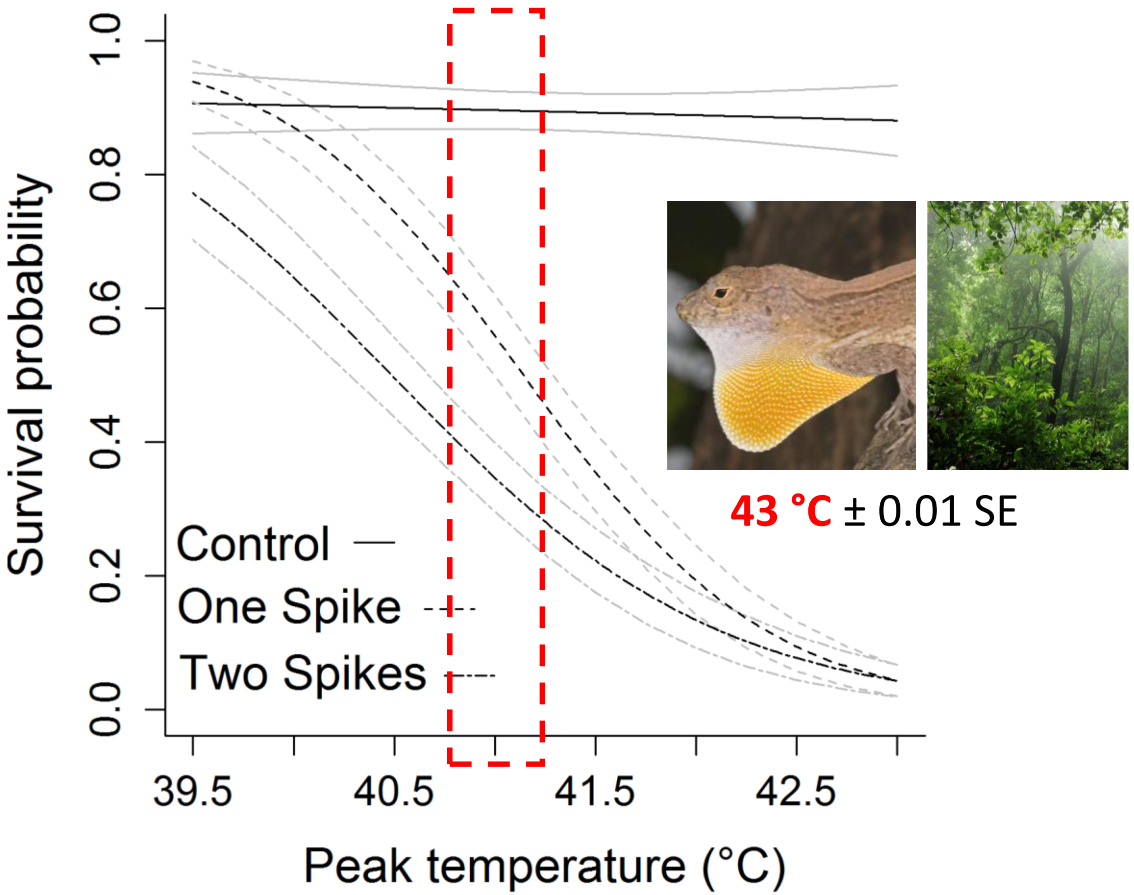
Treatment by Temperature: χ^2_1=51.52; p<0.0001

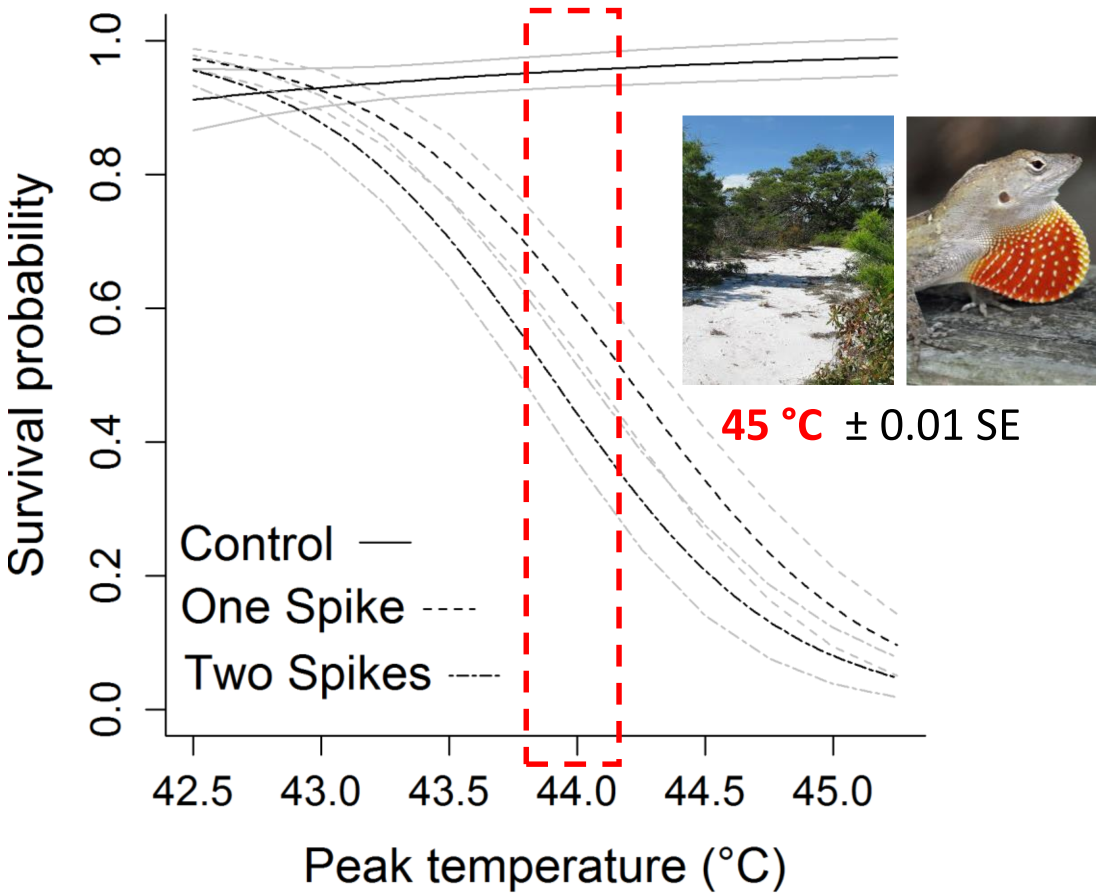


Treatment: χ^2_1=20.45; p<0.0001

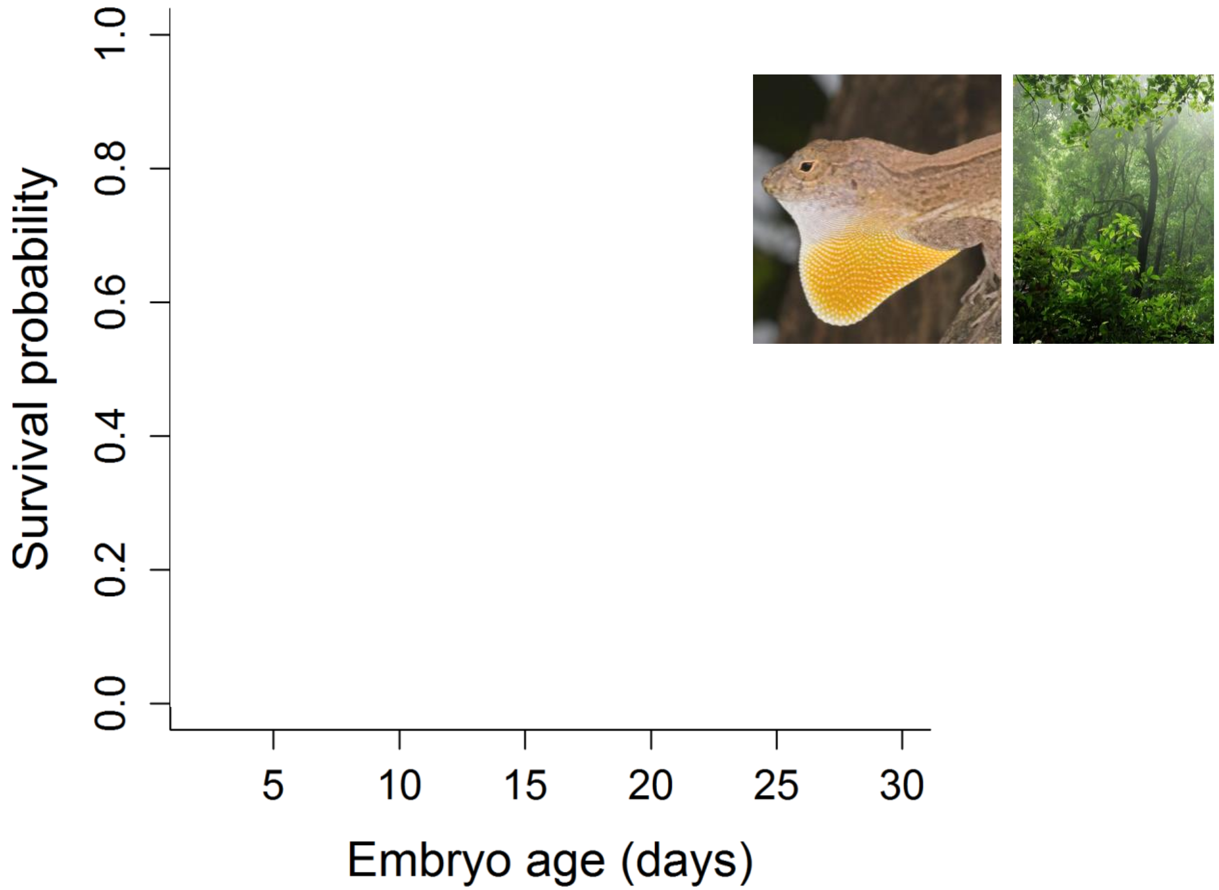
Treatment by Temperature: χ^2_1=62.7; p<0.0001

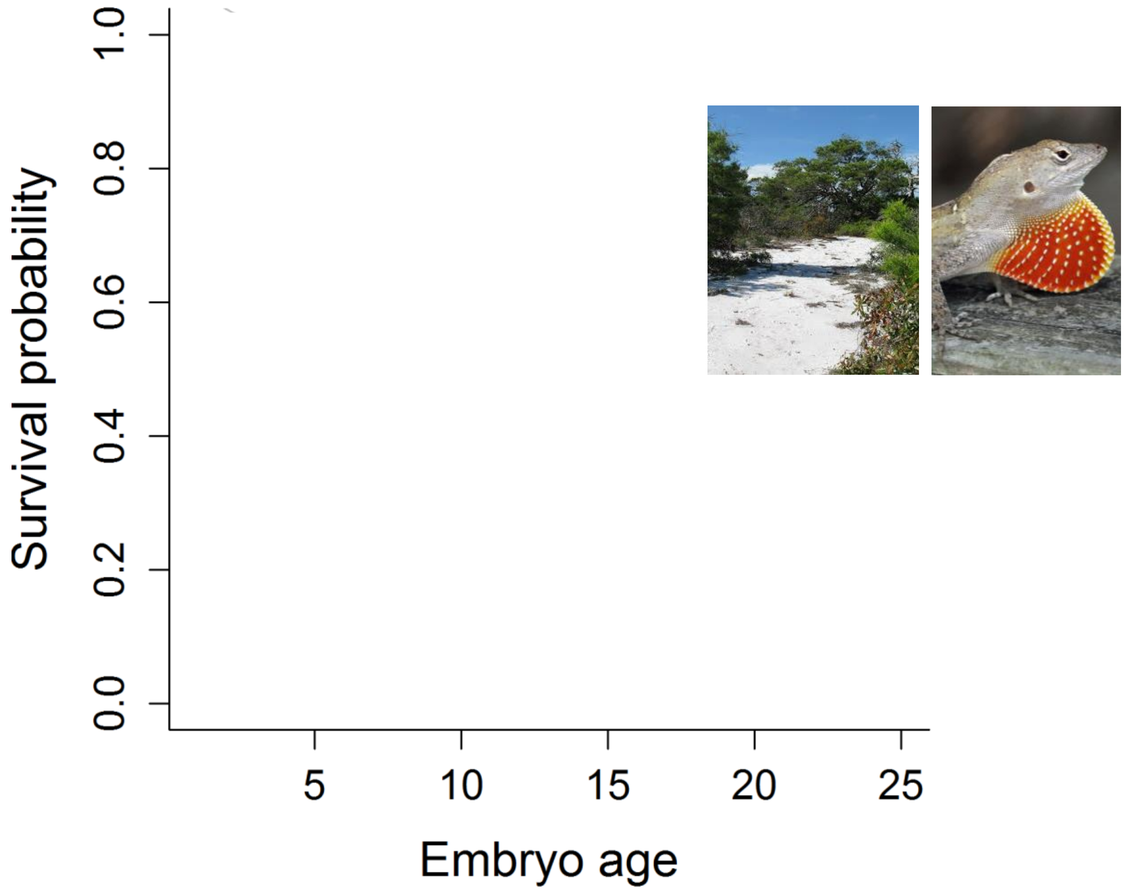
Effect of age?



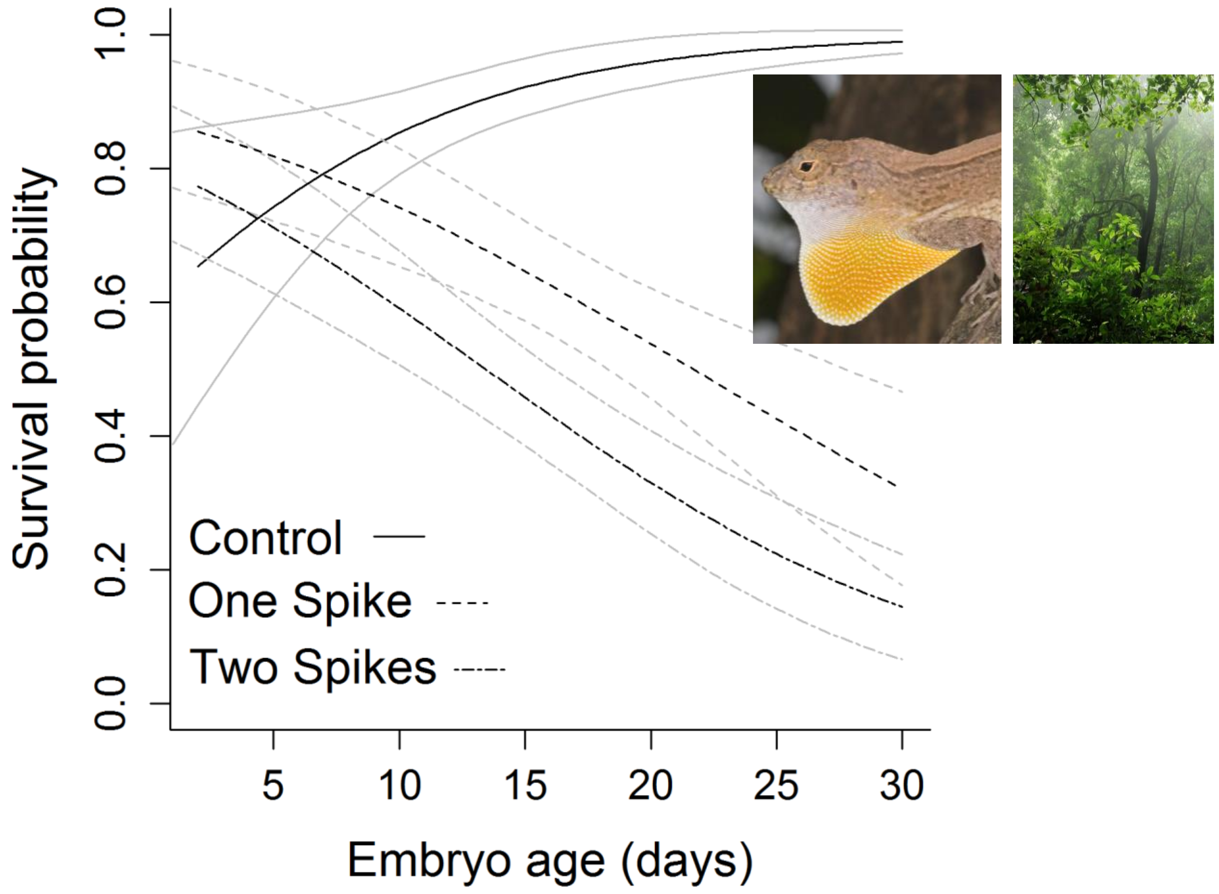


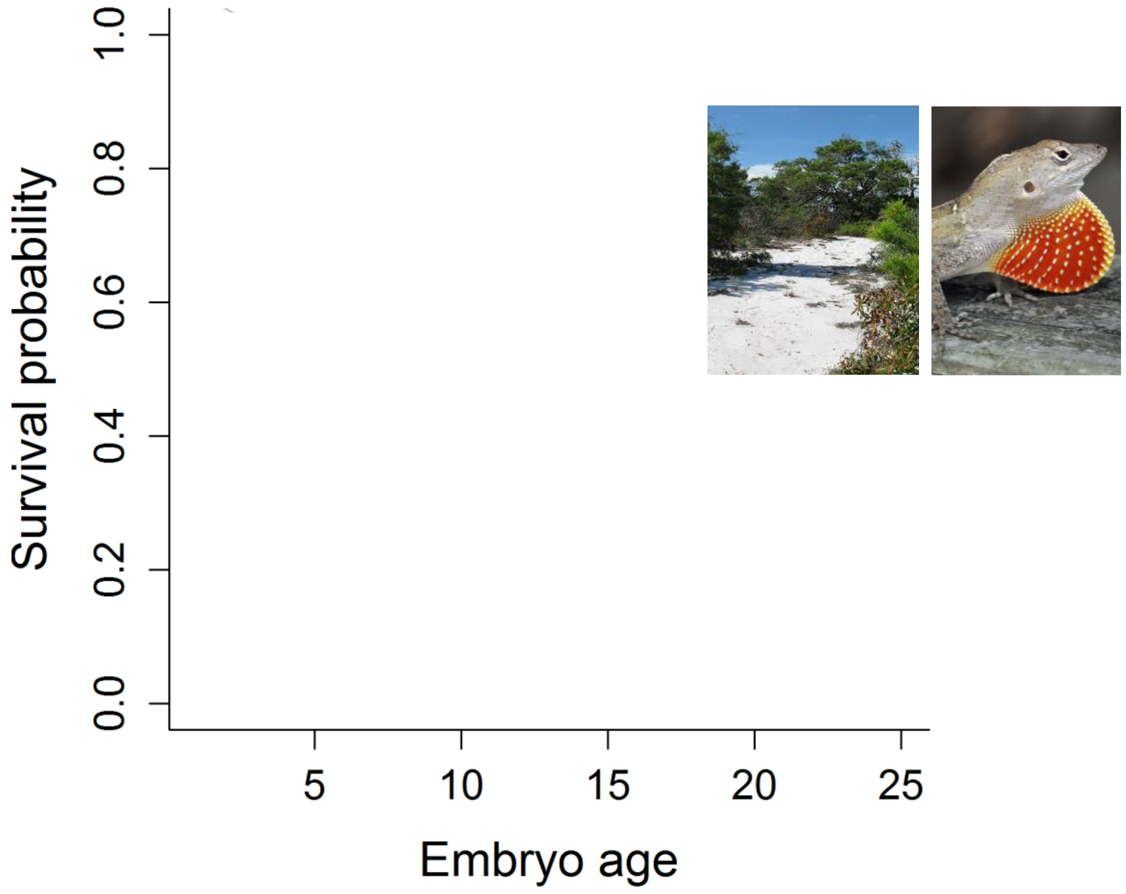
Effect of age?





Effect of age?

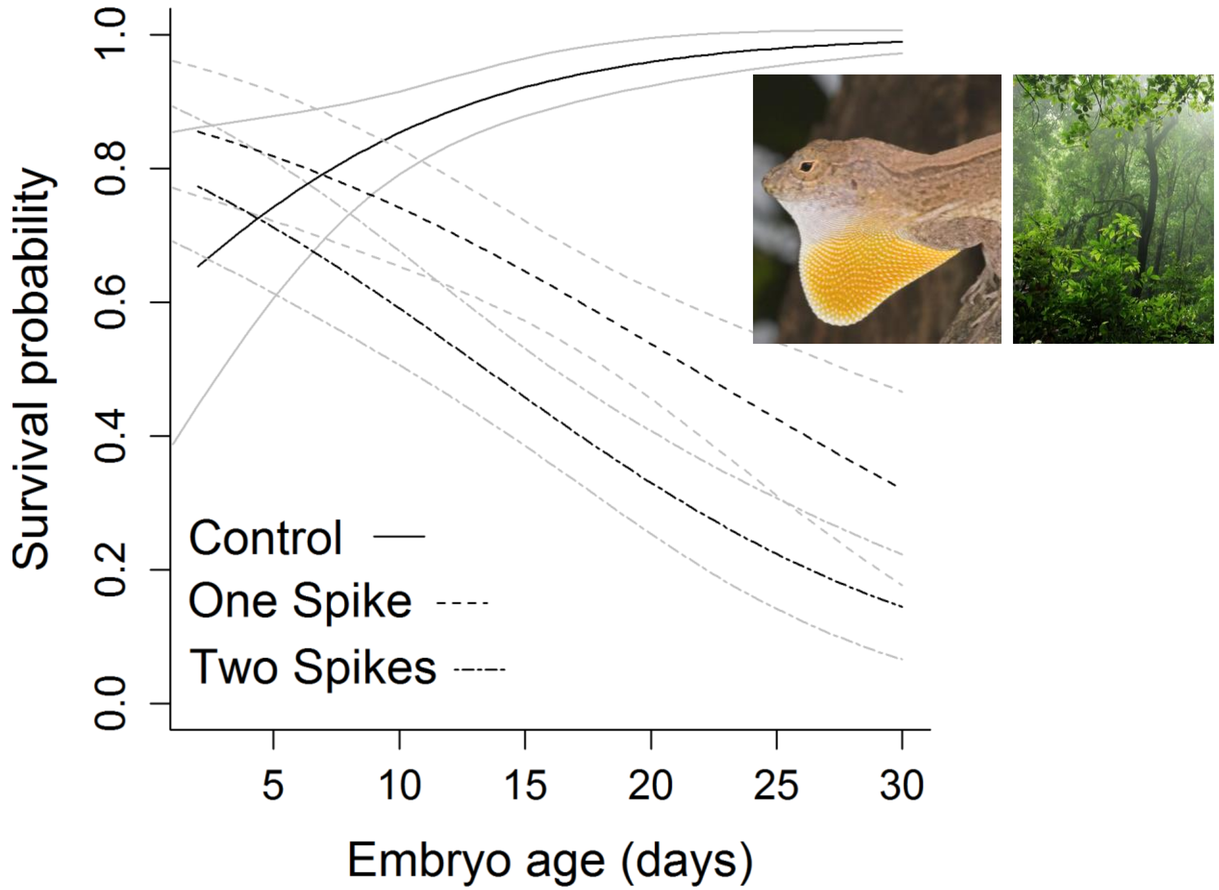


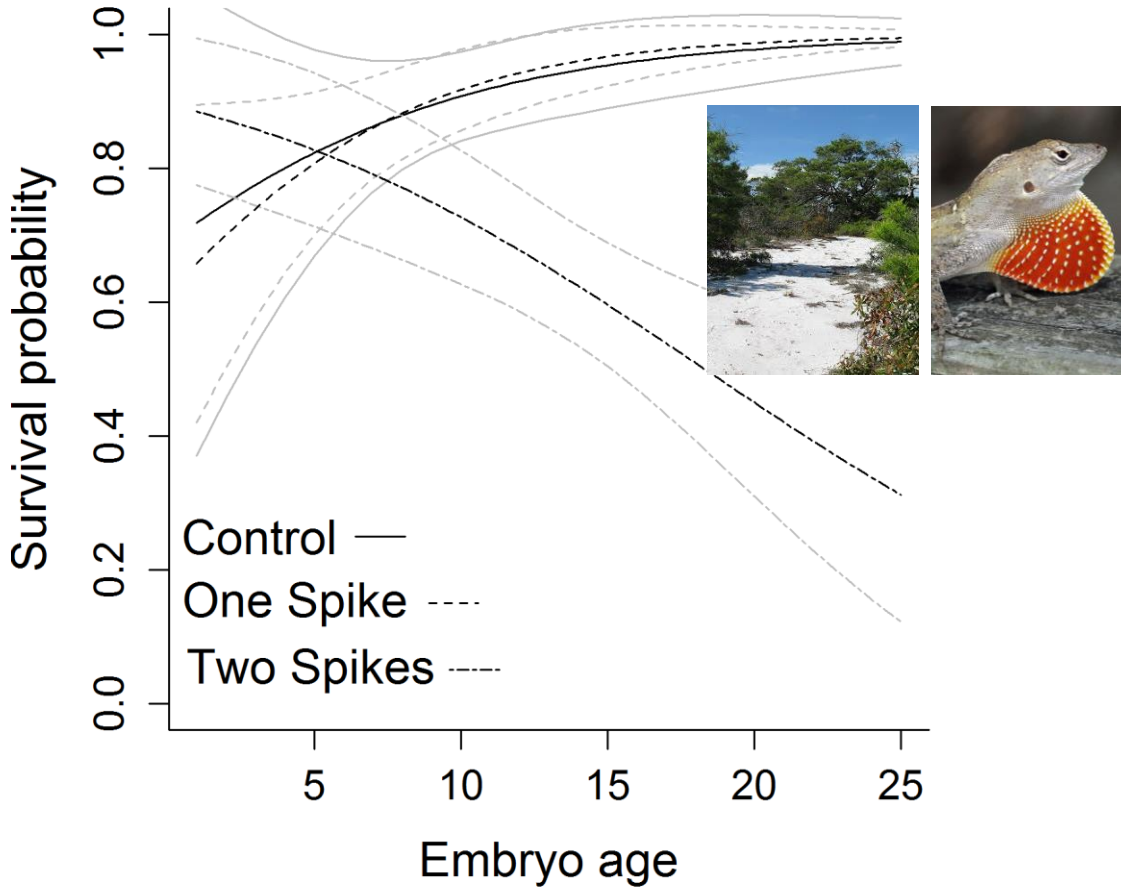


Age: χ^2_1=5.51; p=0.02

Age by Treatment: χ^2_1=5.14; p=0.02

Effect of age?





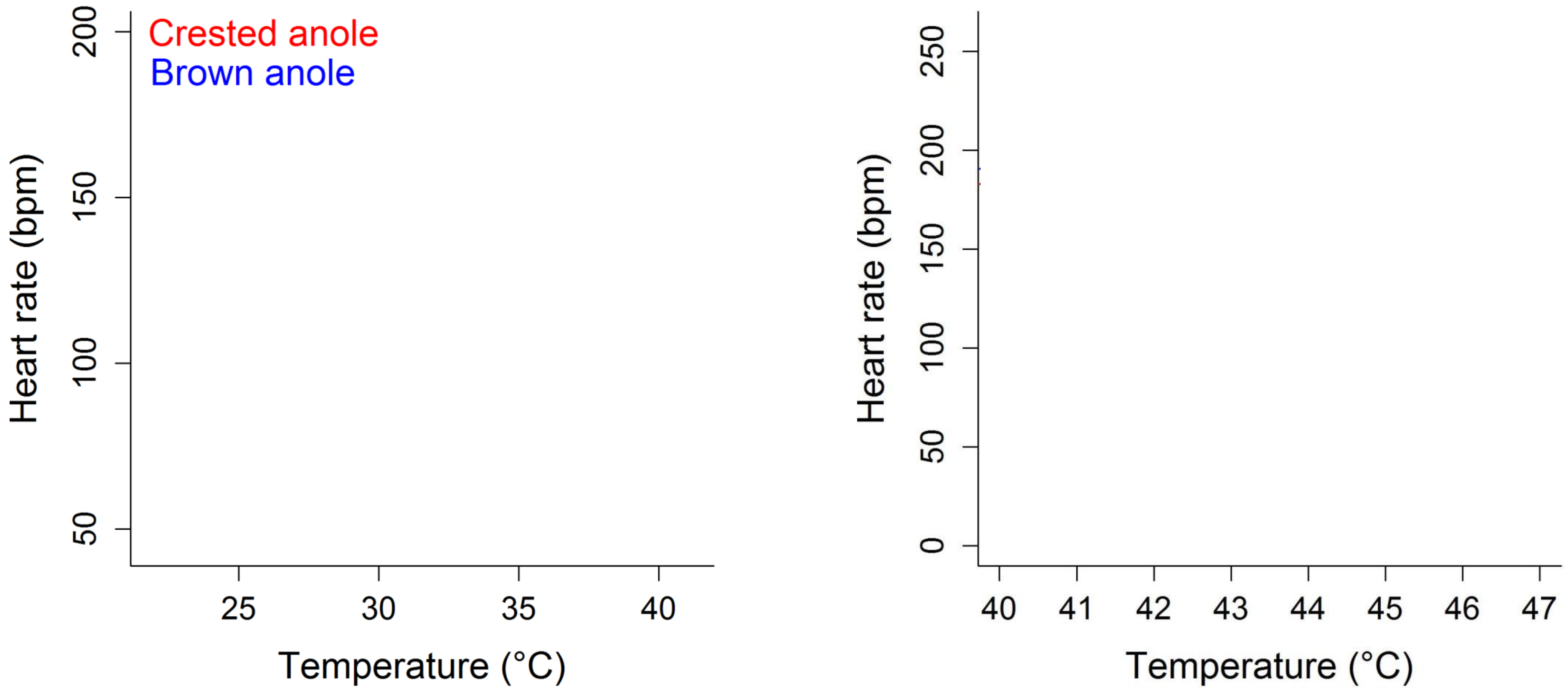
Age: χ^2_1=5.51; p=0.02

Age by Treatment: χ^2_1=5.14; p=0.02

Age: χ^2_1=3.63; p=0.06

Age by Treatment: χ^2_1=4.87; p=0.03

Embryo survival: NOT Eco Relevant



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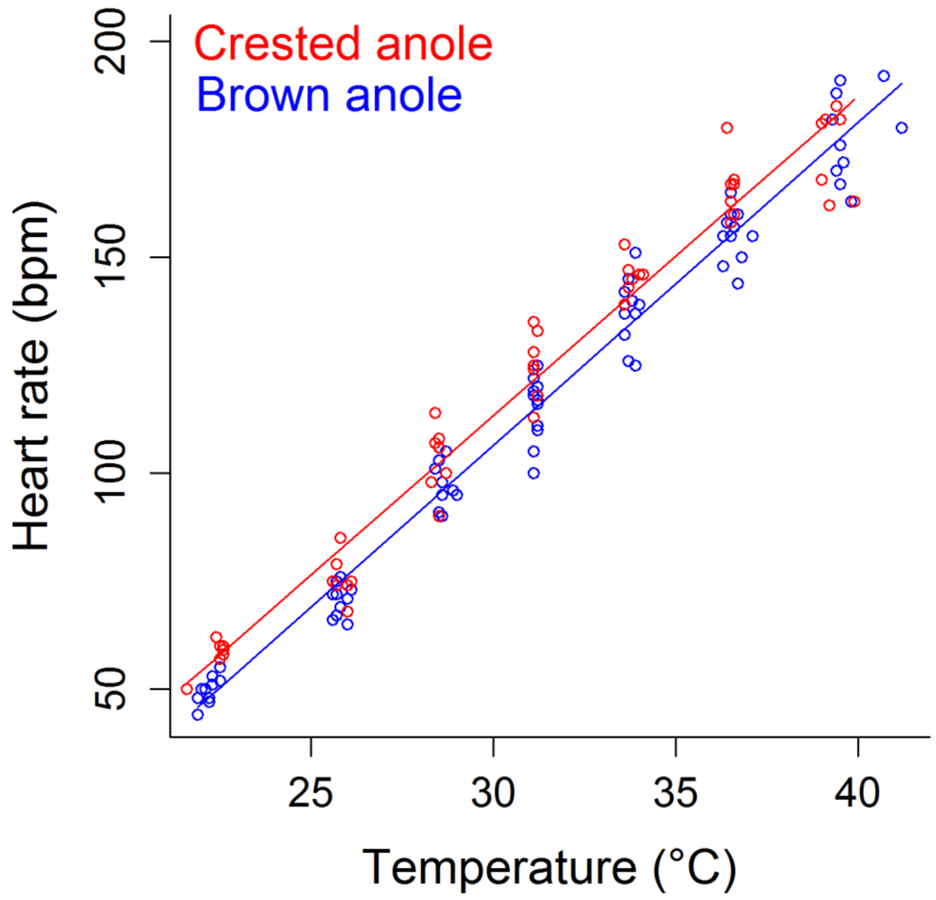
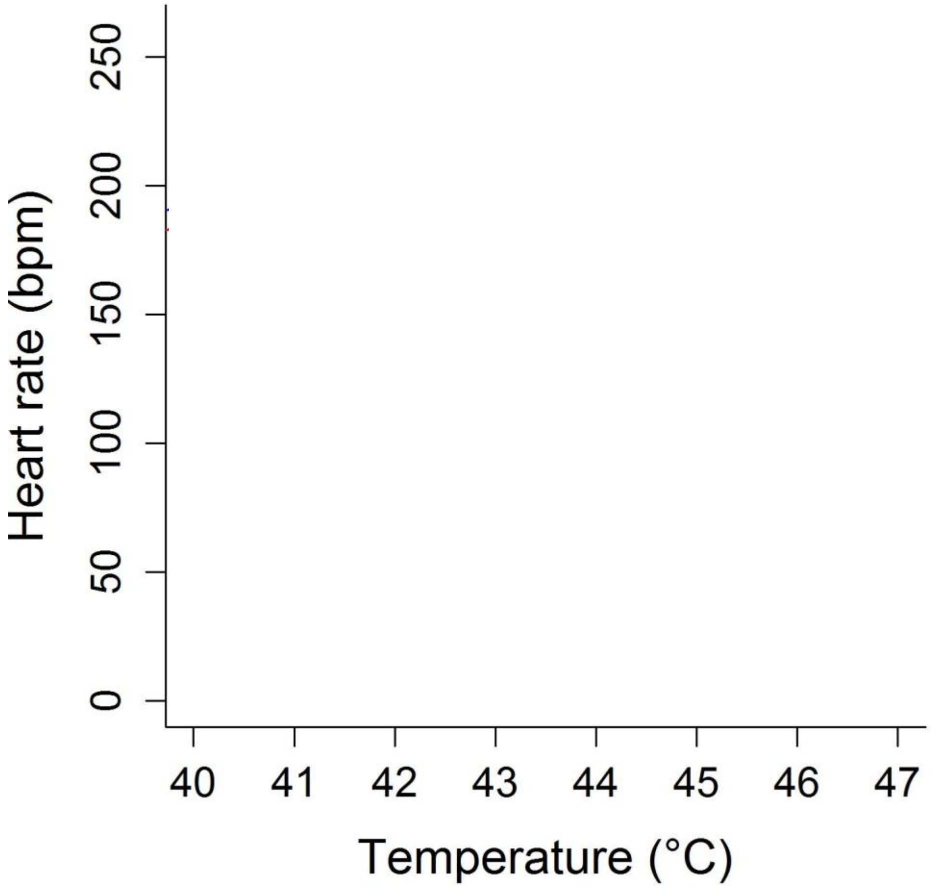
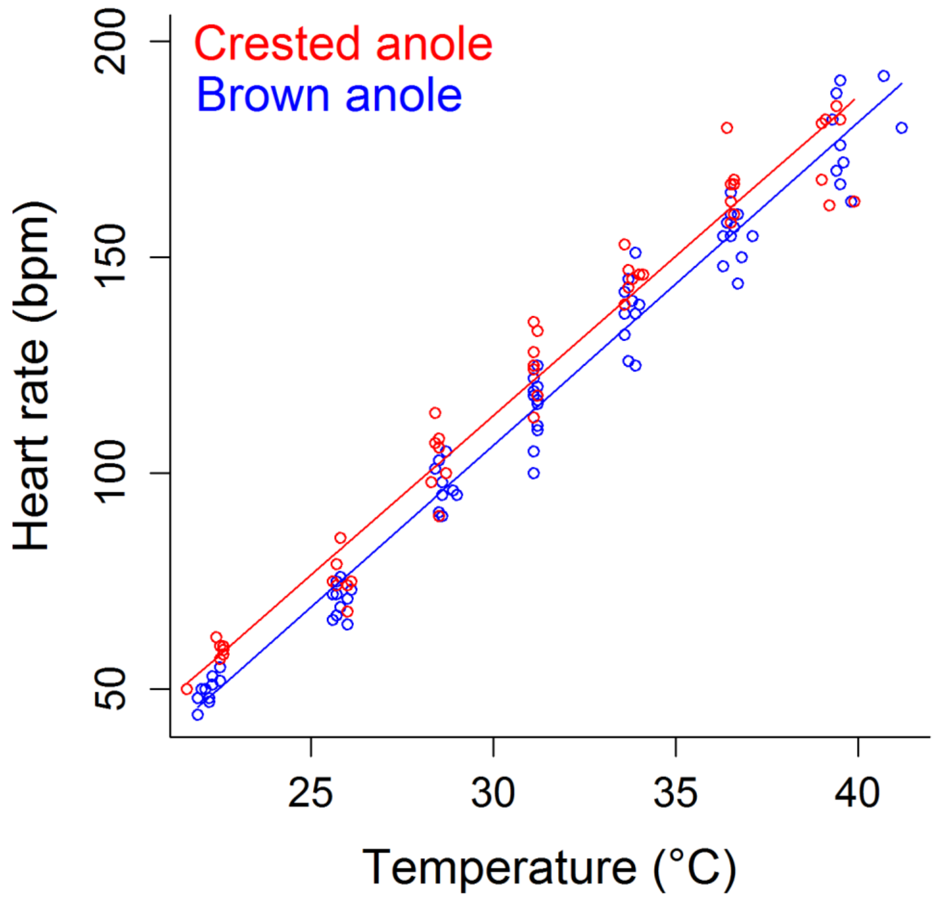
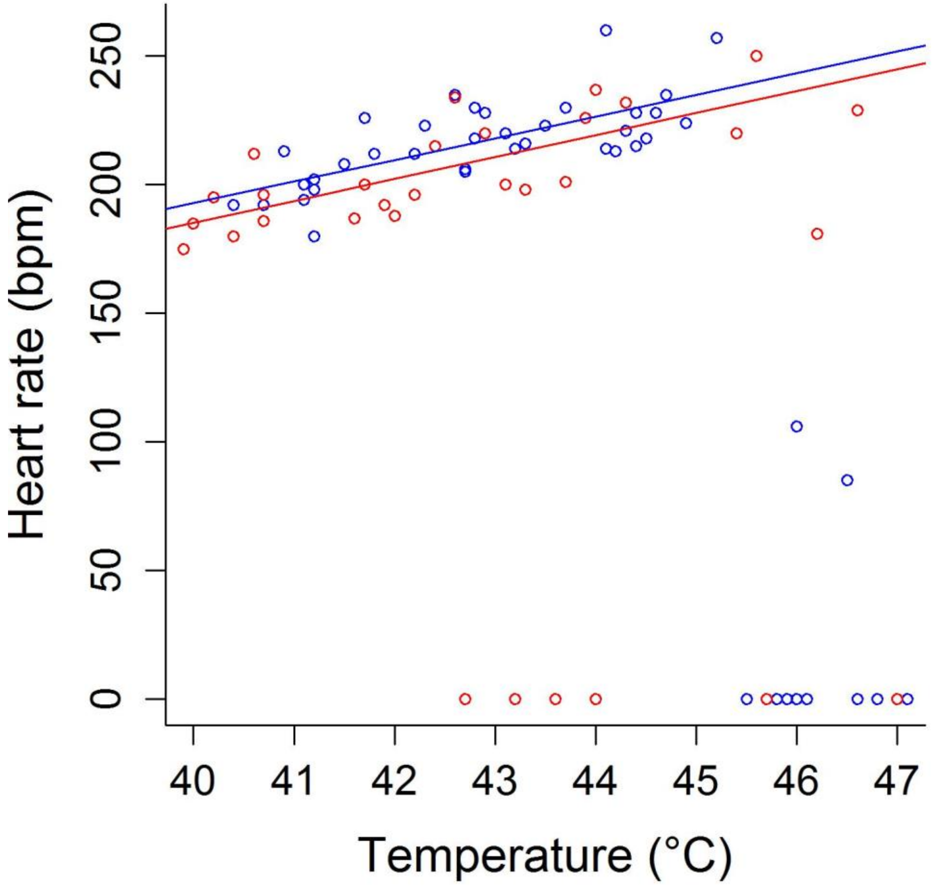


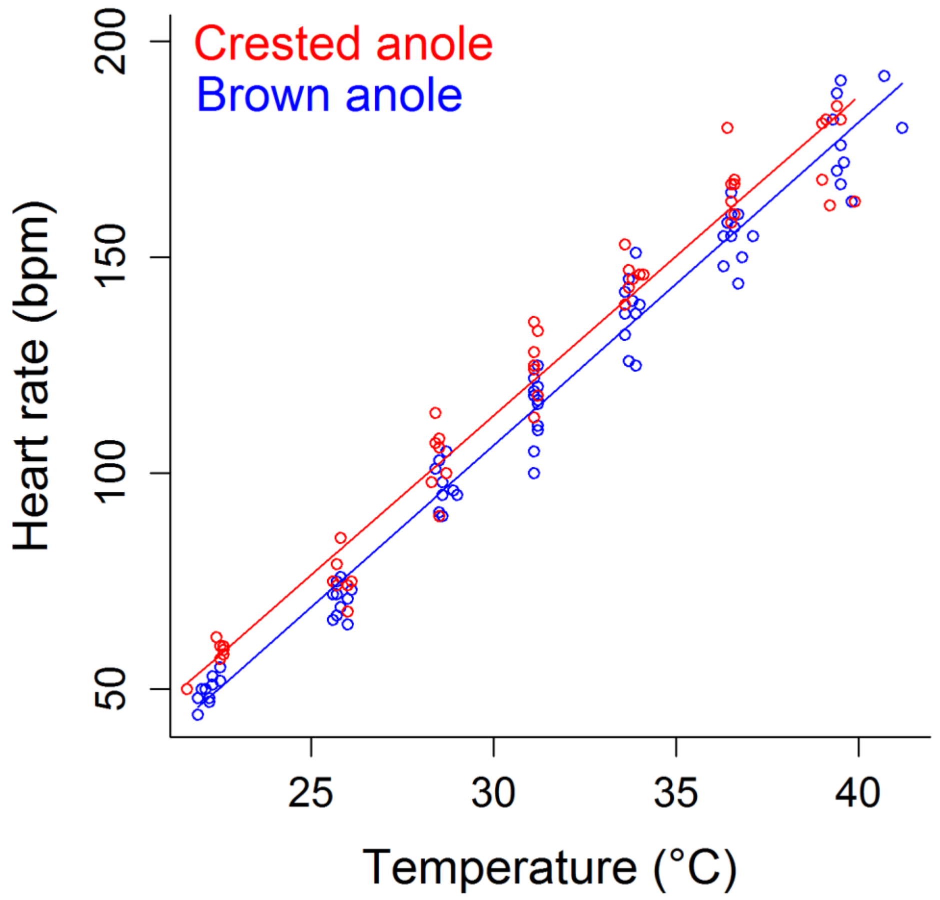


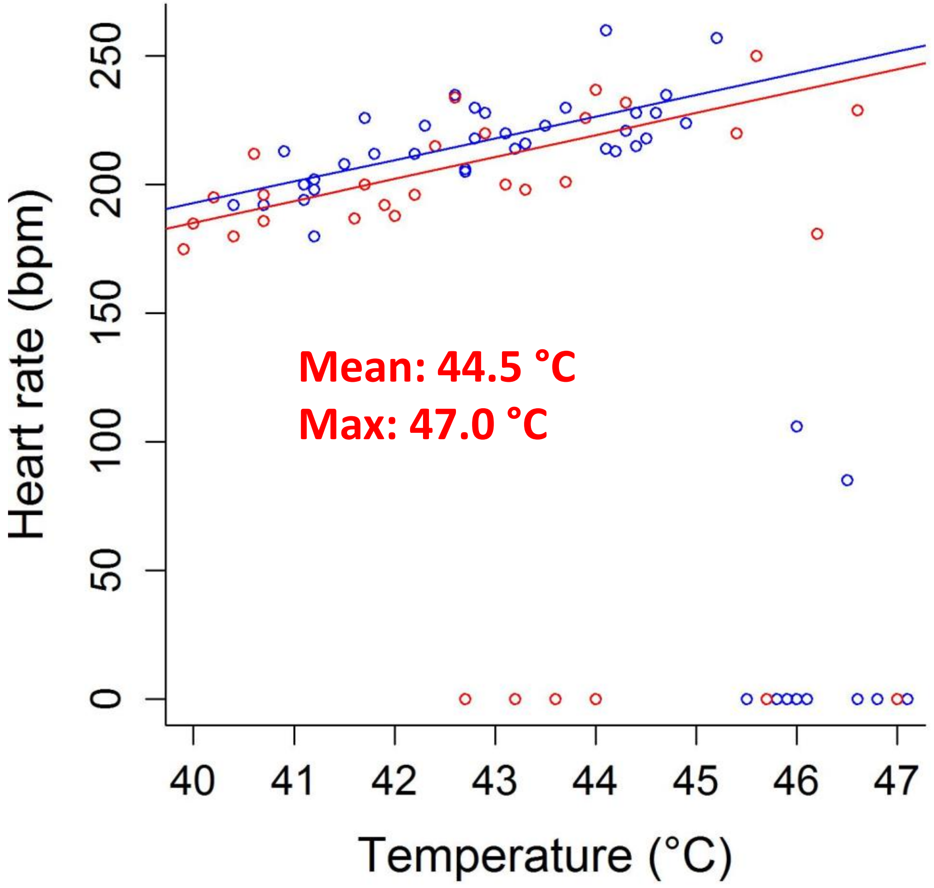
Embryo survival: NOT Eco Relevant



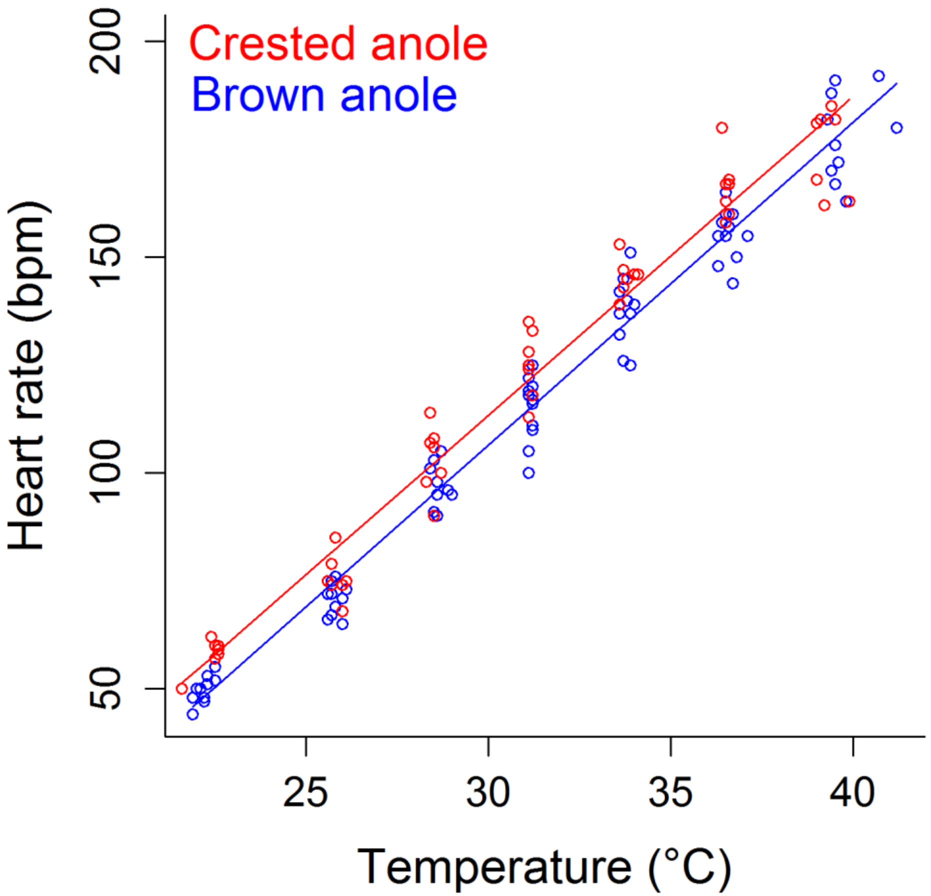


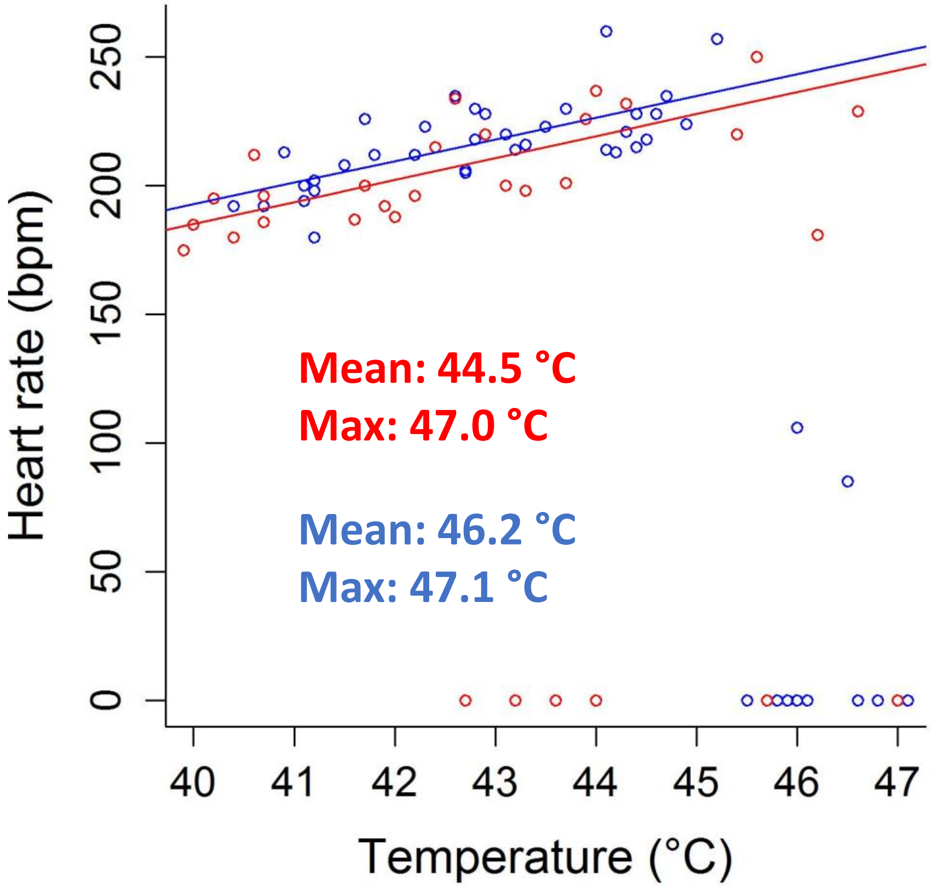
Embryo survival: NOT Eco Relevant





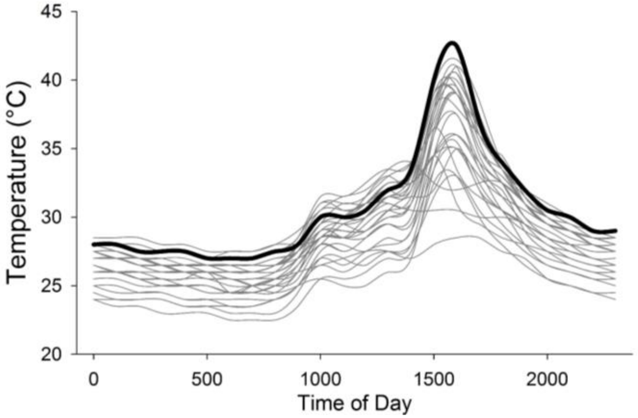
Embryo survival: NOT Eco Relevant

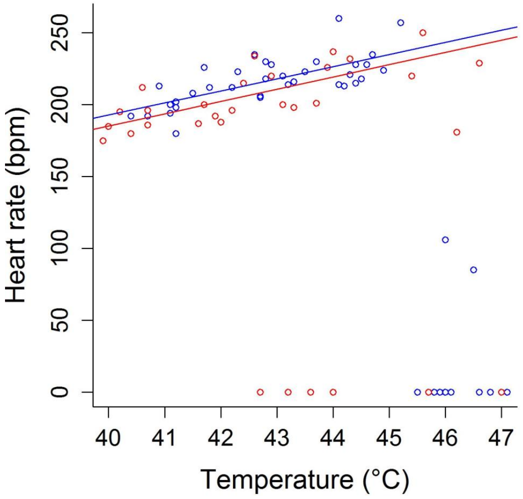


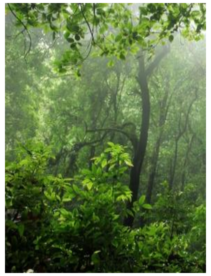


Hulbert et al., 2017

Methods matter





43 °C

47.0 °C


45 °C

47.1 °C

The Everest Effect

The Everest Effect

Of 94 mountaineers who died after climbing above 8000 m, 53 (56%) died during descent from the summit, 16 (17%) after turning back, 9 (10%) during the ascent, 4 (5%) before leaving the final camp, and for 12 (13%) the stage of the summit bid was unknown.

Firth et al. 2008. British Med J

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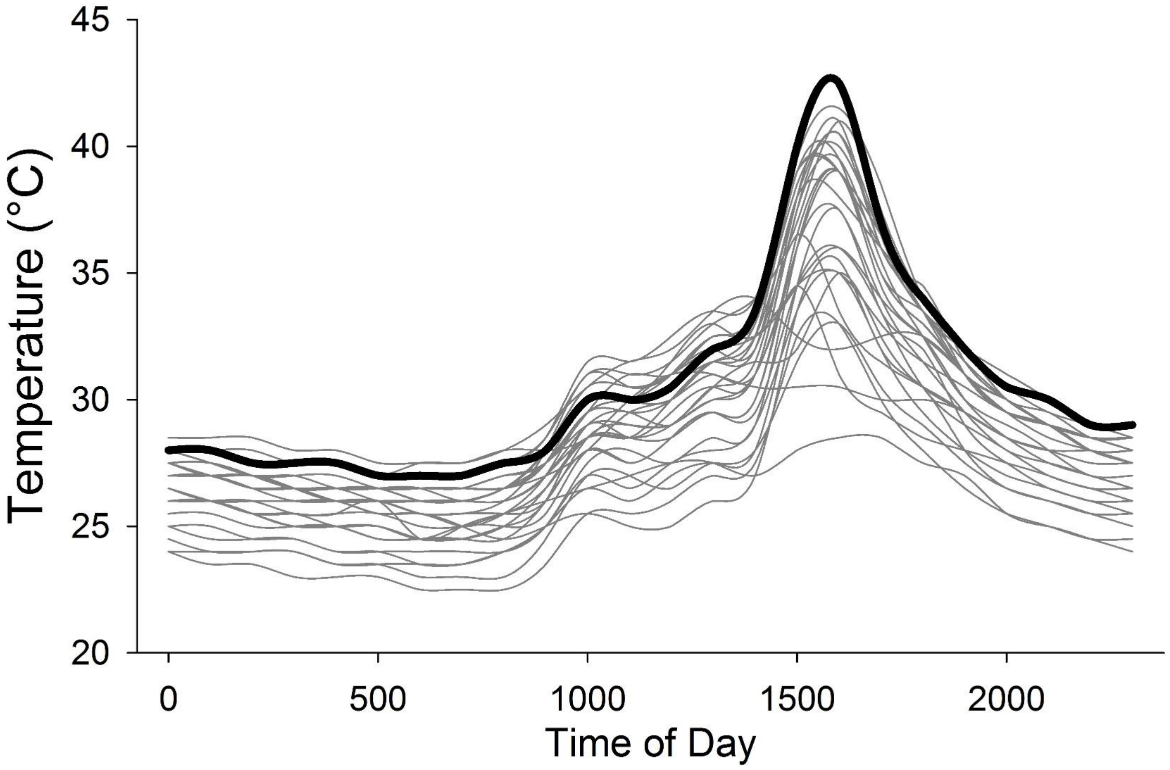

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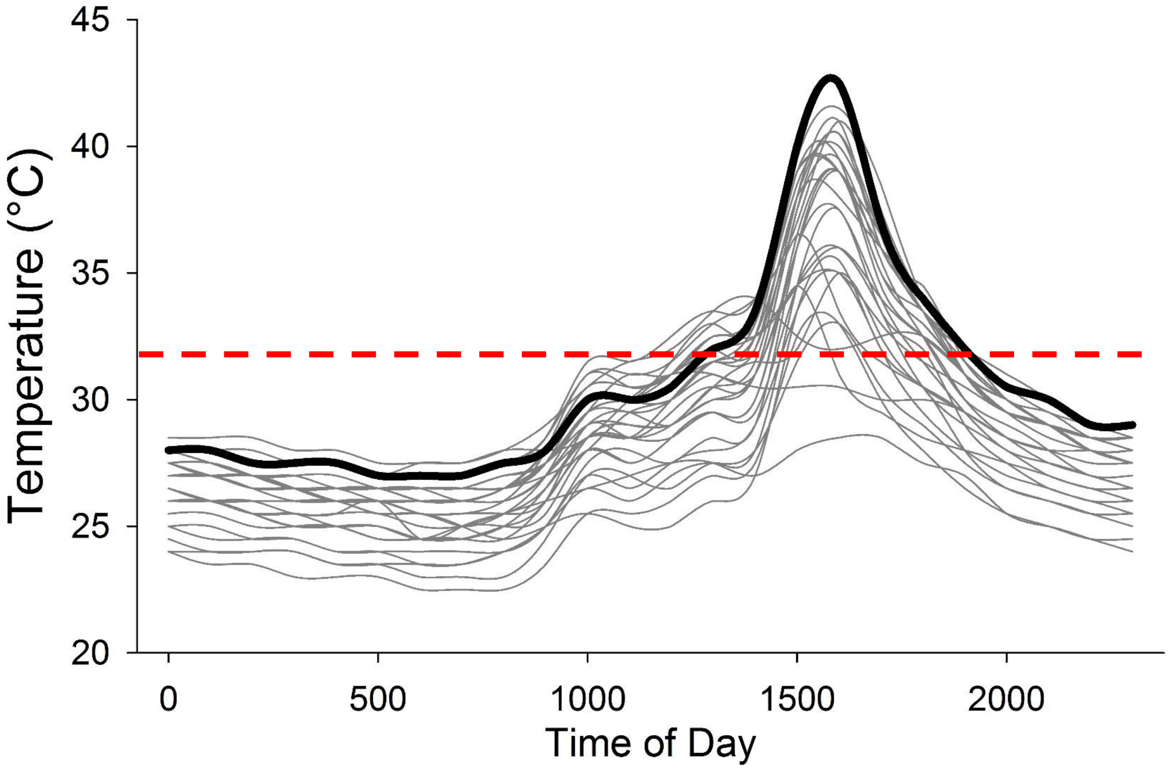
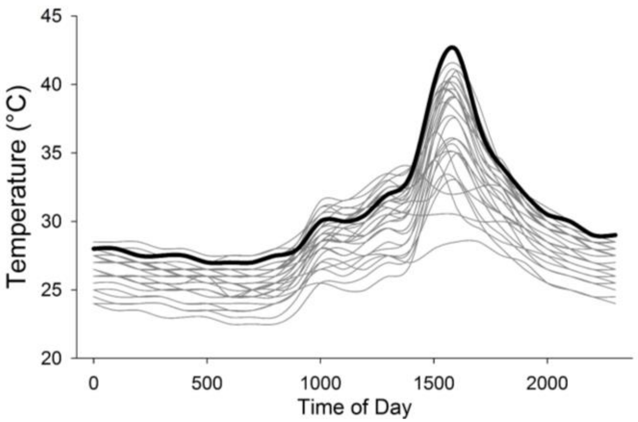
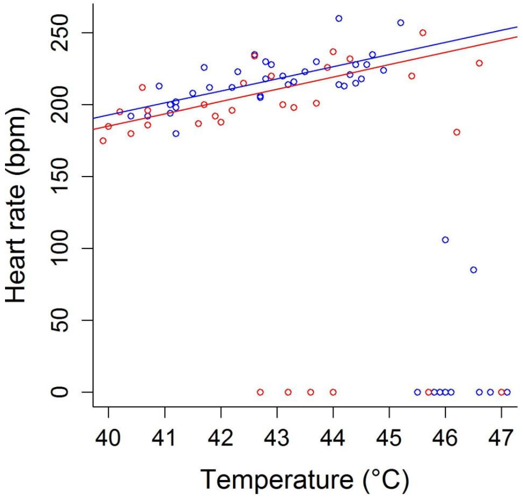
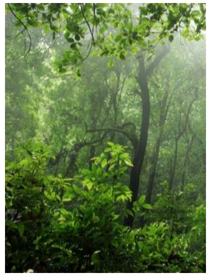


The Everest Effect?







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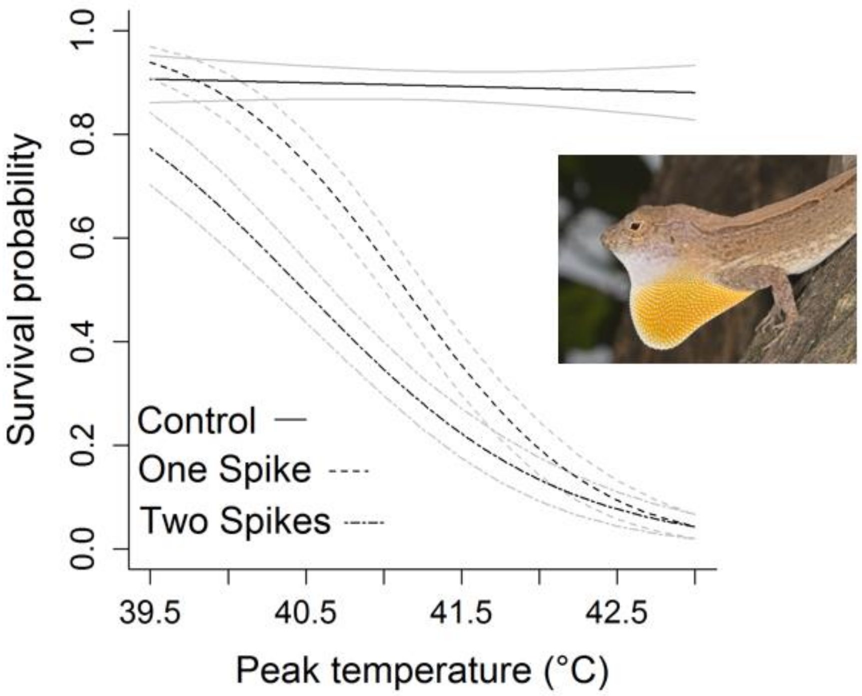
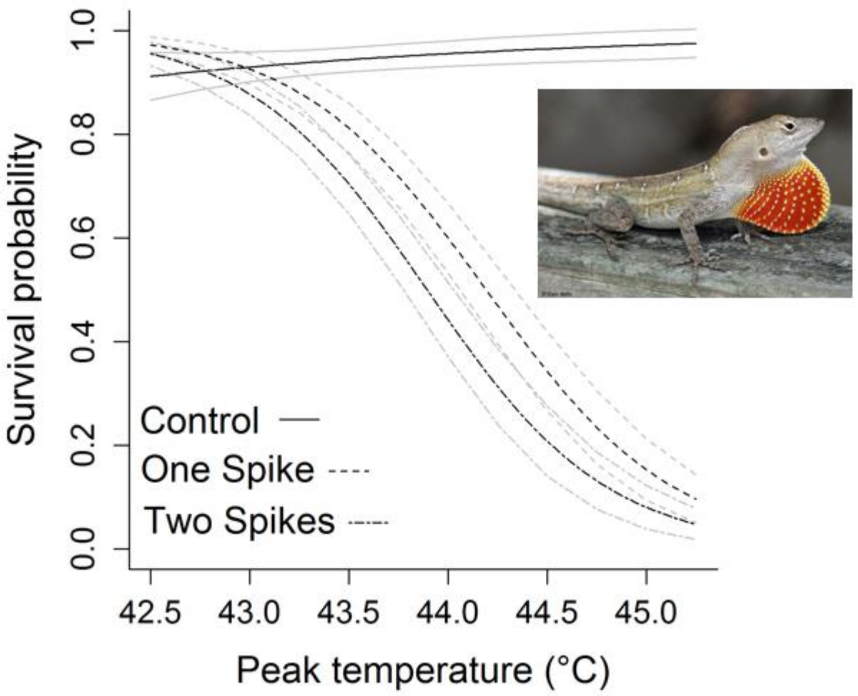
Conclusions

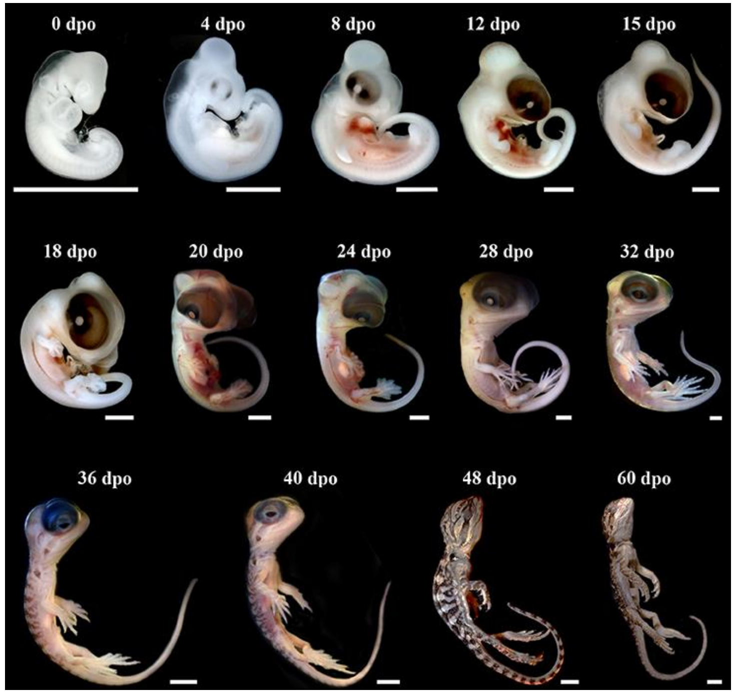
- Thermal tolerance of embryos may vary widely across species



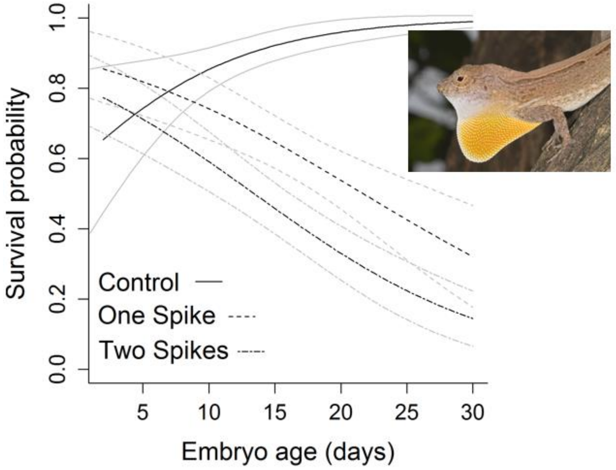


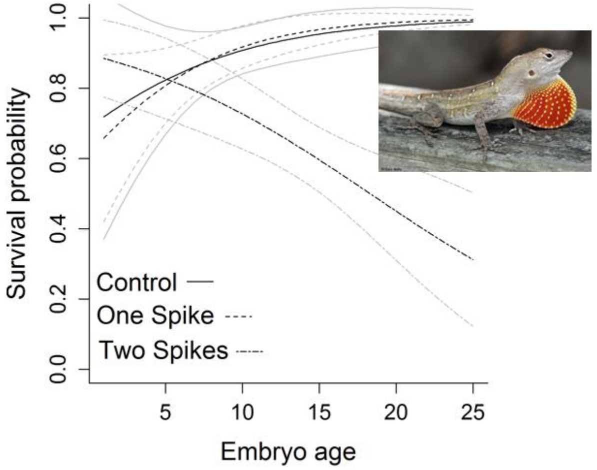
Conclusions

- Thermal tolerance of embryos may vary widely across species
- Tolerance changes through development



Ollonen et al. 2018. Front. Physiol.

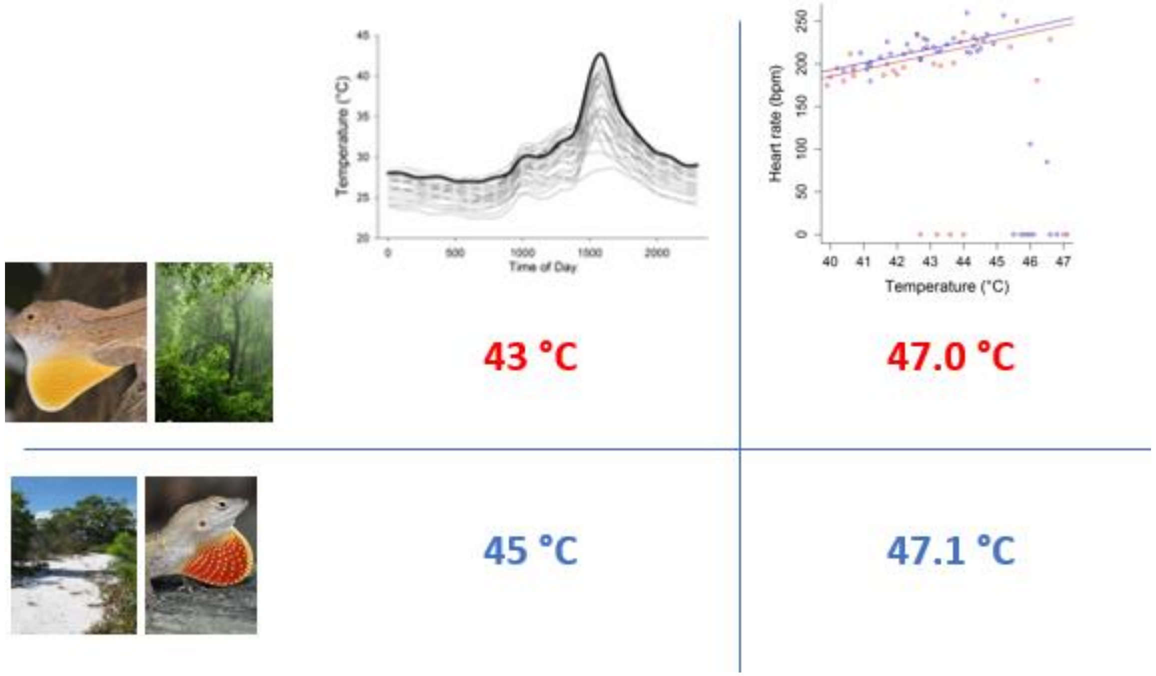




Conclusions

- Thermal tolerance of embryos may vary widely across species
- Tolerance changes through development
- Measuring thermal tolerance in an ecologically relevant way is vital

Methods matter



Conclusions

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REVIEW

Thermal tolerances of sea turtle embryos: current understanding and future directions

Robert Howard[1], Ian Bell[2], David A. Pike[1,*]

[1]School of Marine and Tropical Biology, James Cook University, Townsville, Queensland 4811, Australia
[2]Department of Environment and Heritage Protection, Townsville, Queensland 4814, Australia

Conclusions

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REVIEW

Thermal tolerances of sea turtle embryos: current understanding and future directions

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ture range that sea turtle embryos can withstand and at which they can successfully hatch, but have not yet determined whether temperature fluctuation and stage of embryonic development interact, such that the thermal tolerance of embryos changes during incubation. Research on olive ridley sea turtles *Lepido-*

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Mentors
Dan Warner
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Jason Kolbe
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Austin Hulbert
Kayla Wilson
Ryan Weesner
David Quinn
Chanel Reali

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