**Thermal ecology in 3D: xxxxxxx**

Karla Alujević1, Leah Bakewell2, Christian L. Cox2, Luke O. Frishkoff3, Eric J. Gangloff4, Matthew E. Gifford5, Samir Gulati1, Alyssa Head4, Monica Miles3, Ciara Pettit4, Charles M. Watson6, Kelly L. Wuthrich2 and Michael L. Logan1

1Department of Biology, University of Nevada, Reno, NV 89557, USA

2Department of Biological Sciences and Institute for the Environment, Florida International University, FL 33199, USA

3Department of Biology, University of Texas at Arlington, Arlington, TX 76019, USA

4Department of Biological Sciences, Ohio Wesleyan University, Delaware, OH 43015, USA

5Department of Biology, University of Central Arkansas, Conway, AR 72035, USA

6Department of Life Sciences, Texas A&M University San Antonio, San Antonio, TX 78249, USA

**Abstract**

**Keywords:** operative temperature model, OTM, biophysical model, 3D print, thermal physiology

**Introduction**

* Predicting ecological responses to rapid environmental change has become one of the greatest challenges of modern biology. Two major hurdles in forecasting these responses are: (1) accurately quantifying thermal environments organisms experience in their habitats and (2) overcoming mismatch between the size of the organism and the resolution at which environmental data are collected. This is especially important for ectotherms that experience thermal environments at small spatial scales, often occupying habitat that is only several square meters in area.
* In thermal ecology, operative temperature models (OTMs) are integral for estimating the temperatures available to ectotherms within their habitats. Description of how they are supposed to work and what they are used for.
* Types of OTMs, variation in approaches, morphological inconsistencies, and lack of reproducibility. This can introduce a significant error and reduce how comparable studies are.
* Recent technological advancements with 3D-printing offer unique benefits for producing robust, easily replicated, morphologically accurate, and cost-effective OTMs.
* Here, we develop these methods using a range of lizard species distributed across different habitats within the continental US.

**Methods**

* Scanning of frozen or preserved museum samples
* 3D printing
* Reflectance measurements
* Painting
* Field validation

**Analyses**

* Production costs and time
* Comparison of function:
* Equilibrium temps of OTMs vs lizards (across all/ per species/ per microsite)
* Time to equilibrate of OTMs vs lizard

**Results**

1. Generated database of scans
2. Cost efficiency (material and time)
3. Equilibrium temperatures across species/microhabitats
4. Time to equilibration
5. Curve fitting full graphs

**Discussion**

* Applications
* Discuss caveats in the approaches of validating OTM data – some people have done it in a not really robust way (see Brewster and Beaupre, 2019; Grant and Dunham, 1988). Present important factors that need to be paid attention to (based on what we’ve learnt in our trials.
* Easy to print models in any postures or sizes easily (importance of OTM mimicking lizard posture tested in Brewster and Beaupre, 2019)
* Could OTMs modelling both thermal and evaporative rates (amphibians) also be 3D printed (what materials to use?)
* Limitations of the approach

**Supplementary**

* Individual lab protocols for data collection