Climate change drives subterranean spiders to extinction: the response of *Troglohyphantes* spiders to global warming

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‘Caves are warm in winter and cold in summer’

Aristotle, Meteorologica - 340 bC
Thermical annual variability decreases progressively at increasing distance from entrance.
Temperature in caves reaches an impressive stability.

Grotta di Bossea - 108 Pi/CN
Mean temperature 22/06/2012 – 18/04/2013

Piano et al. 2015. Sc Tot Env, 536: 1007-1018
Temperatures recorded inside caves provide an ideal approximation of the mean annual temperature outside.
Model species
*Troglohyphantes* spp.

- Moderate to high levels of *troglobiomorphy*
- Restricted or point-like ranges of distribution and proved monophyly
- Narrow microclimatic requirements
- Genetically structured population
- Reduced dispersal ability
Model species
*Troglohyphantes* spp.

- Moderate to high levels of *troglomorphism*
- Restricted or point-like ranges of distribution
- Narrow microclimatic requirements
- Genetically structured population
- Reduced dispersal ability
Troglobiomorphy

T. lucifer

T. vignai

T. pedemontanus

Isaia et al., 2011. Mon Museo Reg Sc Nat. XLVII: 1-325
Model species
*Troglohyphantes* spp.

- Moderate to high levels of *troglobiomorphy*
- Restricted or point-like ranges of distribution and proved monophyly
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Distribution of the Western Alpine species

- *Troglohyphantes lucifuga*
- *Troglohyphantes lanai*
- *Troglohyphantes nigraerosae*
- *Troglohyphantes bornensis*
- *Troglohyphantes lucifer*
- *Troglohyphantes henroti*
- *Troglohyphantes vignai*
- *Troglohyphantes konradi*
- *Troglohyphantes pedemontanus*
- *Troglohyphantes pluto*
- *Troglohyphantes iulianae*
- *Troglohyphantes bolognai*

Isaia et al., 2011. Mon Museo Reg Sc Nat. XLVII: 1-325
Isaia et al., 2016. Inv. Syst., in press
LINYPHIIIDAE Gen. *Troglohyphantes*

T. bornensis

T. iulianae

T. konradi

T. lanai n.sp.

T. lucifuga

T. nigraerosae

T. pedemontanus

T. pluto

T. vignai

Isaia et al., 2011. Mon Museo Reg Sc Nat. XLVII: 1-325
Because of the lack of reliable calibration points (e.g., fossils, relevant geological or biogeographical events) for the lineage, we relied on informed priors of the substitution rates of the cox1, based on available information for spiders.
Model species

\textit{Troglohyphantes} spp.

- Moderate to high levels of \textit{troglobiromorphy}
- Restricted or point-like ranges of distribution
- Narrow microclimatic requirements
- Genetically structured population
- Reduced dispersal ability
Troglohyphantes spiders preferably occur inside caves where the temperature is stable.

GLM-ber. Estimated $\beta$ for $D_s^2 \pm se = -0.0044 \pm 0.0008$, $p < 0.001$. 

Temperature range estimation based on GIS interpolation.

Model species

*Troglohyphantes* spp.

- Moderate to high levels of *troglobiomorphy*
- Restricted or point-like ranges of distribution
- Narrow microclimatic requirements
- Genetically structured population
- Reduced dispersal ability
Lacking shared haplotypes between caves and showing very reduced dispersal ability
Model species
*Troglohyphantes* spp.

- Moderate to high levels of *troglobiomorphy*
- Restricted or point-like ranges of distribution
- Narrow microclimatic requirements
- Genetically structured population
- Reduced dispersal ability

*→ Troglohyphantes* spiders are good candidates as climatic bioindicators
**Study area**

Western Italian Alps
33 hypogean sites

33x2 temperature dataloggers
2 years monitoring

_Troglohyphantes_ spp.
18 presence vs 15 absence points

Hygrochron i-Button temperature dataloggers
The probability of *Troglohyphantes* occurrence decreases with increasing mean annual temperature.

GLM-ber. Estimated $\beta$ for $T_{\text{int}} \pm se$: $-0.543 \pm 0.249$, $p=0.02$
Extending the trend to the regional scale: Ecological Niche Modeling

361 hypogean sites

Presence/absence data derived from Isaia et al., 2011

Minimization of spatial correlation (Newbold., 2010)

5 out of 19 bioclimatic variables
+ Ice cover during LGM

Modeling
Generalized linear models (GLM)
Boosted Regression Trees (BRT)
Maximum Entropy Model (MaxEnt)

→ Projections
- Present
- LGM
- High and low emission scenarios for 2050 and 2070
Current climate projections overlay the known distribution of *Troglohyphantes*. Pleistocene: Southern border of the Alps very suitable. Areas bordering the glacial masses acted as microrefugia during LGM.

Mammola Goodacre and Isaia, 2016. Ecography (in press)
A future general decline of suitability all over the range of distribution.
Approximately half of the current localities are predicted to be unsuitable.

Mammola Goodacre and Isaia, 2016. Ecography (in press)
Temperature increase due to global warming poses serious concerns about the long-term survival of *Troglohyphantes* spiders.
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CAVELAB

From microclimate to global change: caves as laboratories for the study of the effects of temperature on ecosystems and biodiversity

and

CAVEAT

The dark side of climate change

Photo credits Francesco Tomasinelli and Mauro Paschetta