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# MicroCliMite

## Exploring the thermal budgets of plant-herbivore interactions

# Uncovering the mysteries of microclimate impacts

Through his detailed investigative work, **Dr Sylvain Pincebourde** is deepening understanding of the wider impacts likely to result from Earth's changing climate

**What kind of selection pressure does climate change put on individual and collective populations?**

The quantification of the impacts of climate change on populations is not a straightforward task. There are several levels of complexity. Climate change is not just a change in temperature average – $CO_2$, rain, humidity and winds are also shifting. In addition, their average levels, variance, frequency and duration of extremes are also changing over time.

If a change does not directly affect an organism, it could still have an impact by altering the other trophic levels that interact with this organism. Each species responds differently to the same change because of their specific ecophysiology and because they might not be adapted to the same microclimate. Overall, the maintenance of a population will depend on the capacity of the species to adapt rapidly to the new environmental conditions.

Finally, climate change is only one side of the problem: fragmentation of the landscape, urbanisation and environmental pollution are all very likely to interact with climate change to set the fate of animal and plant populations.

**Studies have demonstrated that environmental change has already impacted the ecophysiology of numerous organisms – can you identify the most notable example of this?**

A huge amount of literature is accumulating reporting the effects of global change on the ecophysiology of diverse organisms including bacteria, insects, arachnids, reptiles, birds and mammals. The most striking example is on the impacts of global warming on the phenologies of some plants, their herbivore insects and the birds that feed on them. Multiple selective pressures may be triggered by climate change, leading to a tug-of-war between the need to stay in synchrony with the timing of maximum food and the benefits of minimising predation. This example is a clear illustration of the temporal constraints that climate change could reinforce – to the extent that the entire trophic system may collapse.

**How can you link the biophysical approach of the MicroCliMite project with more common species distribution models that are widely used nowadays?**

An analysis of published studies using species distribution models to forecast the impact of climate change on these distributions demonstrated that there is a huge gap between the size of organisms studied and

the scale at which environmental parameters are sampled, and at which distributions are modelled. Indeed, these species distribution models completely ignore the heterogeneity at local- and microscales simply because it is technically and conceptually difficult to model otherwise. Developing biophysical tools will likely help to fill the gap.

**How do you translate your knowledge on leaf microclimates to other kinds of microclimates?**

Many microclimates are quite heterogeneous in space and time, such as the leaf habitat. Our approach is potentially applicable to any kind of microclimate. To demonstrate this broad interest, we asked what habitats are thought to be the least variable. Aquatic insects, such as dragonfly larvae, are thought to live in a relatively stable microclimate as they remain underwater in marshes and ponds. We are now interested in testing the extent to which the water temperature of ponds is stable in time as well as in space along the pond, and if dragonfly larvae have the opportunity to choose a thermal environment, as much as mites or aphids in a tree canopy. Preliminary results were surprising in terms of thermal amplitude during a single day as well as between various locations within a single pond. Dragonfly larvae in a pond might not be so different from a mite on an apple leaf!

**Are there further research avenues you plan to pursue after this study?**

The logical follow-up to this work would be to add the predator into the picture. We are keen to learn if there are thermal refuges within tree canopies where the mite or the aphid could still survive and develop while the predator cannot. In addition, the response of organisms and populations will depend on their eco-physiology and the kind of microclimate they live in. So it would be helpful to understand how well the thermal sensitivities of organisms match with their microclimate across latitudes. In particular, this revolves around whether the amplitude of microclimate change will be the same across latitudes, and if not, how well organisms can keep track of their changing microclimate across their biogeography.

# A mitey challenge

Work underway at the University of Tours, France is exploring the thermal budgets of plant-herbivore interactions, ultimately aiming to reveal more about the impact of global climates on small-scale processes

INCREASINGLY, SCIENTISTS ARE drawing the world's attention to the impact of climate change on ecological phenomena. While knowledge of the effects of global warming on the geographic distribution of different species grows, understanding of the mechanisms that drive this change and its impact on individual species remains less clearly understood. The University of Tours' Physical Ecology & Multitrophic Interactions Group is exploring how climate change influences individual species within different trophic levels of a food chain – known as a multitrophic system. In a project called Connect global climate and microclimate: thermal budgets of plant-herbivore interaction (MicroCliMite), researchers are investigating the impact of direct and indirect influences on these changes and aim to quantitatively assess the net impact effect of climate change on each species within a multitrophic system.

## INVESTIGATING SPECIES RESPONSE

By filling this knowledge gap in such important mechanisms, research leader Dr Sylvain Pincebourde hopes his group will be able to provide critical information on the ecological impacts of global climate change. The researchers are studying different kinds of microclimates, the first of which is the leaf surface. This particular microclimate provides different thermal habitats for various small arthropods, which is influenced by both weather and plant physiology. One anticipated impact of global climate change is temperature rise, which includes that of a leaf surface. Warming the external temperature of a leaf is known to homogenise its surface temperature, which subsequently reduces an organism's ability to escape from a spot on a leaf that is too hot. Of particular significance are the interactions between the plant and insect at the microclimate level. "Plant-arthropod associations are very interesting in this context because the physical or thermal environment of the herbivore is created by another organism, the plant," Pincebourde enthuses. This means that any direct effect of environmental fluctuations on the plant has the potential to indirectly impact upon the insect itself.

In some instances, changes in $CO_2$ have not been shown to have a direct effect on the insect, yet may impact on leaf surface temperature variations and ultimately pose a danger for insects if the leaf gets too hot: "Among the insect microclimates, the leaf has more complex indirect and direct relationships, making it very exciting to study," Pincebourde reveals. MicroCliMite has been developed around a number of different spatial scales ranging from those of the leaf and canopy to the biogeography of leaf microclimates. Most of the small-scale work is completed in an experimental station at an apple orchard near the town of Tours. The group has selected four additional sites – mostly experimental stations – from Belgium down to the south of France near Montpellier where the biogeographic study will be completed. Throughout the growing season

Populations of the green aphid (*Aphis pomi*) developing on the surface of apple leaves. The project seeks to understand how the within-leaf surface thermal heterogeneity translates into variable population growth rates. © Sylvain Pincebourde

INTELLIGENCE

# MicroCliMite

## OBJECTIVES

- To build a flexible and fast 3D leaf temperature model to predict main trends of spatial temperature patterns and dynamics at the leaf surface, which will be compared across spatial scales
- To predict spider mite and aphid population dynamics under climate change scenarios by integrating microclimatic processes

## KEY COLLABORATORS

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**SYLVAIN PINCEBOURDE** received his PhD in 2005 at the University of Tours, France, working on the biophysical ecology of insects. He then studied the thermal ecology of intertidal organisms as a postdoc at the University of South Carolina. Finally, he obtained a position at CNRS (France) in 2009 to work on the impacts of climate change on organisms.

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the researchers will measure leaf temperatures across each of the sites.

A key part of the work is studying the ways in which very small animals respond to changes in leaf surface temperature. Such creatures are deeply immersed in the leaf boundary layer and are consequently at greater risk of habitat alteration. This is the case for herbivorous mites. One of the advantages of studying such a species is that a single population develops on each leaf. Moreover, mites are able to move quite quickly, meaning they can rapidly respond to changes in their environment. Such processes offer important insights, particularly in regards to population dynamics and metapopulations. The work has highlighted that spider mites are able to find the most suitable location on a single leaf surface through moving: "We have demonstrated that these mites move to the leaf spot with the optimal temperature for development or they move to the coldest part of the leaf under extreme conditions".

## MODELLING APPROACHES

The researchers are focusing on using biophysical modelling as a way to develop a complex mechanistic model to anticipate temperatures of leaf surfaces. A number of different modelling tools have been adopted which can then be used to forecast this alteration under a range of climate change scenarios. The group is using a biophysical modelling approach based on a leaf heat budget model which was developed decades ago. This takes into consideration the different heat exchanges that take place between the leaf and the wider environment, including conduction, solar energy absorption and transpiration. This model has been adapted in order to merge leaf heat budget data with the micro-topography. This has enabled them to discern in detail the heterogeneity of the leaf surface temperature for the very first time. Furthermore, the researchers have combined this model with one of radiation interception by tree canopies to allow them to study the other end of the spatial scale. "Such an approach allows us to predict the leaf microclimate using only weather data and the known canopy architecture of a tree," Pincebourde expounds.

Using an infrared camera the team discovered that the surface of a single leaf has a fairly heterogeneous temperature. This led them to identify that the small-scale changes in the topography of the surface can have major effects on temperature. "This is because the orientation and inclination angle of a leaf portion, relative to the heat source, directly sets the amount of energy it receives," elucidates Pincebourde. As a consequence of this, the group decided to create a 3D leaf temperature model which is founded on the basic principles of both fluid dynamics over surface and heat budget calculations. The goal of this 3D model is to be able to replicate the intra-leaf thermal heterogeneity for any leaf within a tree canopy and any tree canopy in a latitudinal gradient. The group hopes to work down from the bigger picture of global and regional climate data to the leaf microclimate using the tree canopy as a filter of environmental conditions.

The information garnered to date has revealed that temperature variations influence the distribution of tiny animals such as spider mites and aphids, within a single tree canopy and even within a single leaf surface. "Climatic fluctuations can therefore induce spatial rearrangements of organisms not only at large scales but also at local and very small scales," Pincebourde articulates. The team has been sharing their findings through a number of highly respected international publications, including the journals *Functional Ecology* and *Global Change Biology*. The team is now keen to continue their success by connecting the biophysical model to a model of population dynamics of spider mites and aphids. This will enable them to predict how temperature variations impact population fluctuations within microclimates of a tree canopy. The data they gather from this work, together with demographic recordings and long-term measurements of body temperatures in apple orchards, will allow them to test a number of different model predictions. The group will then be able to widely disseminate their findings in the hope they can provide new insights into how climate change is likely to impact different species distributions.

The two-spotted spider mite (*Tetranychus urticae*) severely damages the apple leaf surface, creating feedbacks within its microclimate. © Amélie Ezanic