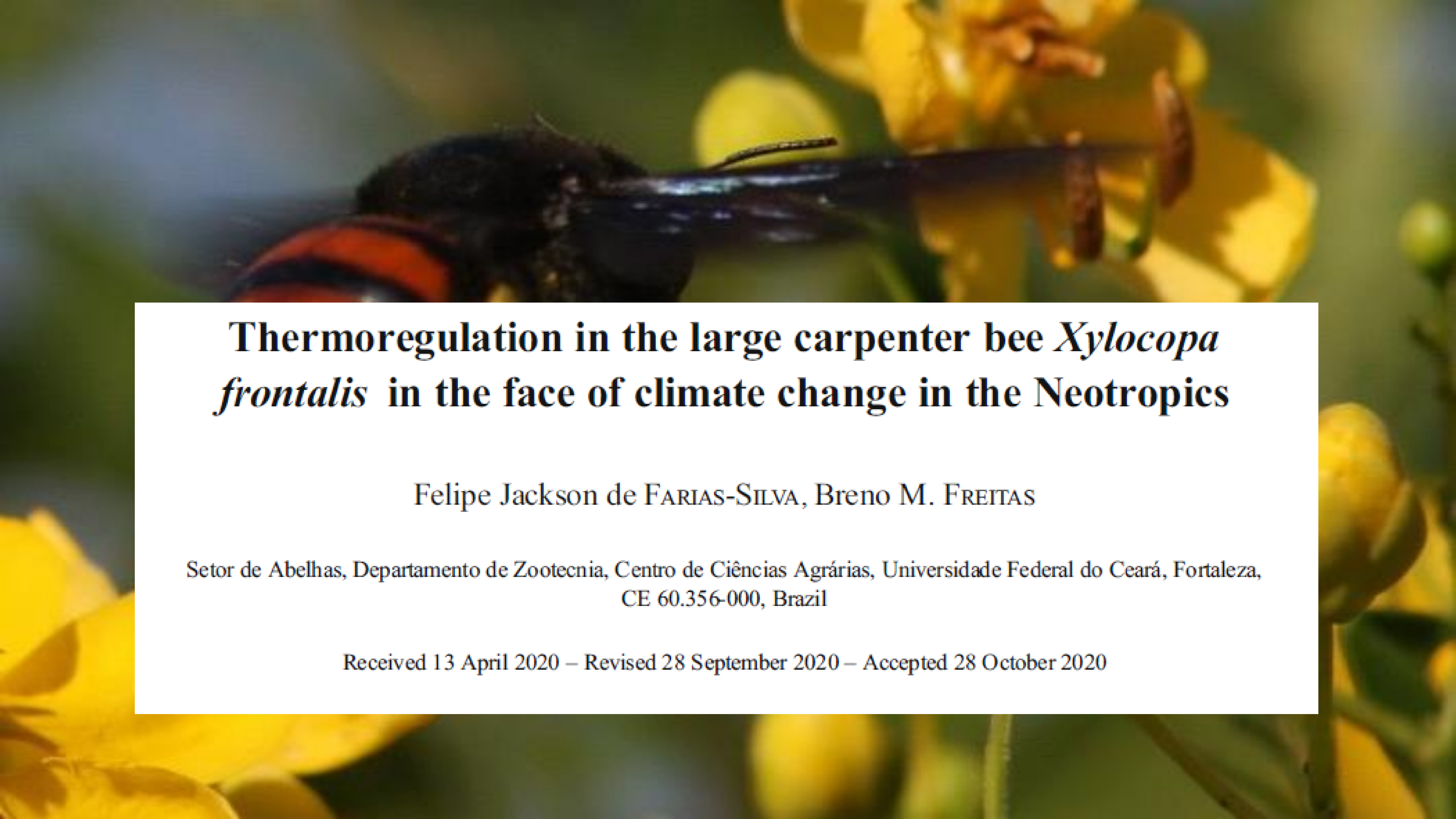

Thermoregulation in the large carpenter bee *Xylocopa frontalis* in the face of climate change in the Neotropics

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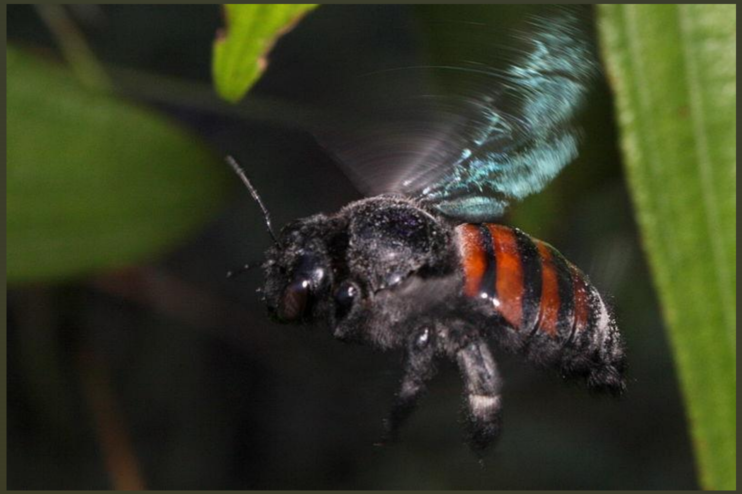
Xylocopa frontalis

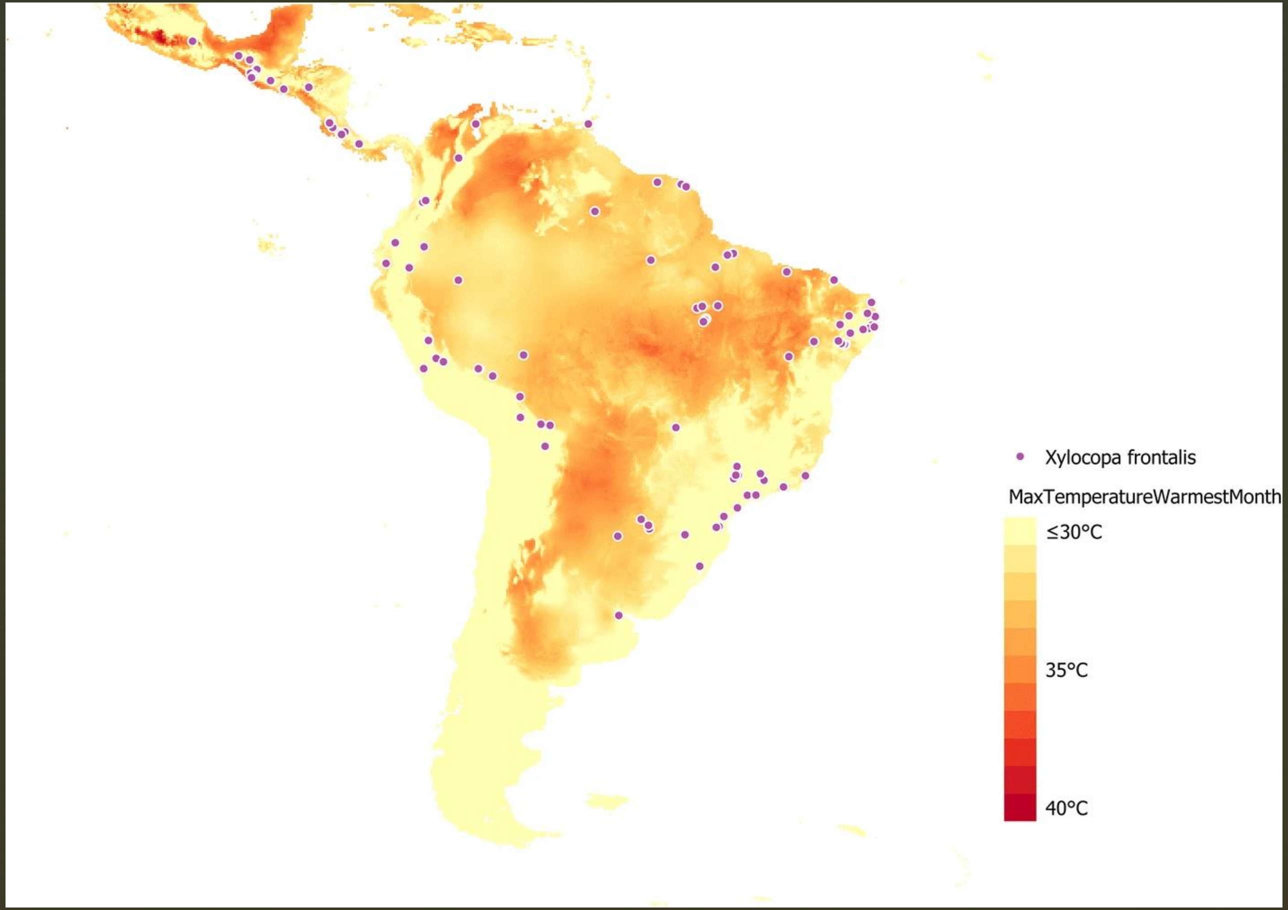
- Large carpenter and solitary bee
- Common in Centre and South-America



Approximately 35% of agricultural production and 87.5% of flowering plants depending to some degree on pollinators.

Genus Xylocopa are essential pollinators of plant with large flower, such as crotalaria (Crotalaria juncea L.), passion fruit (Passiflora edulis L.), Brazil nut (Bertholletia excelsa Humb. & Bonpl.), annatto (Bixa orellana L.) and pitaya (Hylocereus spp.).

Thermal map of maximum ambient temperatures in the Neotropics and records of the occurrence of *Xylocopa frontalis*



No occurrence in areas with maximum ambient temperature of 35 °C or higher.

THE AIM OF THE EXPERIMENT

➡ IPCC:increases between 0.3 and 4.8 °C in mean temperature by 2080

The aim was to investigate the thermoregulation processes of these bees in a hot environment to understand how these processes are related to the predicted reductions in areas where *X. frontalis* occurs, due to a rise in the mean ambient temperature in the near future.

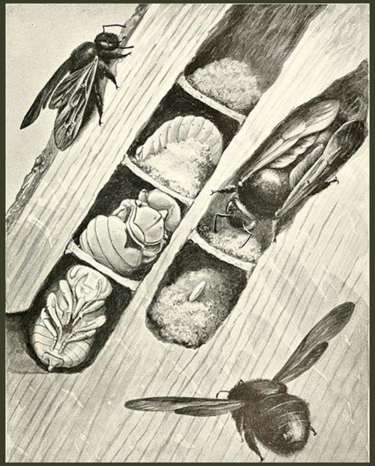
STUDY AREA

LOCATION: Federal University of Ceará, in the city of Fortaleza, Brazil

LOCAL CLIMATE: hot tropical sub-humid (max and min annual temperature of 26.9°C – 30.4°C)

PERIOD: August, September, October and December 2018, and January and February 2019

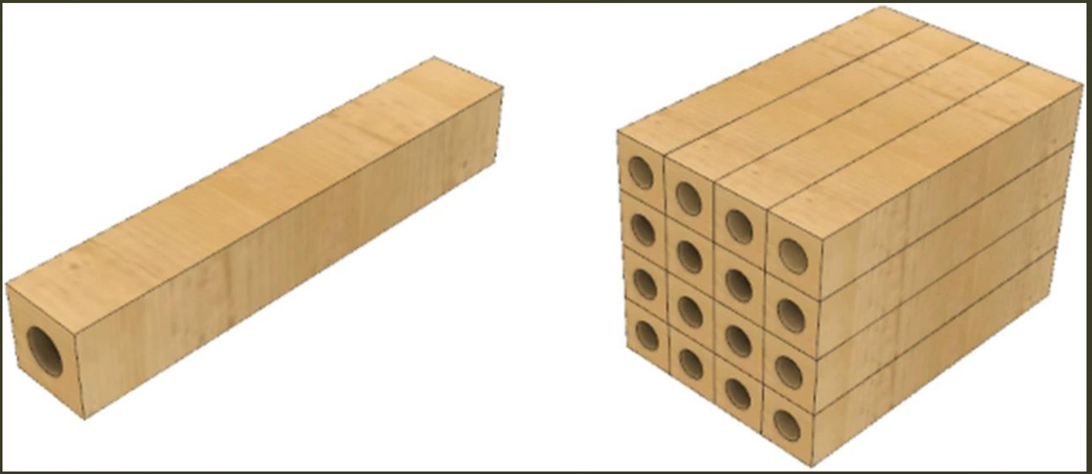
MEASUREMENTS



→ MEAN BODY TEMPERATURE

→ Mean ambient temperature (Weather Station)

A nest made of pinewood with 30 cm × 5 cm × 5 cm and a total volume in the wood of 750 cm^3 .
Pinus is a relatively soft substrate, facilitating excavation by the carpenter bees.



ONE in a bee breeding facilities
and ONE in a small forest fragment

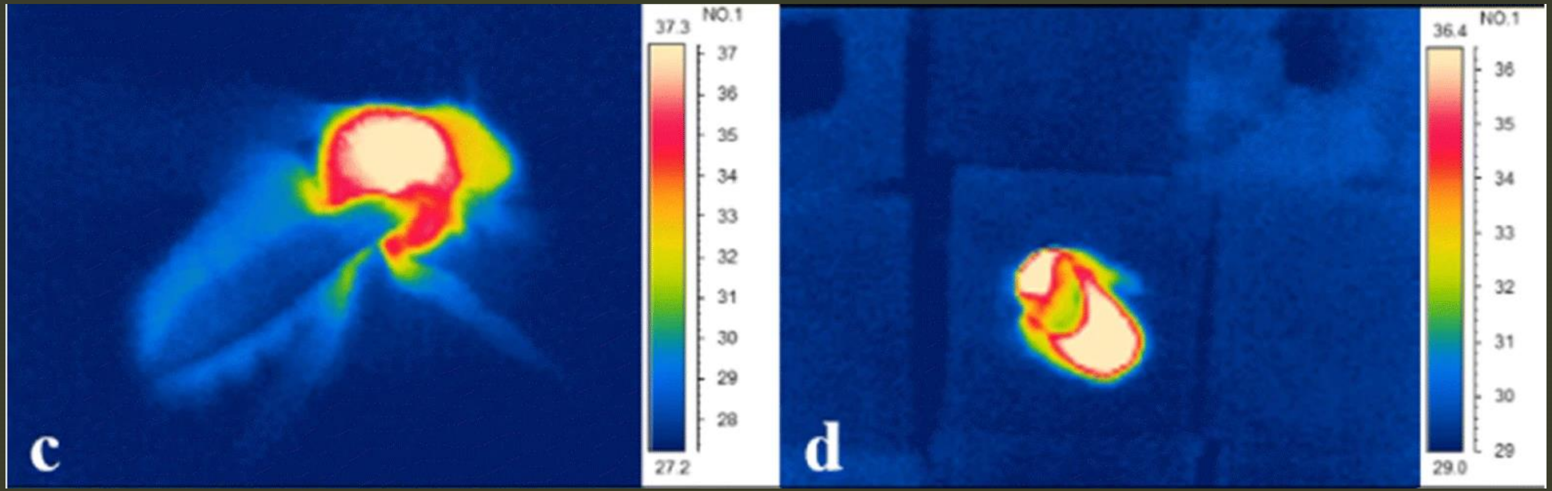
MEASUREMENTS

Different type of behaviours:

- resting inside the nest
- returning from the field after foraging
- excavating the wood to build the nest/cells
- dehydrating nectar
- during the process of warming up the flight musculature (pre-flight warm-up) before leaving for the field.

REGULARITY: 15h per week (different period of the day), total of **180 h** in 6 month (first and third weeks of each month)

MEASUREMENTS



The **mean body temperature** was calculated by considering only images where at least the thorax and head or thorax and abdomen were visible, as the thorax generates heat and is generally hotter than the head or the abdomen.

STATISTICAL ANALYSIS: mean, max ad min body T°C and ambient T°C analyzed between different behaviours, period of the time and nest location.

RESULTS AND DISCUSSION

Table I. Number of events and percentage value for body temperature recorded for some types of behaviour in *Xylocopa frontalis* throughout the day, in Fortaleza, Ceará, Brazil, from August 2018 to February 2019

Time	Behaviour					
	DN (%)	*E* (%)	*PA* (%)	*R* (%)	*VC* (%)	*O* (%)
04:30–07:30	5 (10.0)	3 (4.7)	52 (69.3)	386 (17.0)	124 (33.3)	0 (0.0)
07:30–10:30	6 (12.0)	7 (11.0)	11(14.7)	462 (20.3)	110 (29.5)	2 (20.0)
10:30–13:30	17 (34.0)	3 (4.7)	5 (6.7)	512 (22.6)	58 (15.5)	2 (20.0)
13:30–16:30	17 (34.0)	17 (26.5)	4 (5.3)	570 (25.1)	62 (16.6)	2 (20.0)
16:30–19:30	5 (10.0)	34 (53.1)	3 (4.0)	340 (15.0)	19 (5.1)	4 (40.0)
Total	50 (100.0)	64 (100.0)	75 (100.0)	2.270 (100.0)	373 (100.0)	10 (100.0)

Values in parentheses refer to the percentage of behaviour performed for time of day within each behaviour. *DN*, dehydrating nectar; *E*, excavating nest; *PA*, pre-flight warm-up; *R*, resting inside the nest; *VC*, returning to the nest from a foraging trip; *O*, others

Resting in the nest is 80% of the observation probably beacuse it is a long-lasting activity, since *Xylocopa* is a solitary species and does not acculumate lots of food resources and even because it is an adaptive strategy to minimise activities that generate heat.

RESULTS AND DISCUSSION

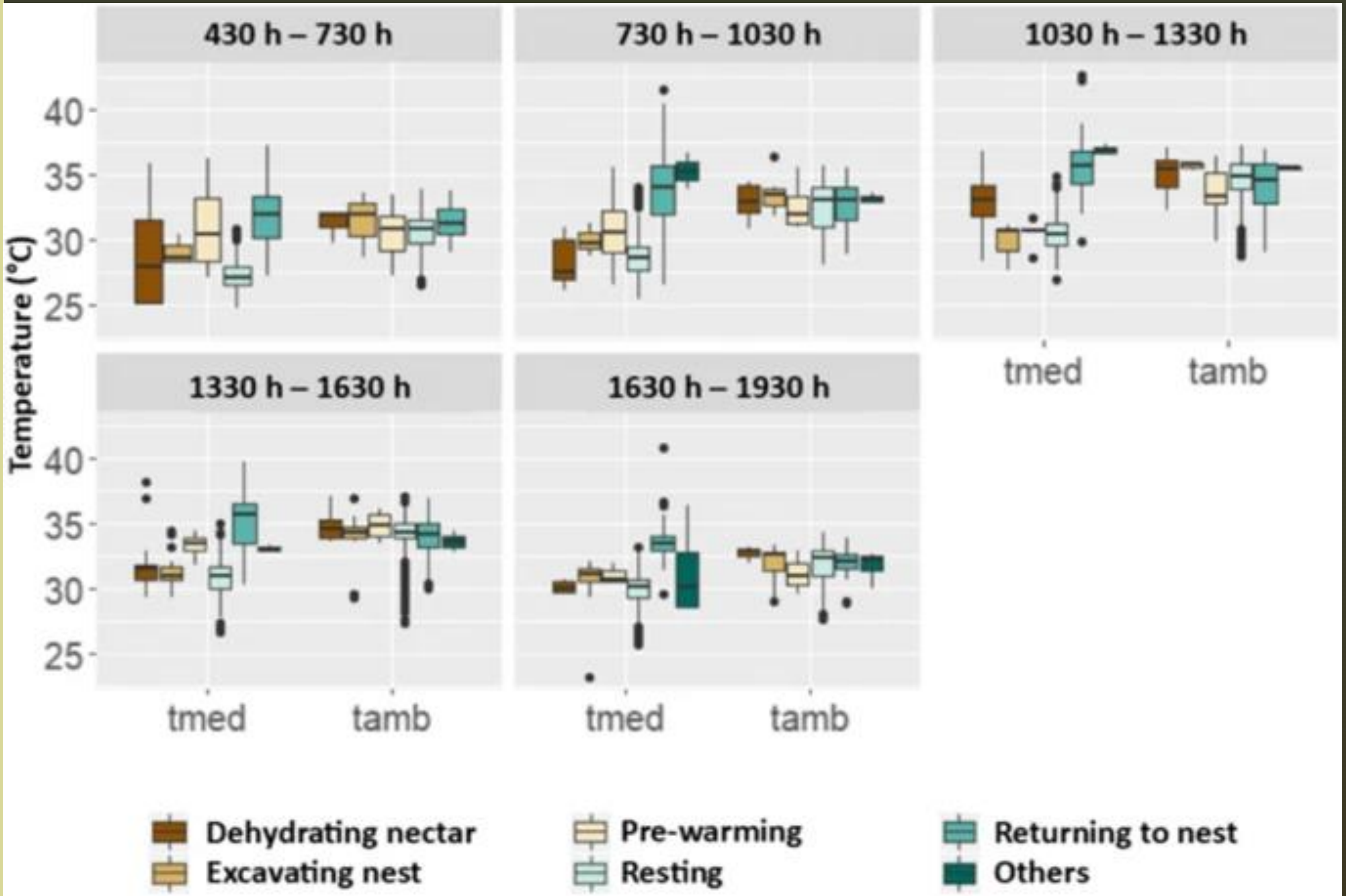


FIG: Mean ambient temperature and mean body temperature in Xylocopa frontalis when performing different types of behaviour in the nests at different times of the day.

Highest mean body T°C = returning to the nest after foraging.

Lowest mean body T°C= resting indide the nest

RESULTS AND DISCUSSION

NO significant difference in ambient temperature as a function of nest location and NO statistical difference for activities carried out by the bees

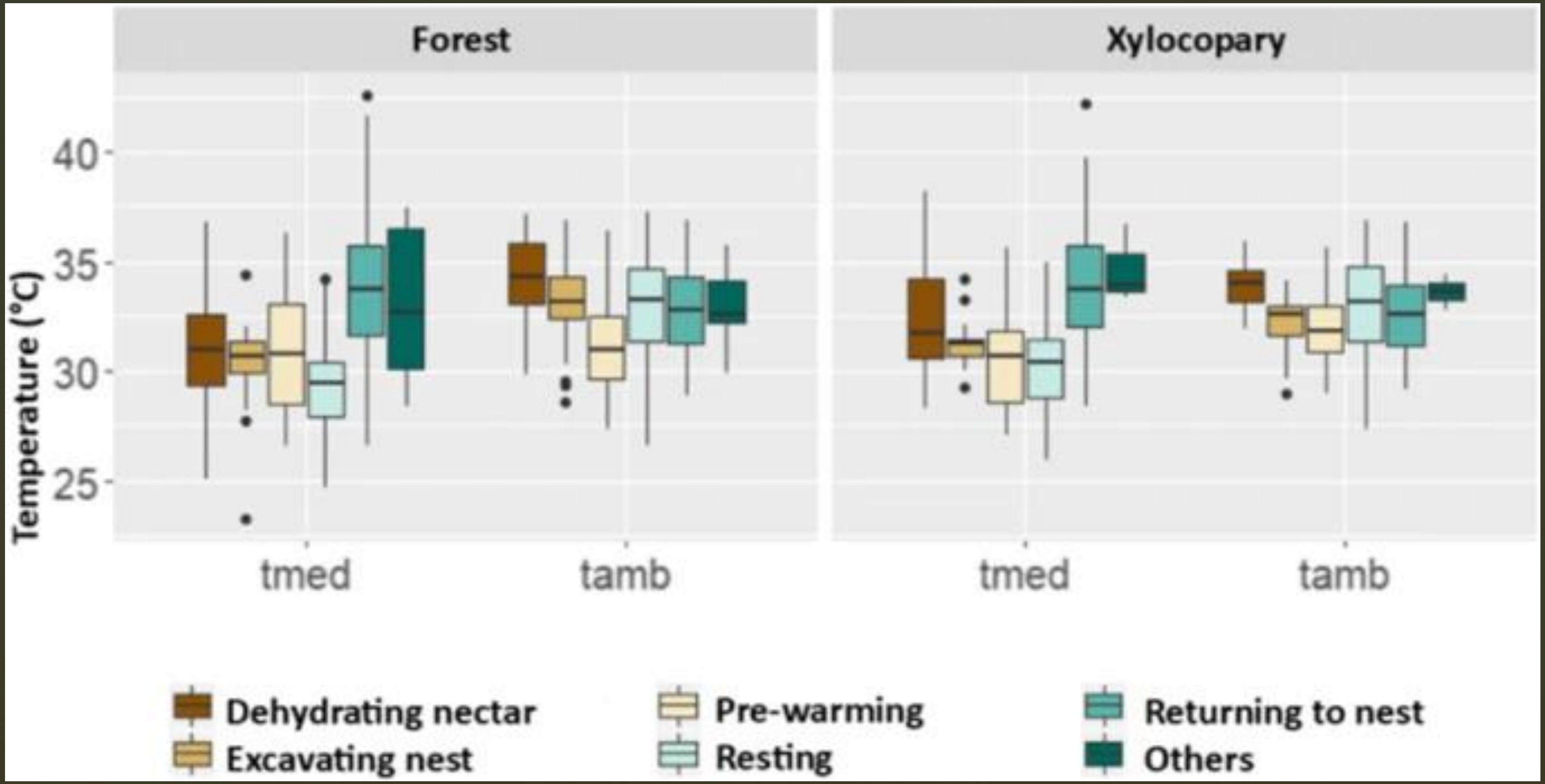
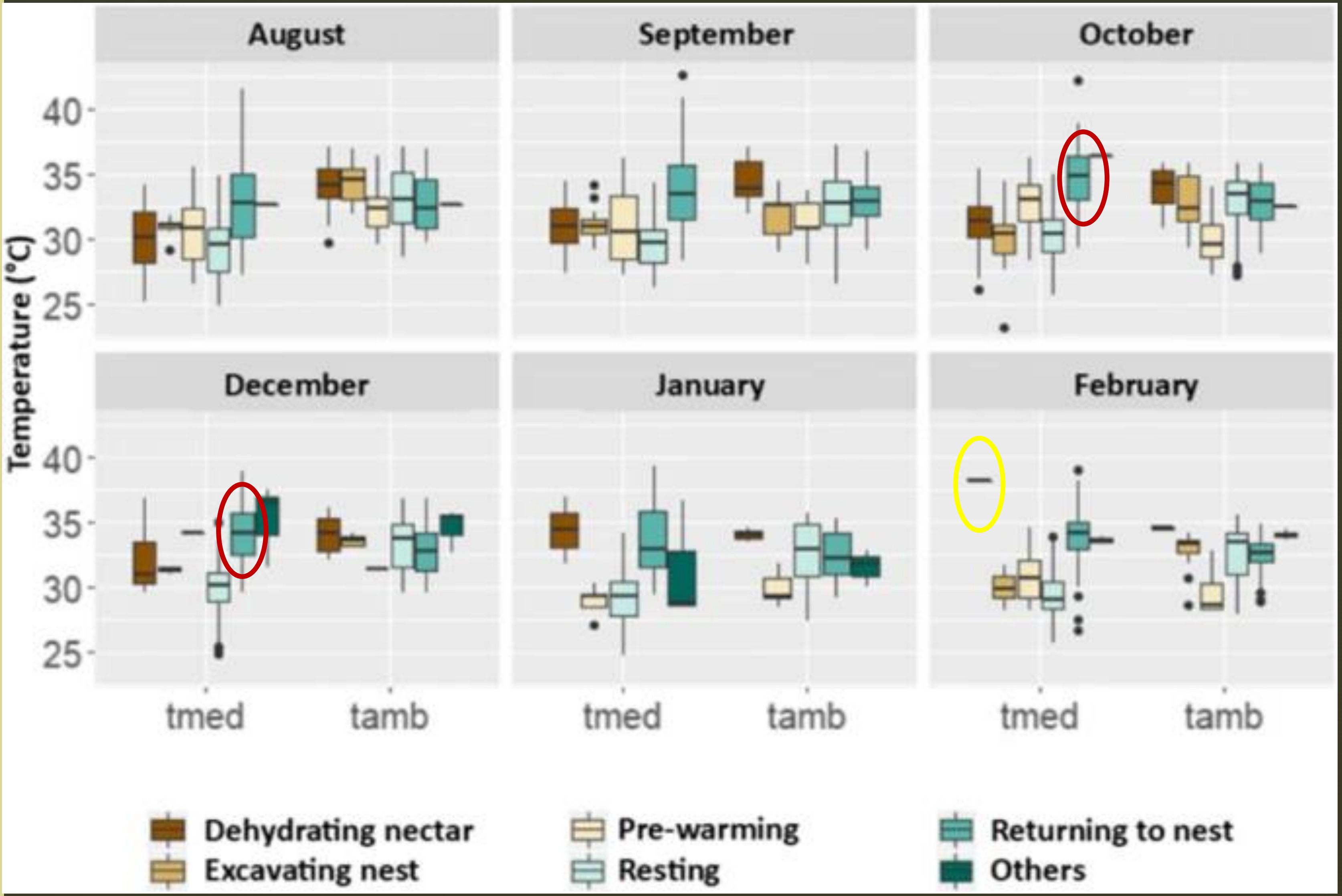


FIG: Mean ambient temperature and mean body temperature of Xylocopa frontalis when performing different types of behaviour in the nests at different locations.

RESULTS AND DISCUSSION

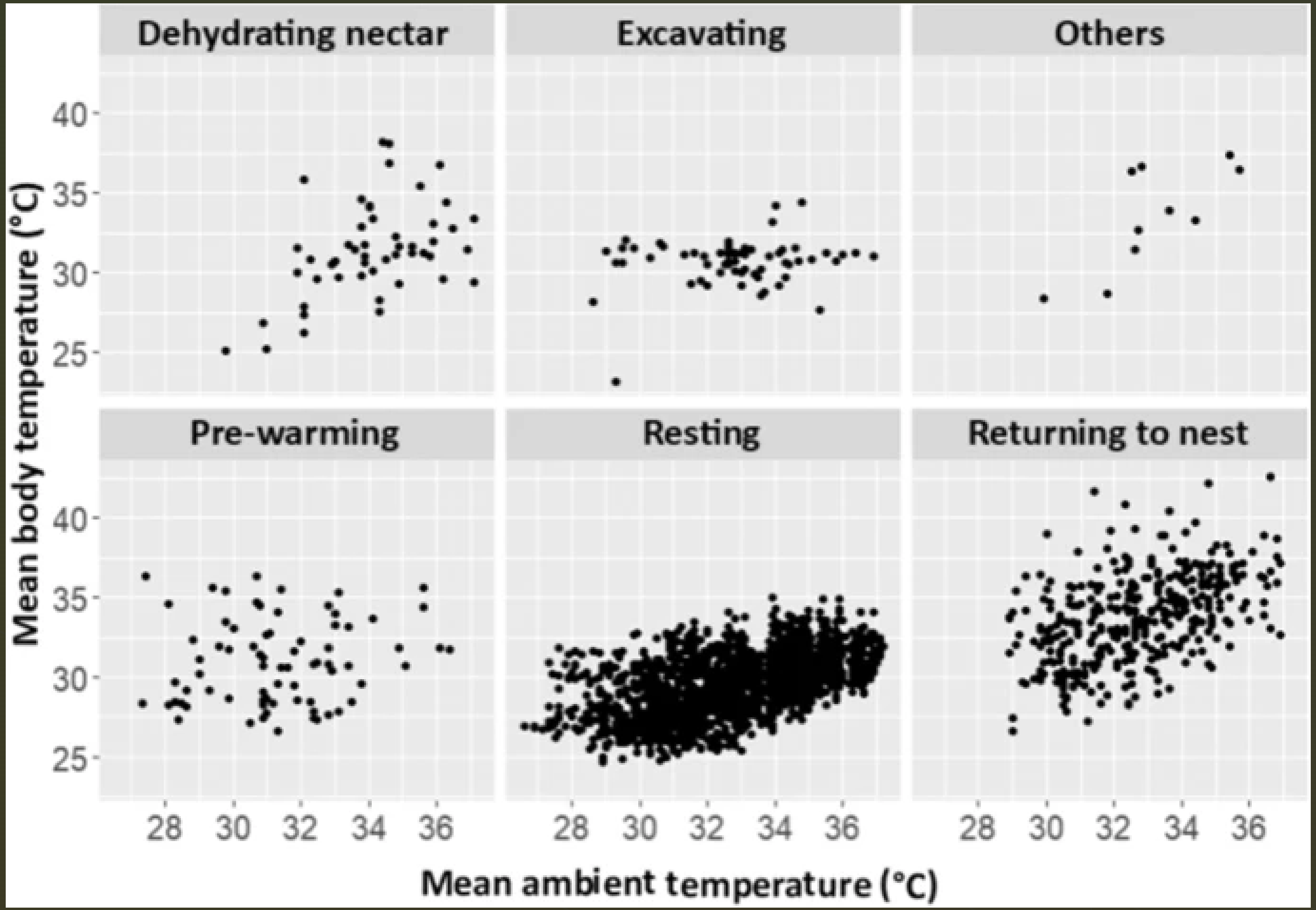


The highest mean body T°C was in October and December, when the bees returned from the field (greater than 34 °C), and February, when dehydrating nectar (greater than 38 °C)

RESULTS AND DISCUSSION

Resting in the nest showed the highest correlation between mean body temperature and ambient temperature

ECTOTHERMIC



CONCLUSION

THERMOREGOLATION OF *Xylocopa frontalis*

- *X. frontalis* concentrates activities that generate more body heat (foraging and pre-flight warm-up) in the cooler hours of the day:
  - *Xylocopa* is a large species so the loss of heat by convection is compensated by lower ambient temperature and the properly function of flight muscle (occurs at least of 30°C) is allowed due to efficient endothermy
  - Dark color helps reaching and maintaining the minimum body temperature necessary for flight but causes a dangerous increment during hotter hours of the day.

- Loss of heat:

  convection → Xylocopa is able to transfer heat from the thorax, considered its thermogenic centre, to the head and abdomen, where heat loss occurs through convection

  dehydrating nectar → the exposure of the collected resource to the air causes a loss of heat through evaporative cooling.
  Wide variations are likely due to this behaviour being adopted by the offspring that stay into the nest and adults that return from foraging

CONCLUSION

X. frontalis is well adpted to the ecological conditions of tropical regions. In fact, in the present study, the foraging activity of *X. frontalis* occurred at ambient temperatures ranging between 28.9 and 36.9 °C and *X. frontalis* should not be affected. But an increase of temperature as predicted by IPCC can affect *X. frontalis* distribution and survival. Studies of climate modelling have shown that increases in the mean ambient temperature due to climate change can reduce the areas suitable for the survival of these bees by up to 47.9%.

It was demonstrated, in a study with a small-size tropical bee (*Melipona subnitida*), that its flight muscle may increase the thoracic temperature by up to 10°C. But, for *X. frontalis* also at an ambient temperature of 35°C, the thoracic temperature may reach up to 45 °C that is a dangerous body temperature for this species.

X. frontalis adjusting to forage at higher temperatures is unlikely since species which already tolerate high temperatures are more sensitive to increases in the ambient temperature than species having a lower critical temperature.

Anyway, other studies are necessary in order to conserve and develop forms of sustainable exploitation of this pollinator.