SUMMER PROJECT REPORT

Comparative analysis of temperature readings of active and inactive potter wasp nests

Submitted by

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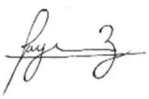
Abhishek Thakur (Intern from IISER Bhopal) helped me to understand the mechanism and usage of different equipment. I would like to thank Krishna Menon (Intern from IISER Pune) for spotting numerous nests near the main building of IISc campus. Each and every second in the IISc campus was amazing. I got to know about various matters for my career.

As my fieldwork progressed, I had the opportunity to engage with numerous individuals outside of the laboratory. Additionally, I would like to express my gratitude to the unidentified security personnel on campus who not only granted me permission to conduct experiments but also shared valuable information regarding the whereabouts of various nests in the area.

I am immensely grateful for the invaluable support and assistance provided by RMB lab members and friends, which played a pivotal role in the successful completion of my internship. I definitely enjoyed walking around campus, locating and spotting various nests. These fieldworks and Lab experience enriched my mind with happiness and insights. I am extremely thankful to everyone who accompanied me for this wonderful journey.

Fayiz M



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INTRODUCTION

In this Summer Internship program, I will be more focused on Investigating and recording Temperature of various Potter wasp nests around the campus and try to discover relations existing that can put lights on thermoregulation of nests by comparative analysis of both active and inactive nests. Throughout this project I will uncoil some of the experiments that I did in order to study the thermoregulation of nests and also some behavioral study of potter wasp.

The subfamily *Eumeninae* or potter wasp is classified in to three, *Zethini, Eumenini* (*Eumenes*) and *Odynerini* (*Odynerus*). Eumenes genera is further divided in to *Coeleumenes*, *Delta*, *Phimenes*…etc.
I was able to spot *Delta* and *Phimenes* species in the campus. These marvelous small organisms which are vibrant to eyes are great builders. Their nests are so strong and rigid. During my internship time at RMB Lab (Centre for ecological science, IISc Bangalore) ultimate task was to locate, spot and then monitor each nest and record the temperature readings. Throughout the internship I was able to monitor 10 active and 9 inactive potter wasp nests. This report mainly contains the data recorded from each nest and their analysis. The report also includes a comprehensive table enumerating approximately 50 nests observed within the IISc campus. This table provides essential information such as the nests' dimensions, shapes, and distinct features.
Most hymenopterans, which include ants, bees, and wasps, are highly social insects. They have two pairs of membranous wings, a mobile head, and chewing or sucking mouthparts. The females of many species have a posterior stinging structure. Many species, such as European paper wasp (*Polistes dominulus*), build large nests.

Social wasp and solitary wasp;

Solitary wasp also known as hunting wasps are non-stinging varieties which in a sense controls pest insect population. They do not form colonies. This group contain largest wasp members. Their size can reach up to 1.5 inches in length. All wasps build nest. The yellow orange colored *Delta* sp. And yellow black colored *Phimenes* sp. are solitary wasps.

Social wasp which contains a smaller number of species compared to solitary wasp, form colony and division of labors. There will be a queen which ultimately control the whole nesting. They include colony builders like yellow jackets and hornets. A social wasp in distress can emit a pheromone that can reach to a nearby colony and form defensive shield. Unlike bees, wasps can sting repeatedly and only female wasp have stingers.
Wasps have a great role in controlling pest population mainly in agricultural practices.

Potter wasp;

The subfamily *Eumeninae*, commonly called potter wasps, is the most species rich subfamily among the Vespidae. The initial tribal division of the subfamily is established using cladistic methods, encompassing *Zethini*, *Eumenini* (referred to as Eumenes sensu lato), and *Odynerini* (known as Odynerus sensu lato). Bingham's comprehensive study in 1897 marked the initial in-depth exploration of the Indian *Eumeninae*. Subsequently, numerous taxonomic revisions occurred, particularly at the generic level. Previous genera, such as Eumenes and Odynerus, underwent significant divisions, resulting in the formation of distinct genera. For instance, Eumenes was separated into *Coeleumenes, Delta, Eumenes sensu stricto (s. str.), Oreumenoides, Pareumenes, Phimenes, Pseumenes*, and others. They are usually solitary and rarely sub-social. Adults are small to large. *Eumeninae* can be easily distinguished.
Solitary wasp builds isolated nest and majority of them nest in the ground, plant branches, walls…etc. Potter wasp feed on flower nectar.
Mud dauber or mud wasp which excludes from potter wasp also build their nest using mud and most of them build nests in cylindrically shaped tubes. Like most of solitary wasps' mud daubers are also parasitoids. In this kind of wasp female builds the nests and male hunt to proviso the nest with spiders and nest guarding. They also depend on flower nectar.
Wasps not only obtain their nourishment from flower nectar but also from various carbohydrate sources and even from body fluids of the species they prey upon.

Active and inactive nests;

The closed and alive (Wasp larvae is alive) nests are called as active nests whereas the opened, damaged, emerged nests that doesn't contain wasp is called inactive nest.
The active nests may contain one or several individual brood cells and adult potter wasp will fill it with paralyzed caterpillar as a nourishment for the developing larvae. In the case of inactive potter wasp nests, it is just a mud structure which may have one or several compartments. Also, it may contain residues of caterpillar and dead larvae. Inactive nests may also home to some visiting insects.

Wasp life cycle;

It all starts with a new queen and end with the death of the colony's queen in case of social wasps. Initially queen lays egg in cells. Then worker feeds hatched larvae. After the complete growth of larvae, worker seals the cell. Inside the cell larvae transform in to a pupa and then to an adult wasp.

As a colony nest is absent in solitary wasp, The parent wasp lays egg inside the nest and provision them with caterpillar or spiders. Egg transforms in to larvae and then to pupae. Finally adult wasps emerge from the nests. The adult females die by the end of the summer. The larvae eventually pupate and emerge the following summer. There is only one generation each year.

Parasitoid wasps, for example, inject their eggs into caterpillars depending on plants for food. The eggs hatch within the caterpillars, and the larvae eat through their organic containers. The larvae then form cocoons on the surface of the host before emerging as adult wasps. The plant also has an important role in this process.

Nesting;

Eumeninae shows a remarkable flexibility in their nesting habits. They are commonly known as "potter wasps" due to their construction of mud nests that resemble earthen pots, some of which are standalone structures. These mud nests can be either single-cell or multi-cell in design. While the preferred nesting sites are borings in decaying wood, certain species also utilize other structures like hollow plant twigs, stems, artificial cavities on man-made objects, ceilings, and even old mud nests. Most of the wasps are entomophagous (An entomophagous organism is one that eats insects (also called an Insectivore) in their immature stages. Many species of *Sphecidae* are narrowly to rather broadly oligophagous (eating only a few specific kinds of food.)
Within the families *Eumenidae, Pompilidae,* and *Sphecidae*, distinct elements have independently evolved behaviors that paved the building of nest cells (often in series) within cavities found in plants. Nesting behavior varies among wasp species. Also, the method by which the prey is grasped for transportation to the nest shows minimal or no variation within genera and often remains consistent within subfamilies or even entire families.

Potter wasp usually provision their broods with mainly larvae of Lepidoptera, Curculionidae and *Chrysomelidae*. The wasp paralyses the larvae before transporting it in to the nest. As the name suggests potter wasp mainly build nest in the shape of a pot and contain a single compartment inside it. It also constructs nest in various shapes and structures like tubular, cylindrical, oval, irregular. Potter wasp build its nest mainly from soil and water. They usually collect materials (soil and water) within four meters perimeter around the nest location. In the images given below, two potter wasp species can be identified. The one in the right shows a *Phimenes* species and its nest. A delta species and its nest can be seen in the adjacent image.

Potter wasp doesn't randomly choose a nesting location. It usually chooses a location where minimal amount of sunlight reaches and at a certain height to avoid attacks from predators. Also, the nesting location depends upon the availability of water sources for ease of its construction.

Figure 1 NB-CSA and delta sp.

Figure 2/ NA-BHL and Phimenes sp.

Temperature of Inactive Nests

Aim;

- To measure the interior and exterior temperature of several inactive nests collected earlier.
- To analyse any correlation between interior temperature and ambient temperature, thus looking for thermoregulation of inactive nests.

Materials Required;

- Thermocouple thermometer
- FLIR IR Thermometer
- Kestrel 3500 pocket weather Meter

Procedure;

Me along with my friend Abhishek Thakur (Another Intern) placed 4 Nests (inactive) on the terrace of biological science building and recorded the variation in internal and external temperature of these nests. Then plotted a graph.

Date of experiment: **26-05-2023**

Data and Observations;

Nests 1,2,3 and 4 size can be referred from figure mentioned in the page no. 9 [Figure 7/ inactive nests at terrace]

Time	Ambient	Surface	Nest 1 Ext	Nest 1 Int	Nest 2 Ext	Nest 2 Int	Nest 3 Ext	Nest 3 Int	Nest 4 Ext	Nest 4 Int
0	32.1	37.3	35.1	29.6	34.2	32.3	37	30.9	37.6	32
15	34.5	37.4	41.7	36.6	36.2	38	38.7	38.8	41	39.5
30	34	38.5	43.5	38.3	37.4	35.9	38.6	35.4	42.3	38.2
45	33.2	38.6	43.7	42.1	37.7	38	38.8	40.1	39.7	38.3
60	34.5	39.5	44.5	44.2	37.9	38.4	38.3	40.2	42	39.9
120	32.8	40.7	45.9	41.2	37.5	38.4	39.4	36.7	41.5	37.5
150	32.4	40.2	44.7	39.2	36.4	40.7	35.8	39.6	38.4	39.9
240	33.1	42.3	45.7	38.5	38	34.4	41	34.9	43.1	36.4
270	33	42.1	46.4	39.4	38.4	33.6	37	34.5	39.8	33
300	34.3	42.9	47	40.2	38.9	36.9	40.5	35.1	41.4	37.3
330	33.5	42.2	45.1	36.4	37.9	34.2	37.2	33.1	40.4	35.1
360	32.5	39.8	41.7	37.5	35.5	36	36.7	34.4	41.9	35
390	32.9	39.6	40.7	36.2	36.4	35	37.4	34.3	39.9	38.1
420	31.3	38	37.2	34.2	34.2	32.4	34.8	32.6	36	33.7
450	30.6	36.2	35.5	33.2	32.7	31.8	33.7	32	35.5	33

Figure 3; Tab 1

Graphical interpretation;

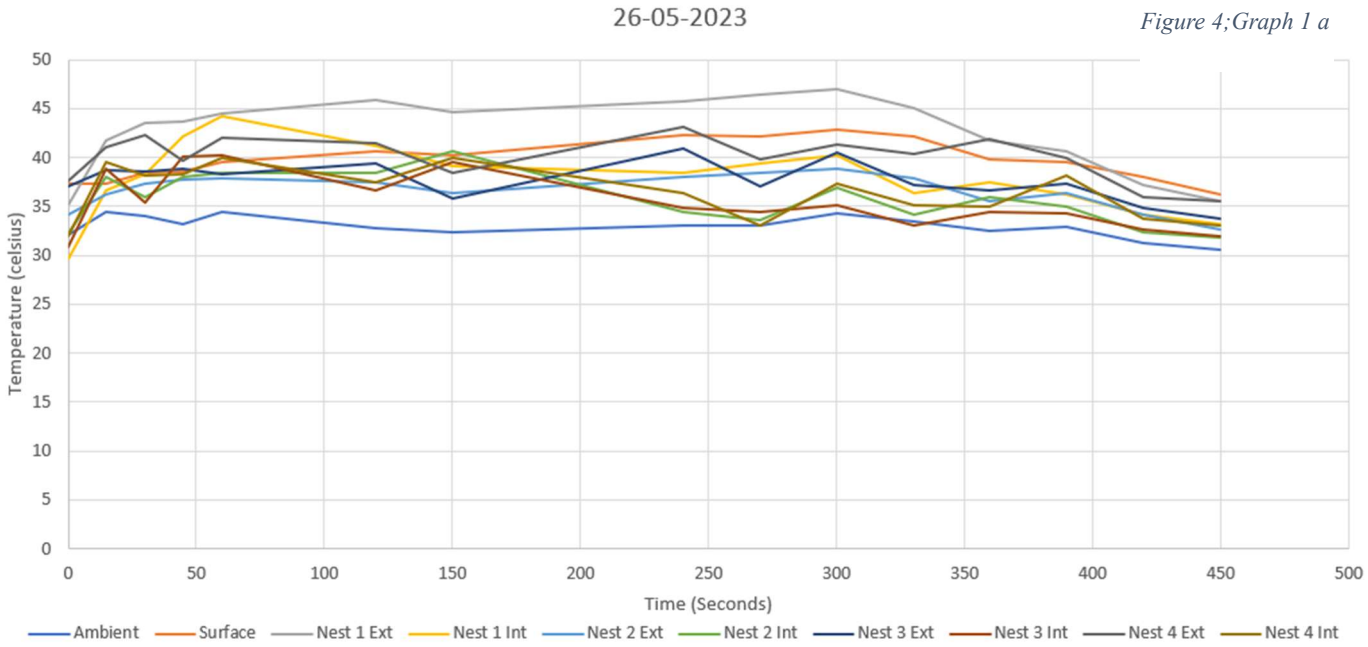


Figure 4;Graph 1 a

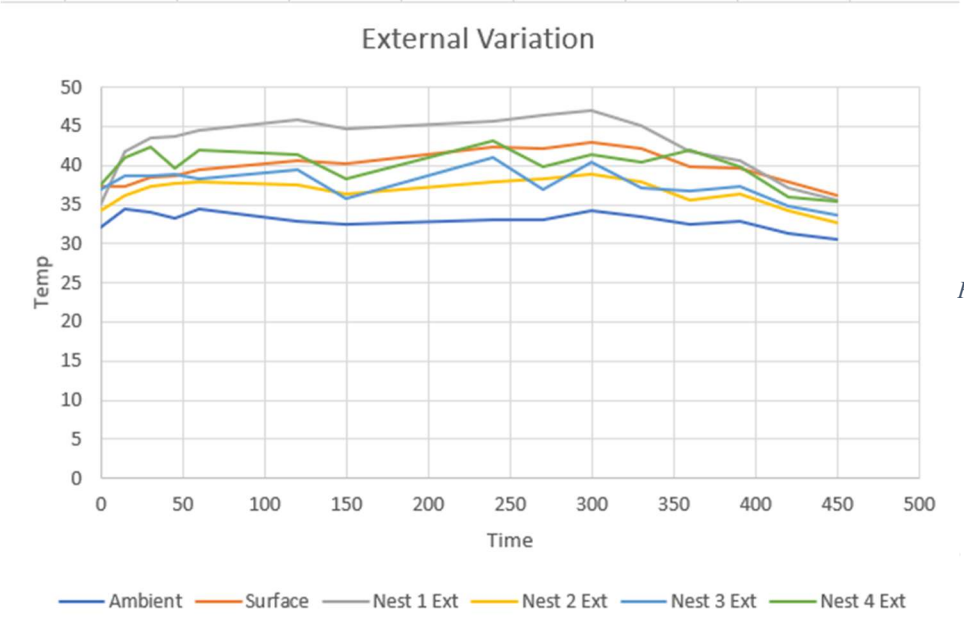


Figure 5;Graph 1 b

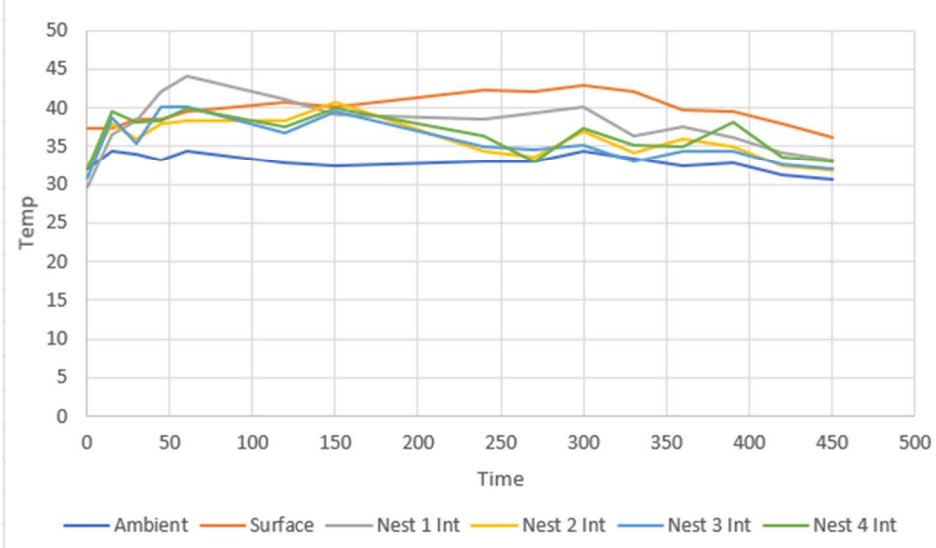


Figure 6: Graph 1 c

Analysis;

- The Mean value of the external temperature of the nests were, 42.56, 36.62, 37.66, 40.03 and the mean value of the ambient temperature was 32.98.
- Similarly, the Mean value of the interior temperature of the nests were, 37.78, 35.73, 35.5, 36.46 and the mean value of the ambient temperature was 32.98.
- From this, we can analyse that there is variation in the mean value of interior temperature of these inactive nests compared to exterior.
- This might indicate significant regulations of temperature inside the mud nests.
- **But with this only we can't conclude anything. So, I need to get data of various active nests and comparing it with inactive nests might solve some questions.**

Gallery;

Figure 8/ Equipment at terrace

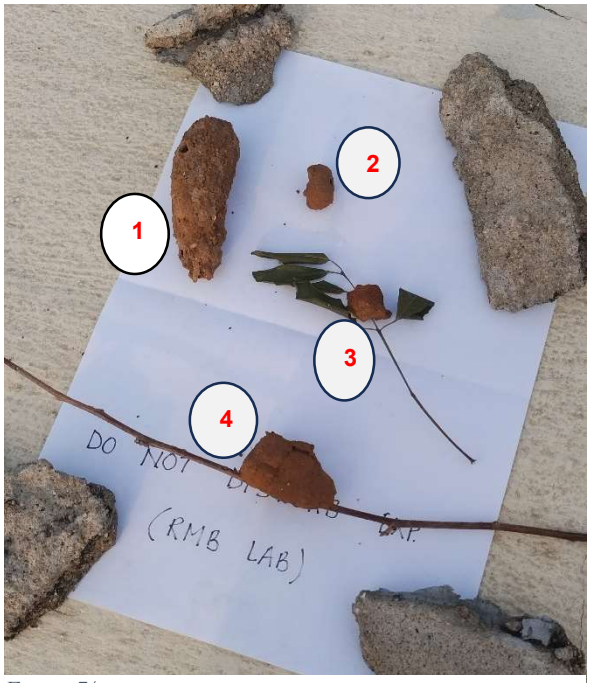


Figure 7/ inactive nests at terrace

Homing behavior of wasp

Aim;

- To cover an active nest with a paper cup containing hole on it.
- To test homing behaviour of wasp

Hypothesis;

- Potter wasp recognizes its nest using visual identification and memory.
- The presence of clay model might interfere and disturb the wasp.

Theory;

Homing behaviour is the movements of an organism to return to a specific or familiar site. It is the inborn ability of an organism to navigate towards a specific constant location through unfamiliar general area. Most of the case the specific location may be its home or nest. Birds uses homing ability to return to its original location during migration. There several examples of true navigation in animals. In order to find their way back home organism uses several techniques like magnetic orientation, celestial orientation, olfaction and topographic memory or visual memory.

The Indian paper wasp (*Ropalidia marginata*) which is a social predatory wasp uses proximal visual cues of the landscape to find its way back home. Wasp of the wasp uses visual identification and memory for its homing behaviour.

Nesting insects conducts a learning flight to create a visual diagram of the nest surrounding that helps in its homing behaviour. Potter wasp mainly delta species regularly monetarizes its nest for any potential attack or damage. This type of monitoring and locating the nest can be done using visual cues.

Materials Required;

Paper cup with a hole on it, Active nest (The wasp should regularly monitor the nest), A video recorder and a Clay model of wasp

Procedure:

I made a hole on a paper cup using a scissors. Then I found an active nest which was regularly monitored by the wasp. Initially made a hole on the nest using a needle. Wasp came and analysed the hole and went for collecting materials to repair it. During that time, I covered the nest using the paper cup.

Using the given clay model of wasp, I placed the model on the nest whenever the wasp returns to repair the holes.

Observation;

- The wasp came with mud and water but couldn't identify the nest of it, Instead It sat above the paper cup and flew away
- After around 15 minutes, it came looking for its nest. But failed to enter through the hole and then flew away
- Again, after around 15 minutes, it came but this time also it couldn't identify its nest. Then flew away
- It came 4 times but failed to enter. At last, when I removed the paper cup, it came and analysed then repaired the hole.
- Clay model was placed in two nests (NB-CSA and NA-IMB) and recorded its behaviour, I observed there wasn't any strange behaviour by the wasp and it's not even minding the clay model. (May be the clay model is not so realistic…!)

Result and Analysis;

- The wasp couldn't identify and repair the hole on its nest when it is covered using some materials
- It was unable to enter the nest. It couldn't enter the nest through the hole around the blocking materials due lack of logic.
- So, my hypothesis may be accurate as it uses only visual characters and memory stored to identify its nest.
- (Also, I do have a video recording in my phone of the event)
- From the clay model experiment we can hypothesis that a wasp species identifies other wasp not by visual identification but may be with the help of olfactory signals.

Some Frames from the recording; (Date of experiment: 01-06-2023)

(Here in these images the top part visible is not the part of the nest, it is just a stone kept to keep the paper cup fixed.)

Clay model experiments;

Date of experiment: 07-06-2023

Nest: NB-CSA

Images;

Figure 10/NB-CSA (a) 07-06

Figure 9/NB-CSA (b) 07-06

The figure [Figure 10/NB-CSA (a) 07-06] contains a clay model attached to the nest

The figure [Figure 9/NB-CSA (b) 07-06] contains both the model and the wasp. Wasp is not reacting to the model.

Clay model experiments;

Date of experiment: 06-07-2023

Nest: NA-IMB

Images;

Figure 11/NA-IMB (a) 06-07

Figure 12/NA-IMB (b) 06-07

Figure 13/NA-IMB (c) 06-07

- Figure [Figure 11/NA-IMB (a) 06-07] contains holes and a clay model attached
- Figure [Figure 12/NA-IMB (b) 06-07] contains the model and the wasp. Wasp is engaged in its own activities without minding the presence of the model
- Figure [Figure 13/NA-IMB (c) 06-07] shows the completely repaired nest. The freshly attached mud can be visible in the picture.

Hole Repairing and preference

Aim;

- To observe the Potter wasp and to study the hole repairing mechanism.
- To record the Interior and exterior temperature readings of the active nests.
- To verify the preference of potter wasp to repair large hole initially and then the rest of the holes

Materials Required;

An active nest, Needle, Tissue paper, Thermocouple thermometer, Ambient temperature measuring device, Scale, A video recorder.

Procedure;

Initially I located an active nest (N B-CSA). Then Made three holes of different diameter (0.1 mm, 0.25mm, 0.4mm).

Then using Data logger and thermocouple, I measured the interior temperature. Used IR Scanner to measure surface and exterior reading and finally measured the ambient temperature during 14:45, 15:00, 15:30 and 16:00

Each time when the wasp came to repair the holes, I covered it using a tissue paper.

Data, Graph and Observations;

The **Nest N B-CSA:** It is located in the computer and automation building (Opposite to civil engineering department). It is attached to a cement surface on the bottom of a window. Given below is the data collected on **31-05-2023**

# 31-05-2023							
Nest	Time	Ambient	Surface	Exterior	Hole A	Hole B	Hole C
N B-CSA	14:45	32.7	31.2	32.5	32.1	31.6	31.2
	15:00	32.4	31	30.9	31.2	31.3	31.1
	15:30	31.6	31.1	31.3	31.2	31.3	31
	16:00	31.2	31	31.8	30.6	30.5	30.6

Figure 14/data table NB-CSA (31-05)

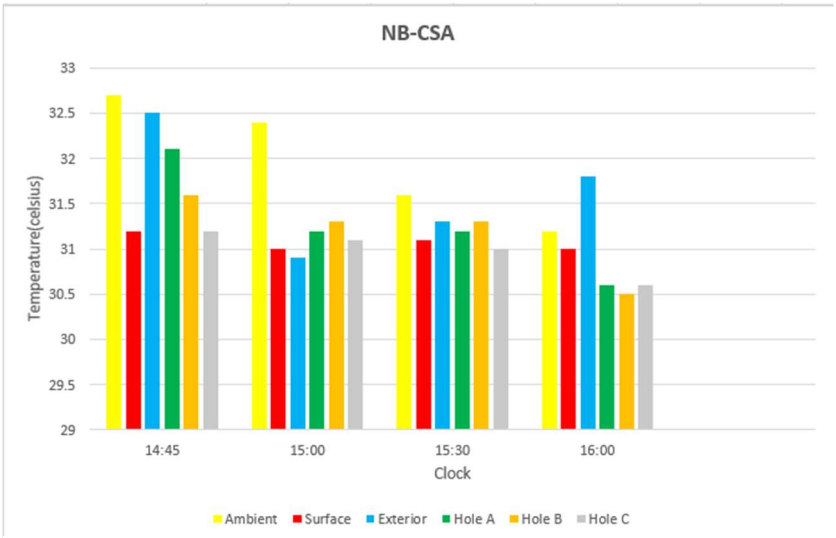


Figure 16/Graph NB-CSA (31-05)

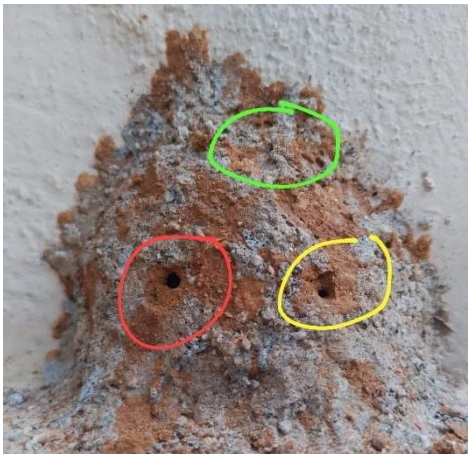


Figure 15/ NB-CSA, HoleA, B, C

Data collected on **01-06-2023**;

# 01-06-2023					
Nest	Time	Ambient	Surface	Exterior	hole
	15:30	31.4	31.4	32.5	31.8
N B-CSA	15:45	31.7	31.2	32	31.4
	16:00	31.2	31.2	32	31.2
	16:15	31.4	31.3	32	30.9
	16:30	30.4	31.2	31.8	31.1
	16:45	30	31.2	31.5	30.5

Figure 18/Data table NB-CSA (01-06)

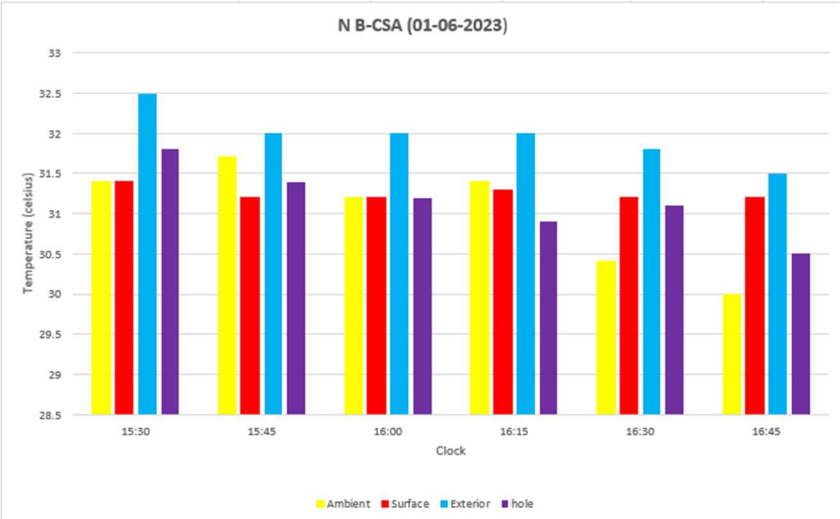


Figure 17/Graph, NB-CSA (01-06)

Figure 19/NB-CSA hole (01-06)

Analysis from Graphs obtained;

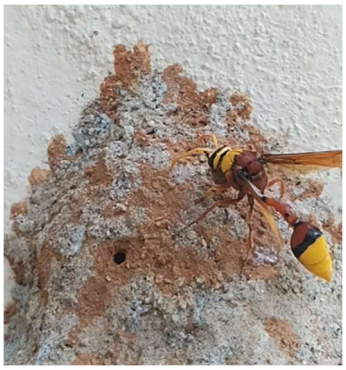
- As the both data are collected during afternoon time, we can't see much variation in ambient temperature

- During afternoon, the surface temperature also remains almost constant
- We can observe that whenever the ambient temperature is reduced the interior temperature will reduces slightly but not so much variation.
- **My assumption is, the potter wasp always choses a nesting location where large variation in ambient temperature is not possible. Also, the nesting location of NB-CSA Nest is such that sunlight never fall on it directly.**
- But from these data we can't verify the assumption. I need to record the temperature reading during the entire day time in a specific interval to conclude my assumption.

Summary of the entire event of hole repairing I observed;

- Around 14:30 I made 3 holes of different size. While I was completing the third hole, the wasp came and repaired every hole. Starting from the largest hole then towards the smallest then finally the medium hole.
- At 14:45 I made 3 hole similar to previous one and covered it using a paper. The wasp came at 14:55 and sat on the paper. After moving around some time, then it left the holes without repairing.
- At 15:08 it came there and without sitting on the paper, it flew away. It came again after 15 minutes then flew away.
- I removed the paper
- After 30 to 40 minutes the wasp came and repaired the holes. It completed the largest hole at last. (I have a recording of it)
  # . So, we can conclude that there is no affinity towards the size of hole while repairing.

Some frames captured;

(Video was recorded on 31-05-2023)



Images Captured using Infrared Thermal camera;

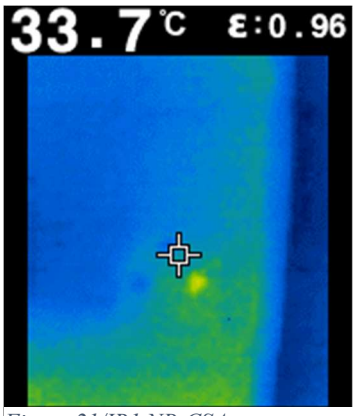


Figure 21/IR1 NB-CSA

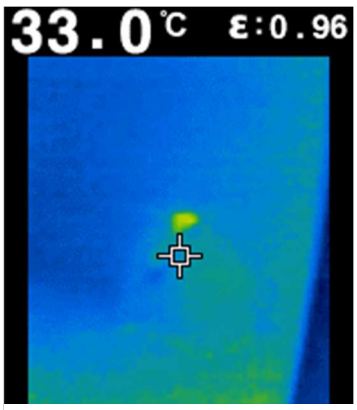


Figure 20/IR 2 NB-CSA

This shows the nest along with the potter wasp during repairing. Here the *bright yellow coloured spot* is the potter wasp.

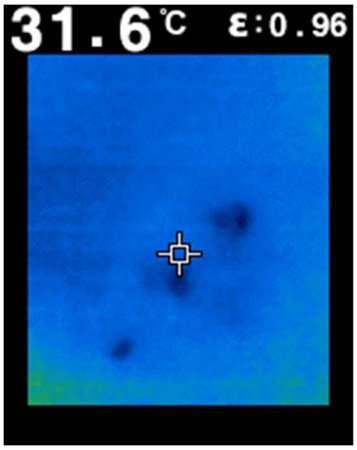


Figure 22/IR3 NB-CSA

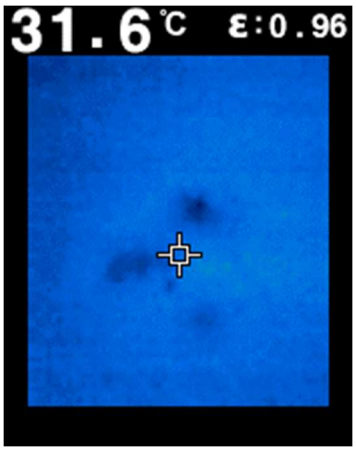


Figure 23/IR4 NB-CSA

These are the images of nest after the completion of hole repairing. Here the *dark coloured spots* indicate new mud and water

Behavior of *Eumenes* sp.

Given below is a wasp species (*Eumenes* sp.) and a nest (NA-OCB) attached to a glass behind the organic chemistry building. The photo of the wasp and the nest is attached below.

Figure 27/NA-OCB 1 (31-05)

Figure 26/NA-OCB 2(31-05)

Data and Observations;

# 31-05-2023						
Nest	Time	Ambient	Surface	Exterior	Interior	artificial hole
N A-OCB	12:10 PM	27.7	29.7	29.8	28	28.6
Behind Organic chemistry building	12:25 PM	28.8	29.8	30.1	28.8	29
On a glass window	12:40 PM	30	30.1	30.6	28.9	29.4
(wasp was sitting inside a hole on 31-5-23)						

Figure 28/Data NA-OCB

- The wasp was sitting inside a hole
- It was not repairing any hole or building the nest
- After sometime I intentionally made a hole on the nest, at that time the wasp flew away
- On the next day, 01-06-2023, the nest was there unrepaired and I could not see the wasp nearby.
- On 13-06-2023, I saw the same wasp staying inside another hole on the same nest without any purpose.
- I intentionally broke the nest and the wasp flew away.

(The image [Figure 31/NA-OCB (01-06)] was captured on 01-06-2023, It show a damaged part that I made on 31-05-2023 and it was not repaired.)

(The image [Figure 30/NA-OCB (15-06)] was captured on 15-06-2023, Some part of it was damaged by me itself)

- Similar case was also observed in a nest on a tree near Main Building (IISc). On 14-07-2023, I was able to spot a nest attached to a tree (*Araucaria cookie*). This nest was also similar to the nest mentioned above (NA-OCB). There was also a wasp sitting inside of it but I was unable to identify the species. It looks similar to *Eumenes* wasps. Image of the nest is attached below;

Figure 29/ nest 14-07

Inference and Analysis;

- I think that the nest was not build by this wasp.
- The wasp is using some other unused nest.
- It is using abandoned nests as a shelter for it.
- **This kind of instances (wasp returning to a nest without engaging in any activities) were not recorded or mentioned by previous workers on potter wasp.**
- This might be **the first report of a potter wasp returning to a nest without engaging in activities** like rebuilding it even if it is damaged.

Figure 31/NA-OCB (01-06)

Figure 30/NA-OCB (15-06)

Comparison of Temperature variation between Active and Inactive nests

Aim:

- To take interior and exterior temperature readings for several active and inactive nests around the campus.
- To measure the Nests dimension.
- To study the Nesting location and structure.
- To learn about thermoregulations inside each nest.

Materials Required;

- Thermocouple thermometer
- FLIR IR Thermometer
- Kestrel 3500 pocket weather Meter
- Needle, Tissue paper and Scale
- Ruler

Figure 34/Thermocouple Thermometer

Figure 33/FLIR IR Thermometer

Figure 32/Kestrel 3500 pocket weather Meter

Figure 35/Needle

Procedure;

Walked around the campus and spotted several active and inactive nests. Using a ruler, measured the approximate dimension of the nest.

With the help of a needle made two (at least) holes on active nest. Then using data logger and thermocouple thermometer measured the interior temperature.

With the help of IR Scanner, I took the readings of surface and exterior temperature. Finally recorded the ambient temperature.

Nest Monitored;

Active nests;

	Nest code		*Nest code*		*Nest code*
1	NA-BHL	4	NA-IMB	7	NB-IMB
2	NB-NSO	5	NB-BHL	8	NB-IMB2
3	NB-CSA	6	NB-ICDS	9	NB-MBP
				10	NB-SP

inactive nests:

	Nest code		*Nest code*		*Nest code*
1	NC-BHL	4	NC-IAP	7	NC-IMB3
2	NC-CE	5	NC-IMB	8	NC-JNC
3	NC-ICSA	6	NC-IMB2	9	NC-MBP

[The details of each nest code (Like the location, surface materials...etc) can be found in the section Nest around IISc campus (Page No. 50 to 63)]

Data Collected (Temperature readings: Ambient, Exterior and interior);

Active Nests:

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
N A-BHL							
$ Category A nest	03-06-2023	11:36	28.9	26.8	27.2	25.6	26
$ Behind hydraulics Lab	06-06-2023	10:55	29.4	26.8	27.1	26	25.9
$ On a wall		13:56	30.6	27.8	28.2	26.1	26.1
		17:27	28.7	27.3	27.5	25.9	25.9
	08-06-2023	10:45	30.1	26.4	26.8	26.4	26.5
		13:53	28.3	27.4	27.7	25.6	25.8
		17:00	28.9	27.6	28	25.9	26.2
	12-06-2023	11:00	27.9	25.5	25.8	25.9	25.7
		14:00	29	26.2	26.4	26.1	25.4
		16:30	29.4	26.6	27	27.3	27
	14-06-2023	11:00	28.6	25.8	26	25.4	25.7
		14:00	29.6	26.8	27.8	26	25.5
		17:30	28.7	26.7	27	25.9	25.8
	16-06-2023	11:00	27.4	25.9	26.2	26	25.9
		13:00	30.5	26.7	27.2	27.4	27.2
		17:00	29.1	27	27.3	26.2	25.8

Figure 36/NA-BHL DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2	Interior Hole 3	Interior Hole 4
N B- NSO	12-06-2023	11:35	28.2	26.8	27.3	25.7	26	26.3	26.3
# It is in a building near to security office		13:30	29.5	27.6	28.5	25.4	25.5	25.9	26
# It is attached to a window		17:00	30.3	27.8	28.5	27.2	27.5	27.8	27.6
# Surface: Cement									
# Here Hole 1,2,3 are artificially created	14-06-2023	11:30	28.6	26.7	27.3	26.6	26.3	26.5	26.5
where as Hole 4 existed there during the beginning		14:30	32	28	29	27.2	27.4	27.8	27.8
		18:00	30	27.7	28.4	27.2	27.4	27.6	28
	16-06-2023	11:20	29.6	27.7	28.1	26.2	26.5	26.8	26.8
		12:45	29.8	28.3	29.1	26.9	27.1	27.2	27.3
		17:20	30.5	28.5	29	27.5	27.8	27.8	28
	10-07-2023	17:20	24.6	23.7	23.6	24.1	24.1	24	24.1

Figure 37/NB-NSO DATA

Category B= Completed & Active nest							
Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
N B-CSA	03-06-2023	11:24	29.9	30.3	32.4	29.1	28.9
$ Category B nest	06-06-2023	11:05	30.3	30.7	32.4	28.8	29.2
$ In CSA building		14:08	31.8	32.9	34.9	32.5	32.4
$ On bottom of a window		17:45	29	31.2	31.6	30.4	30.3
$ On a cement surface							
	08-06-2023	11:01	30.2	29.9	32	29.8	29.9
		14:10	30.8	32.1	34.5	30.9	31
		17:15	30.7	32.5	33.3	31.8	32.1
This is no longer an Active nest							
# On 09-06-2023 the wasp emerged							
	14-06-2023	11:15	28.4	29	31	28.4	28.8
		14:15	31.5	30.7	30.9	31.4	33.4
		17:45	30.1	31.5	32	30.5	30.4
	16-06-2023	11:15	29.6	29.4	32	29.8	29.3
		13:00	32.2	31	33	29.9	30.3
		17:15	30.3	32	32.9	30.8	30.9

Figure 38/NB-CSA DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2	Interior Hole 3
NA-IMB								
# Located infront of main build	07-07-2023	11:10	25.5	24.6	24.8	23	22.9	23.2
# On a stone wall		14:30	26.3	27.6	27.7	25.9	26	25.8
	10-07-2023	11:00	26.1	25.1	25.2	24	23.6	24
		14:00	27.2	29.5	29.6	28.9	28	28.2
		17:00	24.1	25.5	25.3	25.4	25.7	25.5
	11-07-2023	11:30	24.5	23.3	23.6	22.5	22.7	23.1
		13:45	26.8	27.6	27.4	26.8	25.7	26
		17:00	26.5	29.3	29.4	29.4	28.8	28.6
	12-07-2023	11:30	26.5	26.3	26.7	25.1	24.3	24.6
		13:30	29.8	30.1	30.3	31.7	31.2	32
		17:15	25	28.5	27.9	27.3	27.7	27.3
	14-07-2023	11:45	25.7	26.3	26	26.2	25.3	25.6
		14:40	28.8	29.4	29.6	26.5	26.3	26.9
		16:30	29.2	29.4	29.5	29.1	28.6	28.7

Figure 39/NA-IMB DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
N B-BHL	03-02-2023	11:45	28.9	26.6	26.7	26.9	27
$ Category B nest	06-06-2023	10:59	29.4	26.3	26.8	26.2	26.2
$ Behind hydraulics Lab		14:00	30.6	27.3	27.6	27	27.2
$ On a wall opposite to N A-BHL		17:36	28.7	26.9	27.2	26.3	26.5
	08-06-2023	10:50	30.1	26	26.2	26.4	26.6
		14:00	28.3	26.9	27.2	26.1	26
		17:00	28.9	27.2	27.6	27.7	27.8
	12-06-2023	11:10	27.9	25.2	25.3	25.6	25.5
		14:00	29	25.8	26.1	26.6	26
		16:30	29.4	26.3	26.6	26.2	26.1
	14-06-2023	11:00	28.5	25.5	25.8	26.1	26.2
		14:00	29.6	26.4	26.9	26.8	26.7
		17:30	28.6	26.7	26.9	26.4	26.3
	16-06-2023	11:00	27.4	25.6	26	26	26.1
		13:00	30.5	26.7	27	26.1	26.3
		17:00	29.1	26.8	27	26.2	26.3

Figure 40/NB-BHL DATA

Nest	Date	Time	Ambient	Surface	Interior Hole 1
NB-ICDS					
# In a light post	12-06-2023	11:00	28	27.4	26.4
# situated in front of CDS Building		14:15	29.5	31.4	31
		16:15	31.2	32.9	30.9
	14-05-2023	11:00	28.5	28.2	26.9
		13:50	30.1	31.5	29.8
		17:30	29.2	31	29.9
	16-06-2023	11:00	28	28.5	27.2
		13:15	30.1	31.3	30.7
		17:00	30.5	33.4	30.6

Figure 41/NB-ICDS DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1
NB-IMB	07-07-2023	11:15	25.5	23.5	23.5	23.4
		14:30	26.3	25.9	26.1	25.4
	10-07-2023	11:10	26.1	23.9	24.2	23.1
		14:00	27.2	27.4	27	26.5
		17:00	24.1	24.3	23.8	24.2
	11-07-2023	11:30	24.5	22.5	22.6	22.7
		17:00	26.6	27.6	27.8	26.6
	12-07-2023	11:30	26.5	23.9	23.7	23
		13:45	30	26.8	27.1	30.1
		17:15	25	27	26.5	26.2
	14-07-2023	11:45	25.7	24.1	23.9	24.1
		14:46	29.3	26.4	26.8	26
		16:30	28.9	27.2	27.3	26.4

Figure 42/NB-IMB DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NB-IMB2	07-07-2023	11:30	25.5	24.6	24.2	24.3	24.1
# Located infront of main building		14:45	26.3	27	27.2	26	26.1
# In the stone wall							
# Surface = Stone	10-07-2023	11:20	26.1	26.1	25.8	24.1	24.3
		14:15	27.2	28.1	28.6	27.5	27.8
		17:00	24.1	24.8	24.6	24.6	24.7
	11-07-2023	11:30	24.5	23.5	23.2	23.3	23
		14:00	25.6	26.4	26.6	25.4	24.9
		17:20	26.8	28.3	28.7	27	26.7
	12-07-2023	11:30	27.5	26.2	25.9	25.5	25.4
		13:30	32.3	28.9	29	26.1	25.8
		17:30	24.8	28.1	28.5	27.4	28
	14-07-2023	11:50	28.3	26	25.8	23.8	24.1
		14:45	29.20	28.2	28.2	26.7	27
		16:40	29.2	28.5	28.8	27.4	28.1

Figure 43/NB-IMB2 DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NB-MBP							
	12-09-2023	10:35	28.5	27.5	26.9	26.3	25.9
# In the molecular biophysics building		14:20	30.1	31.5	30.7	29.3	29.1
# On a window glass		16:15	31	31.3	31.8	30.3	30.3
	14-06-2023	10:50	27.9	28.4	27.7	27.3	27.5
		13:45	30	30.9	31	28	28.1
		17:20	28.9	30.8	31.1	28.5	28.1
	16-06-2023	10:50	28.3	27.6	27.7	27.8	27.5
		13:20	30.1	30.8	30.8	29.6	29.5
		16:50	30.1	31	31.2	29.3	29.2

Figure 44/NB-MBP DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2	Interior Hole 3
NB-SP								
#Nest in the swimming pool area	12-07-2023	12:00	28.3	28.5	27.5	25.6	25	25.2
		17:40	25.2	25.5	25.4	24.3	24	24.5
	14-07-2023	11:30	25.3	27.1	27.2	25.7	25.5	25.8
		15:00	28.2	27.7	27.5	28.4	28.2	28.2
		17:00	26.8	26.8	27.1	26.6	26.4	26.5

Figure 45/NB-SP DATA

Inactive Nests:

Category C= Non active nests						
Nest	Date	Time	Ambient	Exterior	Interior Hole 1	Interior Hole 2
N C-BHL						
	03-06-2023	11:45	28.9	27.8	27.5	27.5
$ Category C nest	06-06-2023	11:03	29.4	27.5	27.3	27.4
$ Behind Hydraulics Lab		14:03	30.6	29.2	29.6	29.1
$ Hanging on a metal rope		17:33	28.7	27.9	27.2	26.9
	08-06-2023	10:47	30.1	27.2	27.2	27.1
		14:00	28.3	28.4	27	27
		17:00	28.9	28.7	28.8	29
	12-06-2023	11:00	27.9	26	26	25.9
		14:00	29	27	27.2	26.9
		16:30	29.4	27.8	27.9	28.1
	14-06-2023	11:00	28.5	26.3	26.4	26.7
		14:00	29.6	27.8	27.6	27.8
		17:30	28.7	27.5	27.1	27.3
	16-06-2023	11:00	27.4	26.6	26.7	26.5
		13:00	30.5	27.7	27.7	27.9
		17:00	29.1	28.1	27.4	27.3

Figure 46/NC-BHL DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NC-CE							
	12-06-2023	11:15	28	27.6	28.1	27.9	27.1
# In the civil engineering building		14:00	29.9	28.2	28.8	28.2	27.5
# hard nest		16:30	30.4	29.1	29.6	28.9	28.6
# exposed to Sun light							
# Surface: stone wall	14-06-2023	11:15	28.4	27.7	25	27.4	27.1
		14:15	31.1	28.8	29.5	29.5	28.4
		17:30	29.7	28.9	29.2	28.6	28.2
	16-06-2023	11:15	28.2	27.6	28.1	27.8	27.3
		13:00	30.8	28.7	29.3	27	27.2
		17:15	29.8	29.1	29.6	29.3	28.6

Figure 47/NC-CE DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
N C- ICSA							
	06-06-2023	14:30	32	28.7	28.2	27.2	26.9
In a building infront of CSA		17:45	28.6	27.2	26.6	26.6	26.8
attached to a PVC Pipe							
	08-06-2023	11:08	29.1	28.1	26.9	26.6	27.3
		14:20	29.4	29	27.7	26.4	26.8
		17:00	29.50	28.7	28	27.6	27.9
	12-06-2023	11:20	28.2	27.4	26	25.7	25.4
		14:00	28.9	28.1	26.6	26.8	26.3
		16:30	29.6	29	28.6	28	27.4

Figure 48/NC-ICSA DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
N C-IAP							
# infront of Instrumentation and applied physics building	08-06-2023	17:20	30	29.5	29.4	29	28.9
# on a rock wall							
	12-06-2023	11:25	28.3	25.1	25	24.8	25.1
		14:00	30.1	26.6	26.3	26.1	26.7
		16:45	30.3	27.2	27.4	27	27.5
	14-06-2023	11:30	28.5	26.2	26.1	25.7	25.6
		14:20	30.8	28.2	28.2	28	28.1
		17:45	29.9	28.5	28.6	27.6	27.8

Figure 49/NC-IAP DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1
NC-IMB	07-07-2023	11:10	25.5	23.9	24	23.7
		14:30	26.3	26.5	26.5	25.3
	10-07-2023	11:00	26.1	24.5	24.8	24.1
		14:00	27.1	28	27.7	26.9
		17:00	24.1	25.1	24.5	24.3
	11-07-2023	11:30	24.5	23	23.1	23.1
		13:30	26.3	26.1	26.3	25.1
		17:00	26.6	28	27.9	27
	12-07-2023	11:30	26.5	25	25.1	25
		13:30	29.2	27.8	27.6	30.8
		17:15	25	27	26.4	25.9
	14-07-2023	11:45	25.7	25	25.2	24.6
		14:45	28.8	27.5	27.5	25.8
		16:30	29.2	28.1	27.9	27.1

Figure 50/NC-IMB DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NC-IMB2	07-07-2023	11:20	25.5	24.2	24	24.3	24.1
# There are 2 nests adjacent to each other		14:45	26.3	26.2	26.3	25.7	25.5
# Both are non active							
	10-07-2023	11:15	26.1	24.8	25	24.8	24.5
		14:10	27.2	27.5	27.7	27.2	27.3
		17:00	24.1	24.9	24.8	24.7	24.5
	11-07-2023	11:30	24.5	23.2	23	23.5	23.1
		13:30	25	25.2	25.2	24.6	24.5
		17:00	26.6	27.7	27.5	26.6	27
	12-07-2023	11:30	26.1	25	25.2	25.3	24.9
		13:30	26.4	26.6	26.9	27	26.4
		17:30	24.8	26.7	26.6	26.3	25.7
	14-07-2023	12:00	28	25.2	25.4	26.3	26.1
		15:00	27.9	27.4	27.4	29.2	29.4
		16:45	27.7	27.6	27.5	27	26.7

Figure 51/NC-IMB2 DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NC-IMB3	07-07-2023	11:30	25.5	24.1	24.3	24.2	24.3
		14:45	26.3	27.2	27.4	26.3	26.1
	10-07-2023	11:20	26.1	26.2	26.4	24.6	24.4
		14:15	27.2	28.2	28.7	28.1	28
		17:00	24.1	25.5	25.2	25.1	24.9
	11-07-2023	11:40	24.5	23.6	23.3	23.1	23
		13:30	25.6	26.2	25.9	24.3	24.6
		17:15	26.8	28.4	27.8	26.3	27
	12-07-2023	11:30	27.5	26.8	26.5	26.2	26.1
		13:30	32.3	29.5	30.2	27.5	27.1
		17:30	24.8	28.5	28.5	26.6	28
	14-07-2023	11:50	28.3	26.4	26.1	25.7	25.1
		14:45	29.2	28.1	28.3	28	28.5
		16:45	29.2	28.9	29.2	27.9	28.1

Figure 52/NC-IMB3 DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NC-JNC							
# on tree branch	16-06-2023	10:30	28	25.4	25	26.2	26.4
# just opposite to JNC		13:30	31.2	29.8	33.6	31.5	31.8
		17:45	30.3	29.2	29.6	29	28.6

Figure 53/NC-JNC DATA

Nest	Date	Time	Ambient	Surface	Exterior	Interior Hole 1	Interior Hole 2
NC-MBP							
	12-06-2023	10:51	28.5	27.1	26.6	26.6	26
# In the Molecular biophysics building		14:20	30.1	30.5	30.2	29.2	28.9
# On a window frame		16:15	31	30.7	30.8	29.8	29.7
#Surface: Metal frame							
# Like a new nest but Abandoned	14-06-2023	10:50	27.9	27.5	27.4	28.1	27.7
		13:45	30	30.4	30.3	28.7	28.8
		17:20	28.9	30.5	30.4	28.3	28.7
	16-06-2023	10:50	28.3	27.7	27.6	27.8	27.7
		13:20	30.1	30.5	30.4	29.6	29.3
		16:50	30.1	30.9	31	28.3	28.4

Figure 54/NC-MBP DATA

Analysis;

Initially I classified my time interval of data collection in to 3,

1. **Time P: 10:30 AM to 11:45 AM**
2. **Time Q: 1:30 PM to 2:45 PM**
3. **Time R: 4:30 PM to 6:00 PM**

The mean of the interior holes' temperature was taken and incorporated to the table.

From basic excel techniques, the mean interior temperature of each nest was calculated and incorporated to the table 1 and table 2 mentioned in the next two pages.

Active Nests

Nest code	Time	Ambient temeprature	Surface	Exterior Temperature	Mean Interior Temperature
NA-BHL	Time P	29.4	26.8	27.1	25.95
		30.1	26.4	26.8	26.45
		27.9	25.5	25.8	25.8
		28.6	25.8	26	25.55
		27.4	25.9	26.2	25.95
	Time Q	30.6	27.8	28.2	26.1
		28.3	27.4	27.7	25.7
		29	26.2	26.4	25.75
		29.6	26.8	27.8	25.75
		30.5	26.7	27.2	27.3
	Time R	28.7	27.3	27.5	25.9
		28.9	27.6	28	26.05
		29.4	26.6	27	27.15
		28.7	26.7	27	25.85
		29.1	27	27.3	26
NB-NSO	Time P	28.2	26.8	27.3	26
		28.6	26.7	27.3	26.47
		29.6	27.7	28.1	26.5
	Time Q	29.5	27.6	28.5	25.6
		32	28	29	27.47
		29.8	28.3	29.1	27.07
	Time R	30.3	27.8	28.5	27.5
		30	27.7	28.4	27.4
		30.5	28.5	29	27.7
		24.6	23.7	23.6	24.07
NB-CSA	Time P	29.9	30.3	32.4	28.9
		30.3	30.7	32.4	29.2
		30.2	29.9	32	29.9
	Time Q	31.8	32.9	34.9	32.45
		30.8	32.1	34.5	30.95
	Time R	29	31.2	31.6	30.35
		30.7	32.5	33.3	31.95
NA-IMB	Time P	25.5	24.6	24.8	23.03
		26.1	25.1	25.2	23.87
		24.5	23.3	23.6	22.77
		26.5	26.3	26.7	24.67
		25.7	26.3	26	25.7
	Time Q	26.3	27.6	27.7	25.9
		27.2	29.5	29.6	28.37
		26.8	27.6	27.4	26.17
		29.8	30.1	30.3	31.63
		28.8	29.4	29.6	26.57
	Time R	24.1	25.5	25.3	25.53
		26.5	29.3	29.4	28.93
		25	28.5	27.9	27.43
		29.2	29.4	29.5	28.8
NB-BHL	Time P	28.9	26.6	26.7	26.95
		29.4	26.3	26.8	26.2
		30.1	26	26.2	26.5
		27.9	25.2	25.3	25.55
		28.5	25.5	25.8	26.15
		27.4	25.6	26	26.05
	Time Q	30.6	27.3	27.6	27.1
		28.3	26.9	27.2	26.05
		29	25.8	26.1	26.3
		29.6	26.4	26.9	26.75
		30.5	26.7	27	26.2
	Time R	28.7	26.9	27.2	26.4
		28.9	27.2	27.6	27.75
		29.4	26.3	26.6	26.15
		28.6	26.7	26.9	26.35
		29.1	26.8	27	26.25
NB-ICDS	Time P	28	27.4		26.4
		28.5	28.2		26.9
		28	28.5		27.2
	Time Q	29.5	31.4		31
		30.1	31.5		29.8
		30.1	31.3		30.7
	Time R	31.2	32.9		30.9
		29.2	31		29.9
		30.5	33.4		30.6

Inactive Nests

Nest code	Time	Ambient temeprature	Surface	Exterior Temperature	Mean Interior Temperature
NC-BHL	Time P	28.9		27.8	27.5
		29.4		27.5	27.35
		30.1		27.2	27.15
		27.9		26	25.95
		28.5		26.3	26.55
		27.4		26.6	26.6
	Time Q	30.6		29.2	29.35
		28.3		28.4	27
		29		27	27.05
		29.6		27.8	27.7
		30.5		27.7	27.8
	Time R	28.7		27.9	27.05
		28.9		28.7	28.9
		29.4		27.8	28
		28.7		27.5	27.2
		29.1		28.1	27.35
NC-CE	Time P	28	27.6	28.1	27.5
		28.4	27.7	25	27.25
		28.2	27.6	28.1	27.55
	Time Q	29.9	28.2	28.8	27.85
		31.1	28.8	29.5	28.95
		30.8	28.7	29.3	27.1
	Time R	30.4	29.1	29.6	28.75
		29.7	28.9	29.2	28.4
		29.8	29.1	29.6	28.95
NC-ICSA	Time P	29.1	28.1	26.9	26.95
		28.2	27.4	26	25.55
	Time Q	32	28.7	28.2	27.05
		29.4	29	27.7	26.6
		28.9	28.1	26.6	26.55
	Time R	28.6	27.2	26.6	26.7
		29.5	28.7	28	27.75
		29.6	29	28.6	27.7
NC-IMB3	Time P	25.5	24.1	24.3	24.25
		26.1	26.2	26.4	24.5
		24.5	23.6	23.3	23.05
		27.5	26.8	26.5	26.15
		28.3	26.4	26.1	25.4
	Time Q	26.3	27.2	27.4	26.2
		27.2	28.2	28.7	28.05
		25.6	26.2	25.9	24.45
		32.3	29.5	30.2	27.3
		29.2	28.1	28.3	28.25
	Time R	24.1	25.5	25.2	25
		26.8	28.4	27.8	26.65
		24.8	28.5	28.5	27.3
		29.2	28.9	29.2	28
NC-JNC	Time P	28	25.4	25	26.3
	Time Q	31.2	29.8	33.6	31.65
	Time R	30.3	29.2	29.6	28.8
NC-MBP	Time P	28.5	27.1	26.6	26.3
		27.9	27.5	27.4	27.9
		28.3	27.7	27.6	27.75
	Time Q	30.1	30.5	30.2	29.05
		30	30.4	30.3	28.75
		30.1	30.5	30.4	29.45
	Time R	31	30.7	30.8	29.75
		28.9	30.5	30.4	28.5
		30.1	30.9	31	28.35

Table 1

Active Nests					
NB-IMB	Time P	25.5	23.5	23.5	23.4
		26.1	23.9	24.2	23.1
		24.5	22.5	22.6	22.7
		26.5	23.9	23.7	23
		25.7	24.1	23.9	24.1
	Time Q	26.3	25.9	26.1	25.4
		27.2	27.4	27	26.5
		30	26.8	27.1	30.1
		29.3	26.4	26.8	26
	Time R	24.1	24.3	23.8	24.2
		26.6	27.6	27.8	26.6
		25	27	26.5	26.2
		28.9	27.2	27.3	26.4
NB-IMB2	Time P	25.5	24.6	24.2	24.1
		26.1	26.1	25.8	24.3
		24.5	23.5	23.2	23
		27.5	26.2	25.9	25.4
		28.3	26	25.8	24.1
	Time Q	26.3	27	27.2	26.1
		27.2	28.1	28.6	27.8
		25.6	26.4	26.6	24.9
		32.3	28.9	29	25.8
		29.20	28.2	28.2	27
	Time R	24.1	24.8	24.6	24.7
		26.8	28.3	28.7	26.7
		24.8	28.1	28.5	28
		29.2	28.5	28.8	28.1
NB-MBP	Time P	28.5	27.5	26.9	26.1
		27.9	28.4	27.7	27.4
		28.3	27.6	27.7	27.65
	Time Q	30.1	31.5	30.7	29.2
		30	30.9	31	28.05
		30.1	30.8	30.8	29.55
	Time R	31	31.3	31.8	30.3
		28.9	30.8	31.1	28.3
		30.1	31	31.2	29.25
NB-SP	Time P	28.3	28.5	27.5	25.27
		25.3	27.1	27.2	25.67
	Time Q	28.2	27.7	27.5	28.27
	Time R	25.2	25.5	25.4	24.27
		26.8	26.8	27.1	26.5

Inactive Nests					
NC-IAP	Time P	28.3	25.1	25	24.95
		28.5	26.2	26.1	25.65
	Time Q	30.1	26.6	26.3	26.4
		30.8	28.2	28.2	28.05
	Time R	30.3	27.2	27.4	27.25
		29.9	28.5	28.6	27.7
		30	29.5	29.4	28.95
NC-IMB	Time P	25.5	23.9	24	23.7
		26.1	24.5	24.8	24.1
		24.5	23	23.1	23.1
		26.5	25	25.1	25
		25.7	25	25.2	24.6
	Time Q	26.3	26.5	26.5	25.3
		27.1	28	27.7	26.9
		26.3	26.1	26.3	25.1
		29.2	27.8	27.6	30.8
		28.8	27.5	27.5	25.8
	Time R	24.1	25.1	24.5	24.3
		26.6	28	27.9	27
		25	27	26.4	25.9
		29.2	28.1	27.9	27.1
NC-IMB2	Time P	25.5	24.2	24	24.2
		26.1	24.8	25	24.65
		24.5	23.2	23	23.3
		26.1	25	25.2	25.1
		28	25.2	25.4	26.2
	Time Q	26.3	26.2	26.3	25.6
		27.2	27.5	27.7	27.25
		25	25.2	25.2	24.55
		26.4	26.6	26.9	26.7
		27.9	27.4	27.4	29.3
	Time R	24.1	24.9	24.8	24.6
		26.6	27.7	27.5	26.8
		24.8	26.7	26.6	26
		27.7	27.6	27.5	26.85

Table 2

 # Maximum and Minimum temperatures;

From the ambient, surface, exterior and mean interior temperature measurements, the maximum and minimum value of it is taken. These values are incorporated in a table and shown below;

Active Nests	*Inactive Nests*

Nest code @Time P	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NA-BHL	30.1	27.4	26.45	25.55
NB-NSO	29.6	28.2	26.5	26
NB-CSA	30.3	29.9	29.9	28.9
NA-IMB	26.5	23.3	25.7	22.77
NB-BHL	30.1	27.4	26.95	25.55
NB-ICDS	28.5	28	27.2	26.4
NB-IMB	26.5	24.5	24.1	22.7
NB-IMB2	28.3	24.5	25.4	23
NB-MBP	28.5	27.9	27.65	26.1
NB-SP	28.3	25.3	25.67	25.27

Nest code @Time Q	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NA-BHL	30.6	28.3	27.3	25.7
NB-NSO	32	29.5	27.47	25.6
NB-CSA	31.8	30.8	32.45	30.95
NA-IMB	29.8	27.6	31.63	25.9
NB-BHL	30.6	28.3	27.1	26.05
NB-ICDS	30.1	29.5	31	29.8
NB-IMB	30	26.3	30.1	25.4
NB-IMB2	32.3	25.6	27.8	24.9
NB-MBP	30.1	28.9	29.55	28.05
NB-SP	28.2	28.2	28.27	28.27

Nest code @Time R	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NA-BHL	29.4	28.7	27.15	25.85
NB-NSO	30.5	24.6	27.7	24.07
NB-CSA	30.7	29	31.95	30.35
NA-IMB	29.2	25.5	28.93	25.53
NB-BHL	29.4	28.6	27.75	26.15
NB-ICDS	31.2	29.2	30.9	29.9
NB-IMB	28.9	24.1	26.6	24.2
NB-IMB2	29.2	24.1	28.1	24.7
NB-MBP	31	28.9	30.3	28.3
NB-SP	26.8	25.2	26.5	24.27

Nest code @Time P	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NC-BHL	30.1	27.4	27.5	25.95
NC-CE	28.4	28	27.55	27.25
NC-ICSA	29.1	28.2	26.95	25.55
NC-IAP	28.5	28.3	25.65	24.95
NC-IMB	26.5	24.5	25	23.1
NC-IMB2	28	24.5	26.2	23.3
NC-IMB3	28.3	24.5	26.15	23.05
NC-MBP	28.5	27.9	27.9	26.3
NC-JNC	28	28	26.3	26.3

Nest code @Time Q	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NC-BHL	30.6	28.3	29.35	27
NC-CE	31.1	29.9	28.95	27.1
NC-ICSA	32	28.9	27.05	26.55
NC-IAP	30.8	30.1	28.05	26.4
NC-IMB	29.2	26.3	30.8	25.1
NC-IMB2	27.9	25	29.3	24.55
NC-IMB3	32.3	25.6	28.25	24.45
NC-MBP	30.5	30.4	29.45	28.75
NC-JNC	31.2	31.2	31.65	31.65

Nest code @Time R	Maximum Ambient Temperature	Minimum ambient temperature	Maximum Interior Temperature	Minimum Interior Temperature
NC-BHL	29.4	28.7	28.9	27.05
NC-CE	30.4	29.7	28.95	28.4
NC-ICSA	29.6	28.6	27.75	26.7
NC-IAP	30.3	29.9	28.95	27.25
NC-IMB	29.2	24.1	27.1	24.3
NC-IMB2	27.7	24.1	26.85	24.6
NC-IMB3	29.2	24.1	28	25
NC-MBP	30.9	30.5	29.75	28.35
NC-JNC	30.3	30.3	28.8	28.8

Table 3

The graph containing maximum ambient and maximum interior temperature is plotted (shown below) for each time (P, Q, R) and analysed;

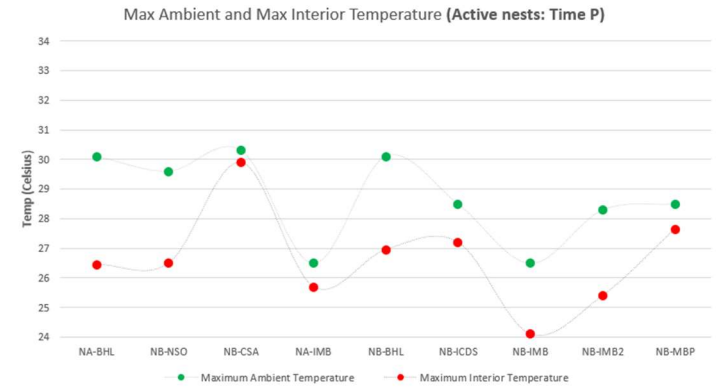
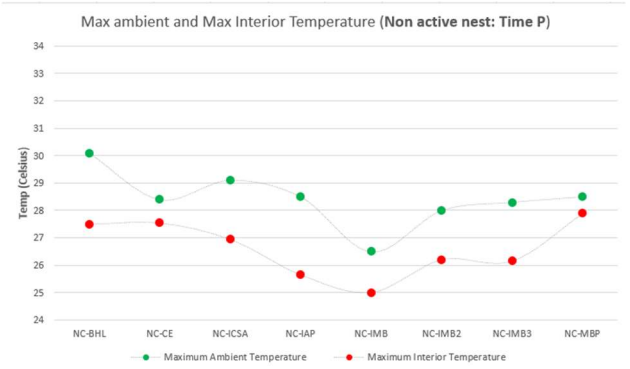
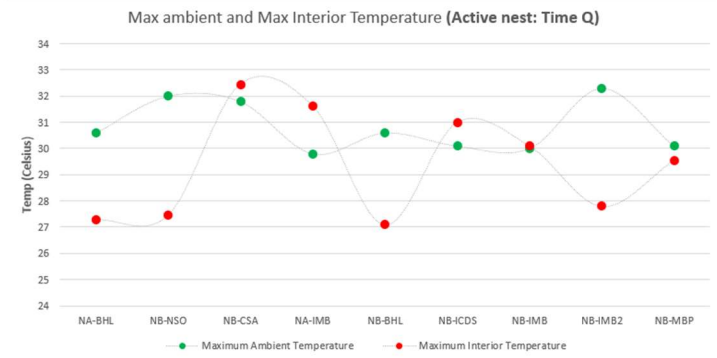
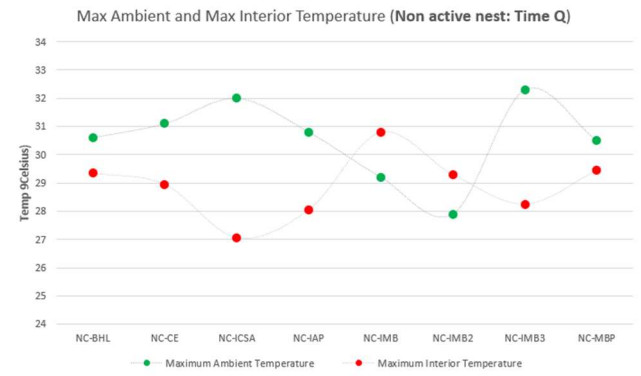
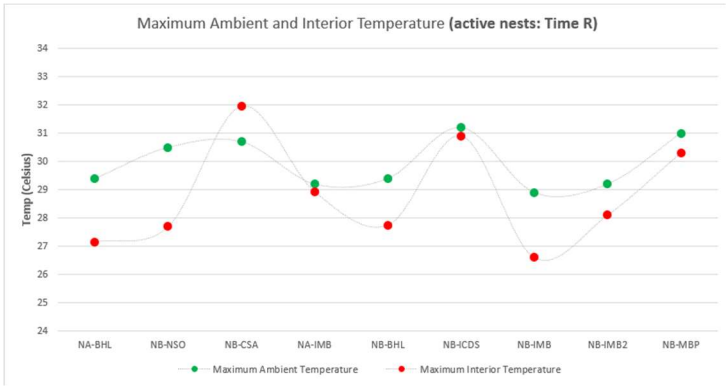
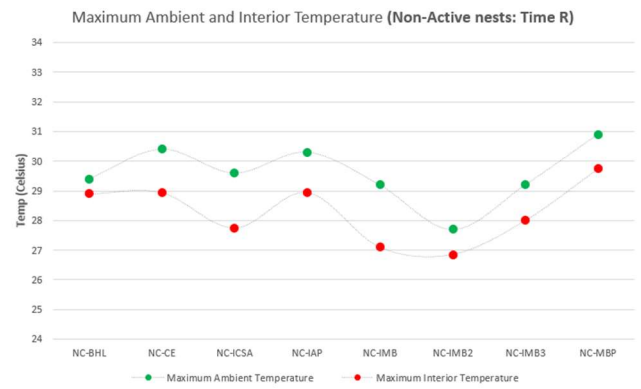
Active Nests	***Inactive Nests***
Time P 	Time P 
Time Q 	Time Q 
Time R 	Time R 

Table 4

From Table 4;

- we can infer that in the case of inactive nests, both maximum ambient temperature and maximum interior temperature follows a regular pattern apart from Time Q.
- The difference between maximum ambient and maximum interior temperature of each inactive nests is much smaller compared to active nests.
- In the case of active nests, during time P, Q and R, there are huge fluctuations in ambient and interior maximum temperature. In time R, for a small increase in maximum ambient temperature, there is huge increase in maximum interior temperature in respective active nests. This feature is unable to visualize in inactive nests.
- In active nests, there are more cases in which maximum interior temperature is greater than maximum ambient temperature compared to inactive nests.

Conclusion based on Table 4;
Interior temperature of inactive nests responds to ambient temperature normally with a regular pattern of ups and down with respect to ambient temperature but in active nests there are variation in the pattern. This may indicate that some level of thermoregulations happens in active nests whereas inactive nests change according to ambient temperature only.

The graph of active nest and inactive nests are modified with additional information (ups and downs bar) and plotted below,

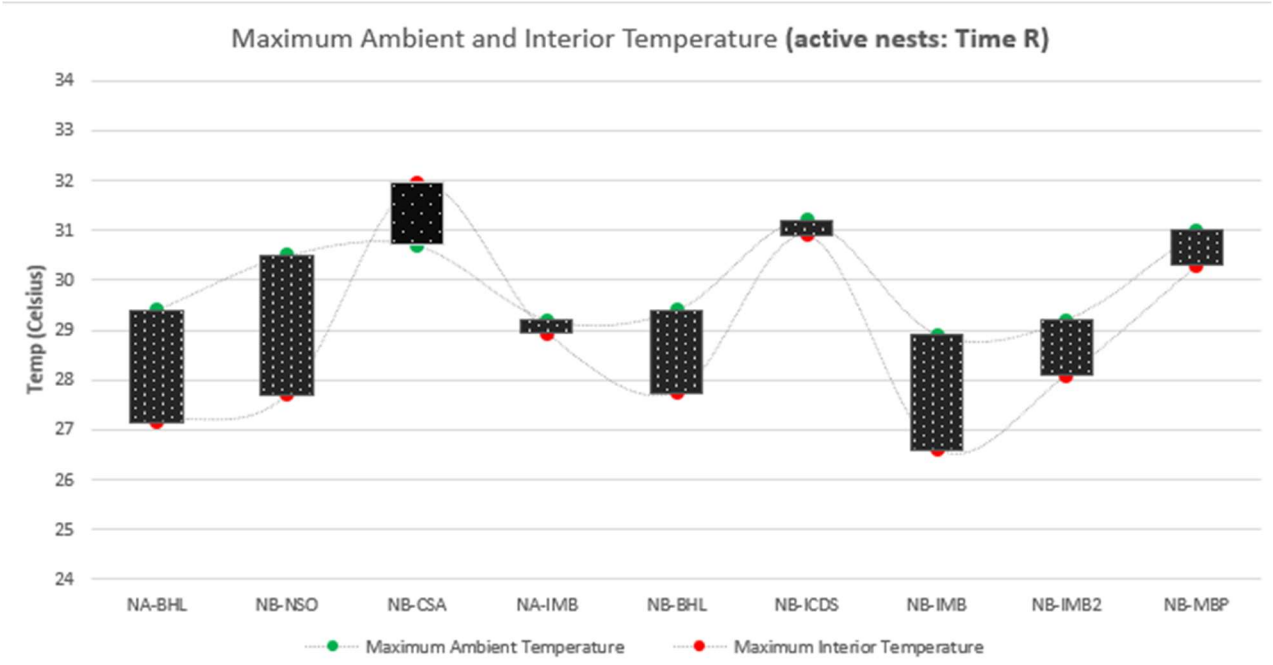


Figure 55

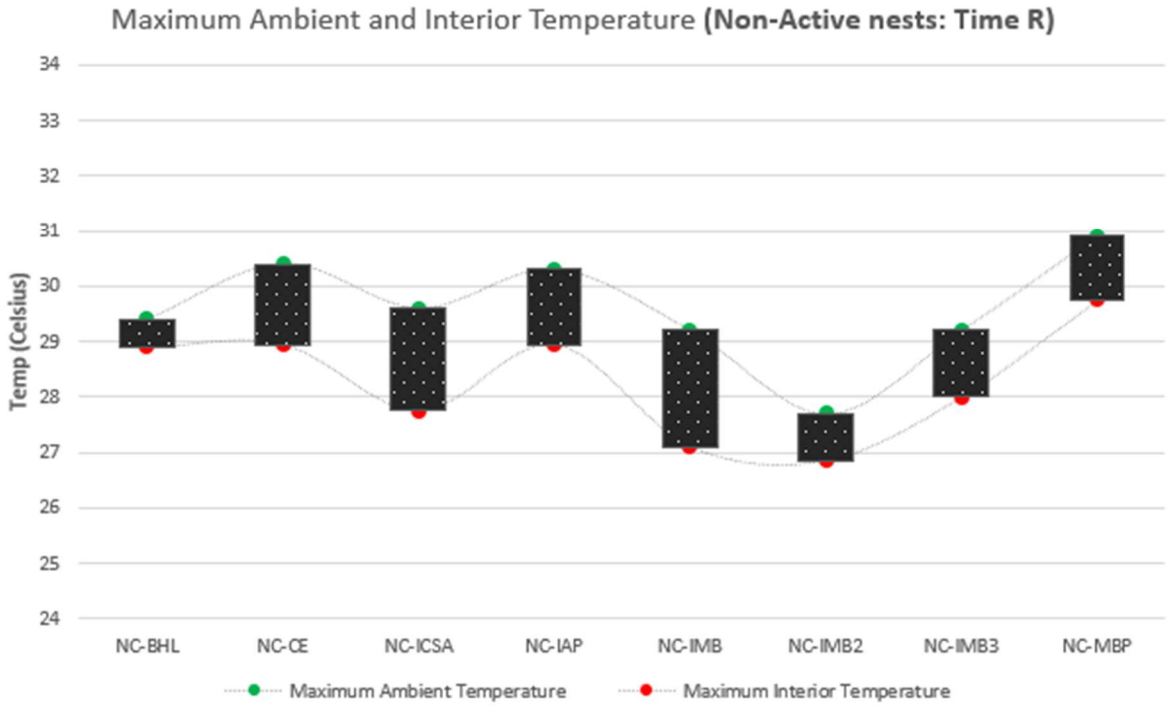


Figure 56

These graphs with ups and down bar give clearer picture about the variation in active and inactive nest's data. In figure 60, the up and down bar in each nest is different. In figure 56, shows more similar up and down bar. This definitely strengthen the assumptions about thermoregulations in active nests.

Looking at individual nest data;

1) **NA-BHL**
   Refer figure (Figure 45/NC-BHL DATA) for Temperature readings

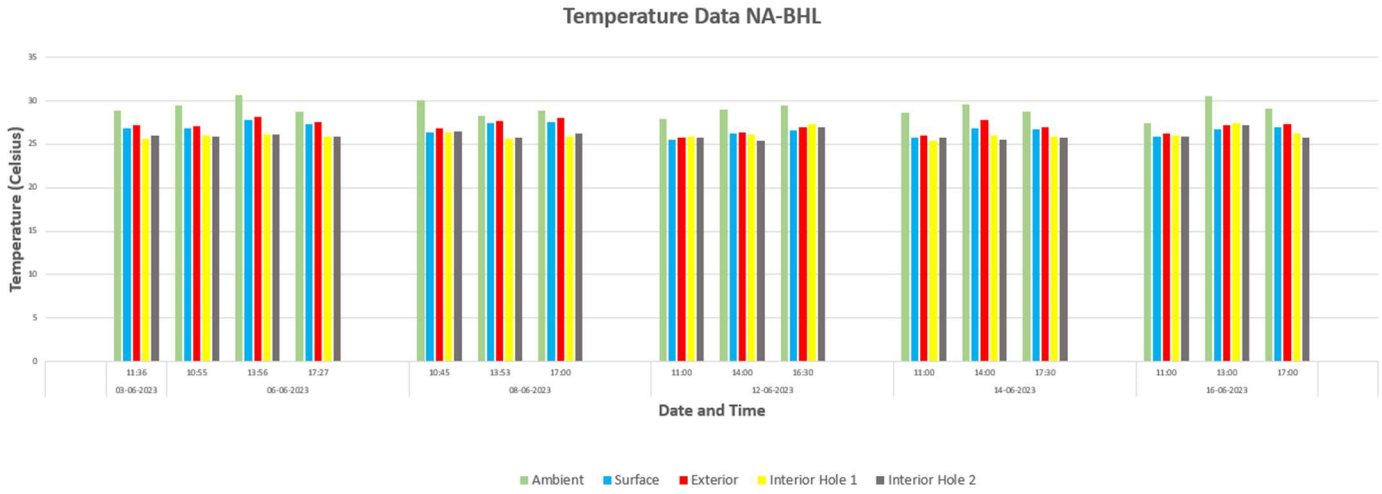


Figure 57

Some observations;

Here the yellow and grey bar indicate interior temperature of different holes within the nest NA-BHL. Almost every time both the yellow and grey bar keeps constant compared to the variation in ambient temperature.

Conclusion;

These active nests contain a thermoregulation within the nests.

2) **NA-BHL and NB-NSO active nests;**
   We can plot graph showing variation in mean ambient, mean surface, mean exterior and mean interior temperature during Time P, Q and R for each nest. The graphs are plotted below,

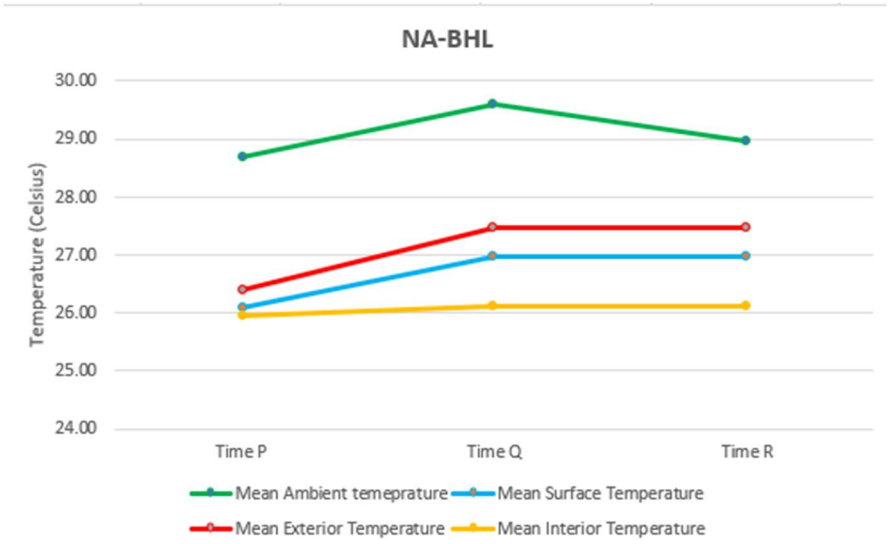
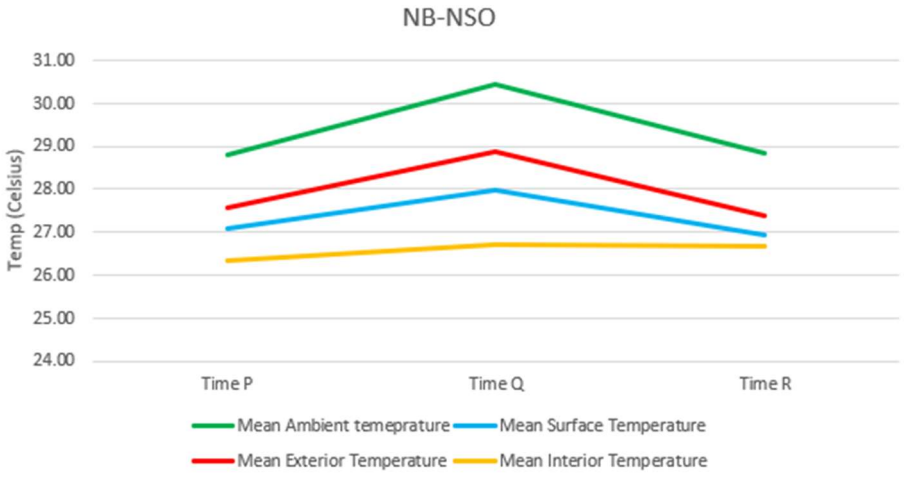


Figure 58

[Refer Table 2]

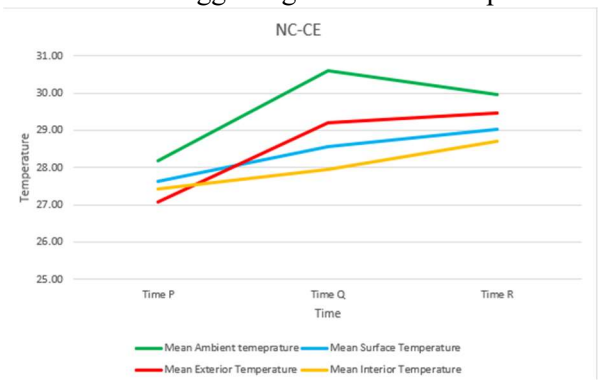


[Refer Table 2]

Figure 59

Inference and conclusion;

- In both these nests during time Q the mean ambient temperature increase and decreases as time R approaches. On the other hand, the mean interior temperature remains more constant.
- This indicate that Interior temperature of these active nests are constant compared to ambient and surface temperature.
- This shows thermoregulations inside active nests.
- Some graphs of inactive nests are also mentioned below. The above-mentioned trend can't be observed in inactive nests suggesting that active nest provide some thermoregulation.



[Refer Table2 for data table for particular nests]

Figure 60

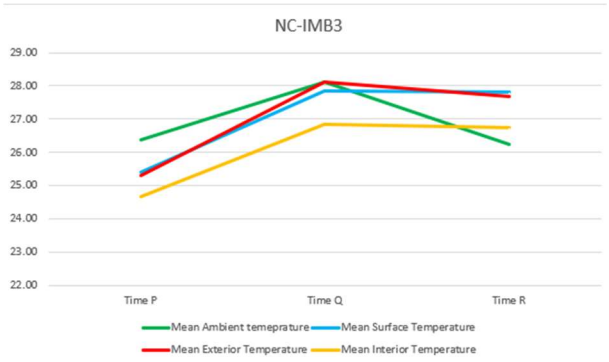


Figure 61

Discussions and Result;

The potter wasp constructs their nests in a spectacular way, most of them construct it in a pot shaped manner but throughout my observation, I noted that nest shape varies greatly depending on the surface and location. I was able to observe tubular shaped, round shaped, oval shaped, irregular and pot shaped nests.

Throughout my research into the temperature relations of active and inactive nests of potter wasps, I have come to a conclusive observation. It is evident from the graphs and analysis presented earlier that active nests respond differently to ambient temperature compared to inactive nests. This distinction in thermoregulation highlights the significance of nest activity in influencing temperature dynamics within the nests, potentially impacting the survival and development of the wasp larvae and other nest inhabitants.

I investigated the nesting location of these potter wasp nest and inferred from that, nesting location is also a main part of potter was, strategy to regulate its nest's interior temperature.

Below I will briefly point my whole observations throughout the field work;

- Potter wasp nest structure differed greatly from pot shaped too tubular shaped.
- Almost all nests are located in a shady region where it can't receive direct sunlight on it.
- In the case exposed nests, the outer surface is quite hard and can't be broken easily.
- Wasp is using different kind of soil materials to build the nests.
- From the graphical analysis: Temperature of inactive nests follows a regular and smooth pattern with respect to ambient temperature on the other hand temperature of active nests follows a curly and irregular path.
- The data analysed from individual nests also supports that active nest responds differently to temperature.
- Figure 55 and 56 provides more valuable information while comparing both active and inactive nests.

Results and conclusion;

- The regular smooth patterned curve in inactive nests may indicate that inactive nests respond to ambient temperature as similar to a mud vessel kept out in sunlight.
- The irregular curve in active nests indicate that some level of temperature regulation exists inside it.
- Result: **By comparing the responses of active and inactive nests to a temperature source, it becomes evident that they exhibit variation, suggesting the presence of thermoregulation mechanisms within active nests.**

Cluster Analysis and Scatter plot

Aim;

- To find whether there exists a relation between size of potter wasp nest and Interior temperature
- To do a cluster analysis and to construct a scatter plot

Theory;

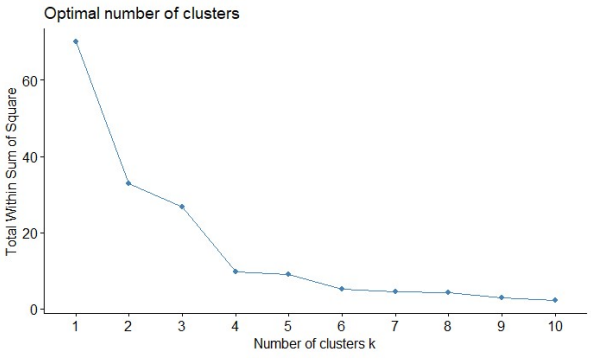
Cluster analysis is a data analysis method that investigate the naturally occurring groups within a data set known as clusters. There are different software and ways to perform a cluster analysis. R studio software is one of them. R studio is an integrated development surface for R (a programming language for statical computing, data analysis and graphical interpretation).

k means clustering is a method of cluster analysis that can be run with the help of R programming. In order to run the program, optimal numbers of cluster are necessary. While running the k means program, it will ask the user to specify the number of clusters k to be generated. The optimal number depends upon the different type of methods used. There are direct methods and statistical methods. Direct methods are further classified in to Elbow and silhouette method. On the other hand, gap statistic method is a statistical testing method. Further information regarding each method can be found from.

- Program Used: **R Studio**
- Testing method: Elbow, Silhouette and gap statistic methods.
- Date input for analysis: Mean interior temperature and ambient temperature of active and inactive nests during time R

Cluster Analysis for Active nest's data;

Results of Testing methods;



Elbow method: k=4

Figure 62/Elbow method active

Figure 63/ Silhouette active

Figure 64/ Silhouette active

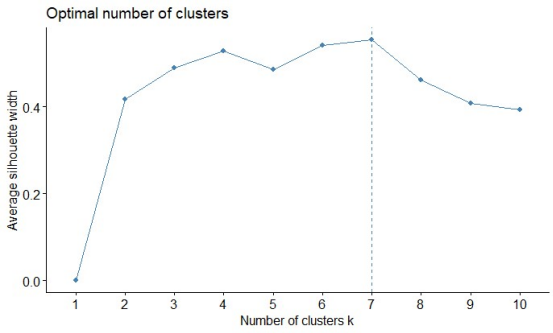


Figure 66/ Silhouette active

Silhouette method; k = 7

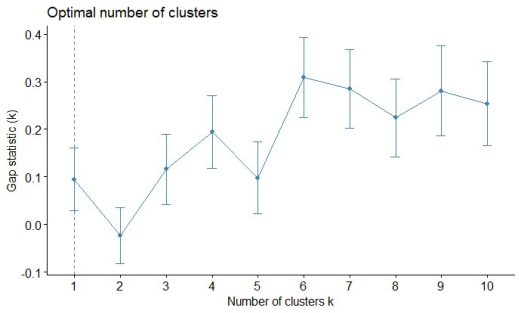


Figure 65/gap static active

Gap statistic method: k=1

Cluster plot based on Elbow method;

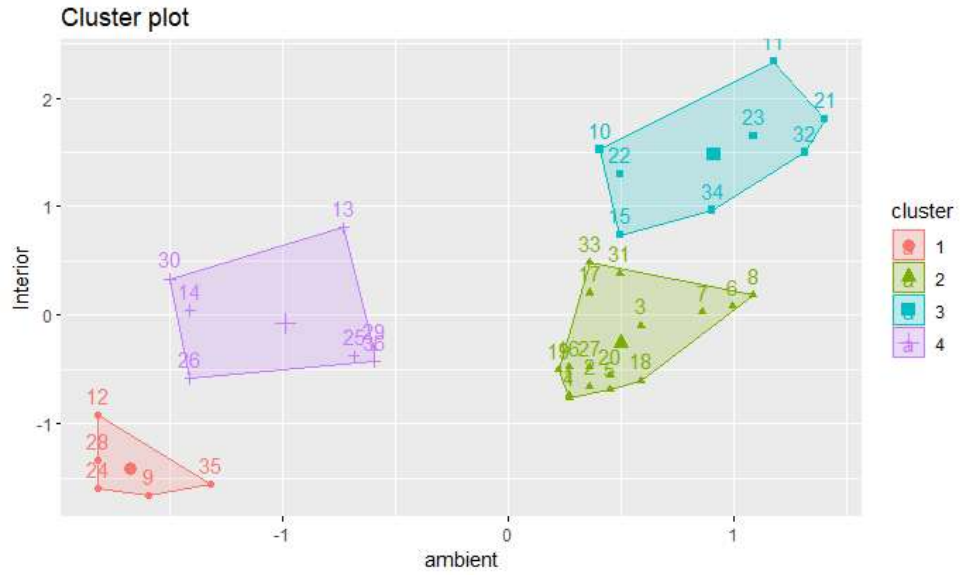


Figure 67/ cluster plot active1

Scatter plot based on Elbow method;

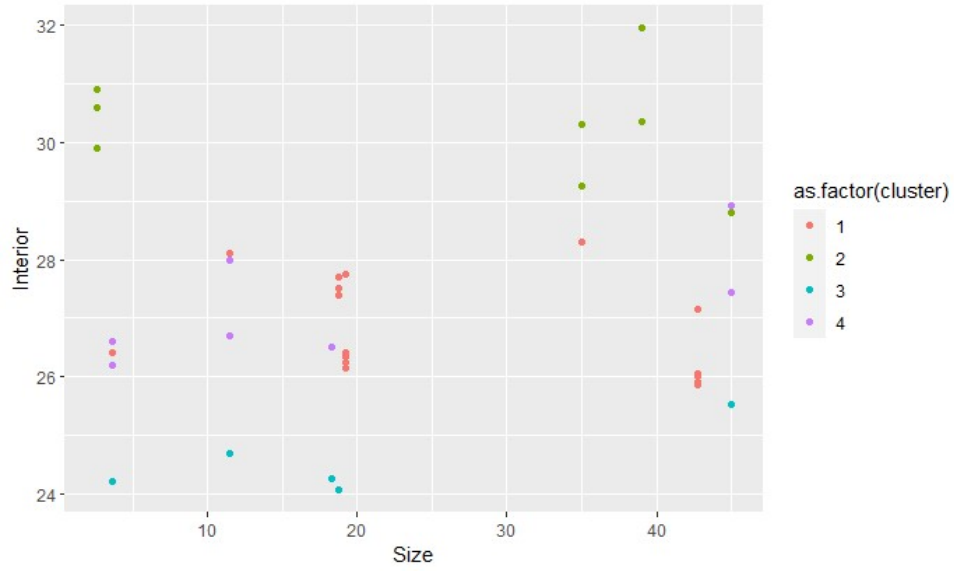


Figure 68/ scatter plot active

Cluster Analysis for Inactive nest's data;

Results of Testing methods;

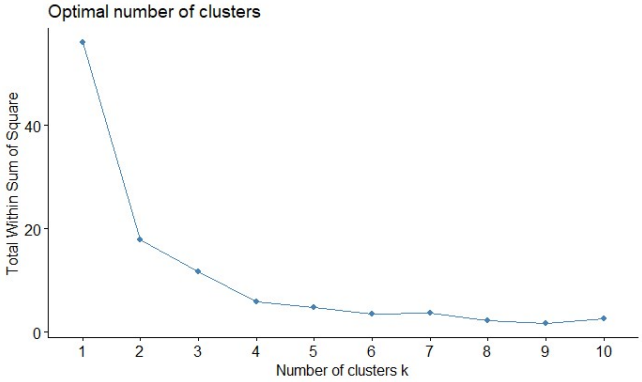


Figure 70/elbow inactive

k = 2

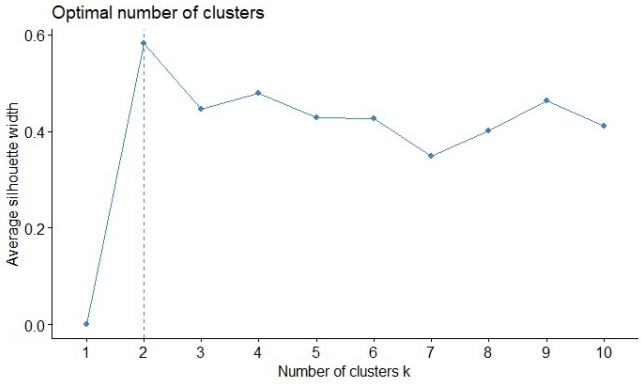


Figure 69/silhouette inactive

k = 2

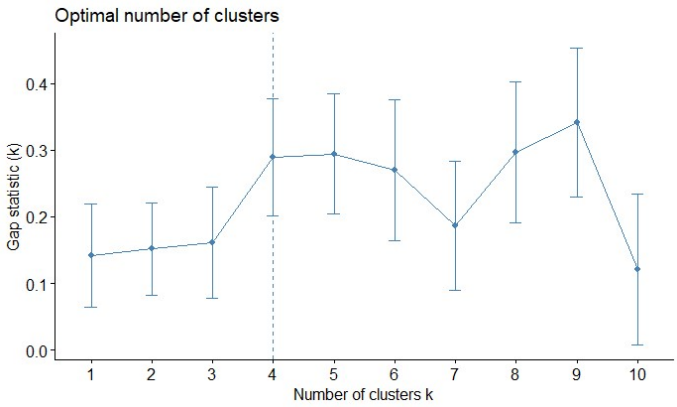


Figure 71/gap statistic inactive

k = 4

Cluster plot based on silhouette method (k=2);

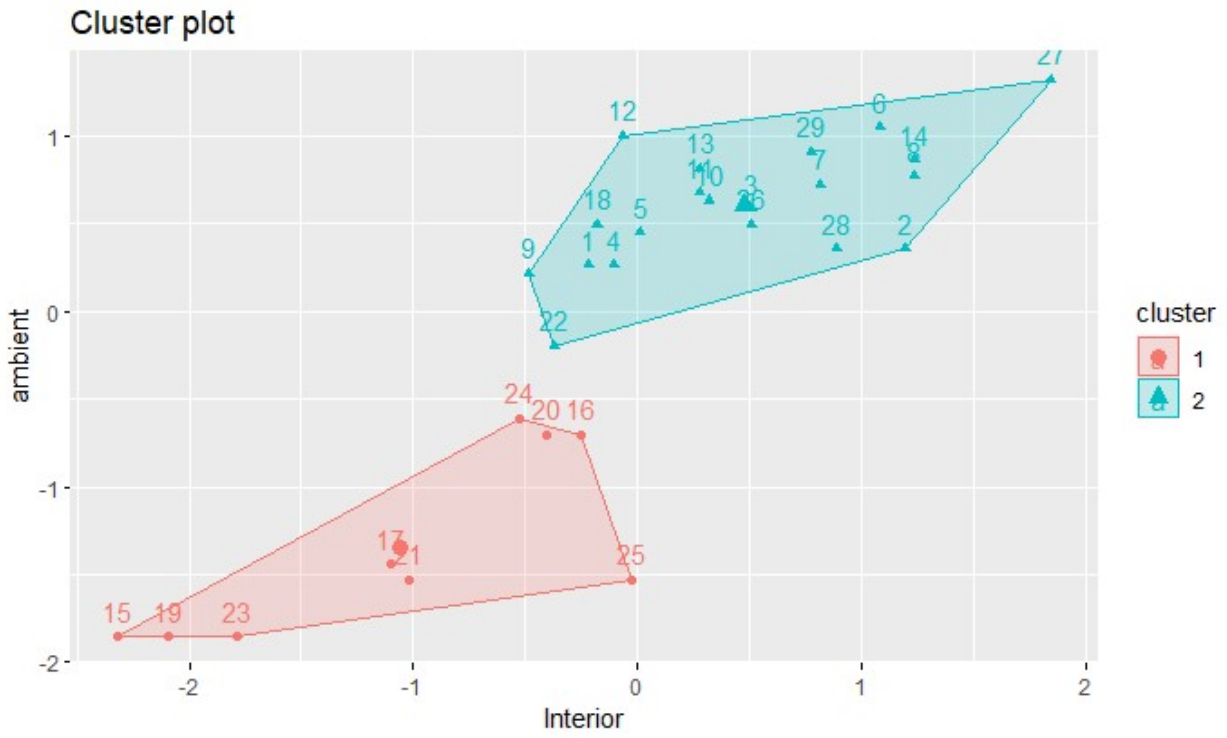


Figure 72/ cluster plot inactive 1

Cluster plot based on gap statistic method(k=4);

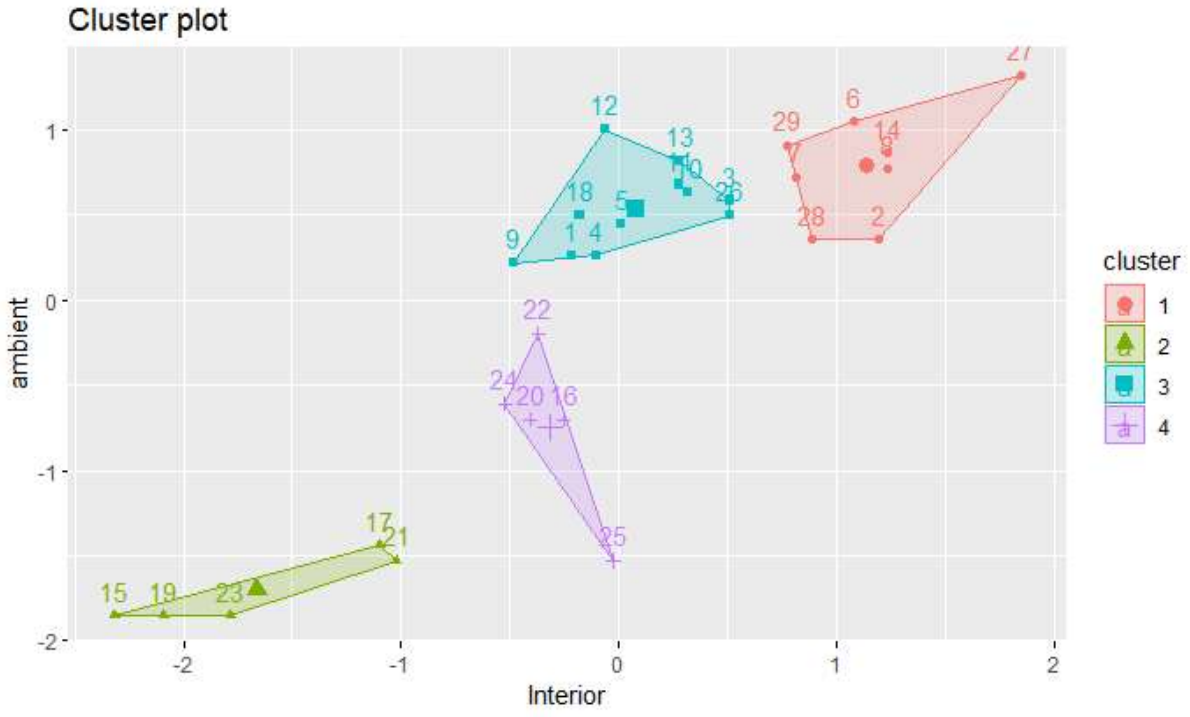


Figure 73/ cluster plot inactive 2

Scatter plot based on silhouette method (k=2);

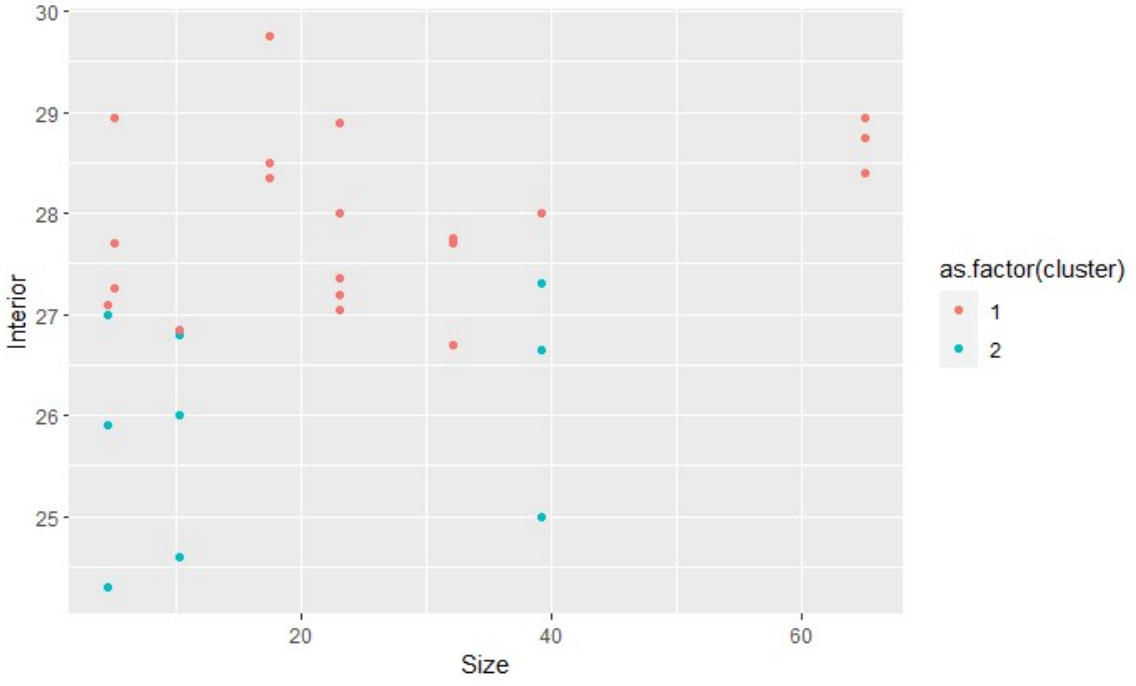


Figure 74/ scatter plot inactive 1

Scatter plot based on statistic method (k=4);

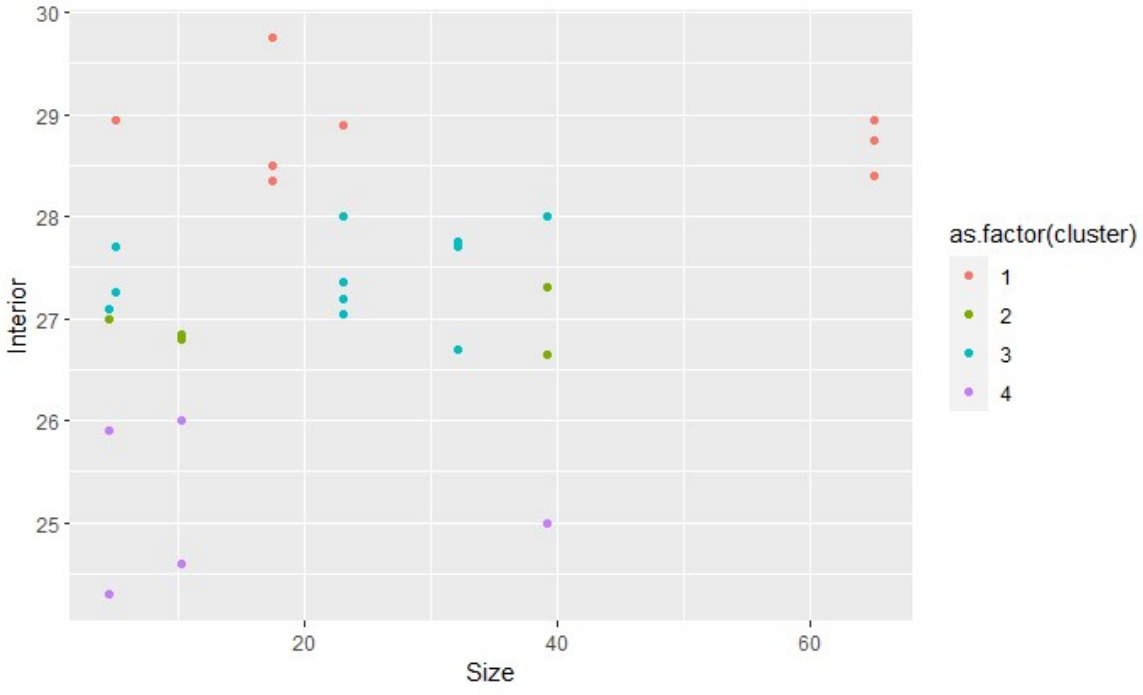


Figure 75/ scatter plot inactive 2

Discussion and conclusion:

My hypothesis was there are some correlations between size of nests and its temperature variation.

From the cluster analysis and scatter plot we can observe that;

- In the case of active nests: Even though there are 4 clusters observed but from the scatter plot we can't point out any relation between size and interior temperature of active nests. Refer figures mentioned above (Figure 67/ cluster plot active1, Figure 68/ scatter plot active)
- In the case of inactive nests: Clusters are made using silhouette and gap statistic method but can't withdraw and relations from the scatter plot mentioned above (Figure 74/ scatter plot inactive 1, Figure 75/ scatter plot inactive 2)

- The cluster plots for active and inactive nests were made and analysed but a perfect cluster can't be plotted.
- I am not able to state or confirm any relation between the size and its interior temperature.

Nest construction by *Phimenes* sp.

Overview;

I was able to observe the process of nest construction by *Phimenes* sp. It constructed the nest behind a cement wall. It collected water and mud from nearby spaces and during this time I measured the time it took to collect the mud and water. Using Bio render application, I created a pictorial representation of it.

The wasp and the Nest (NA-BHL);

These images are taken from my Mobile camera (Nokia 5.4), In this the wasp and the nest are clearly visible. One thing to note is that it had constructed some sort of outer covering.

Figure 77/NA-BHL(a) construction

Figure 76/NA-BHL (b) construction

Mud and Water collecting spot;

The wasp was collecting water from a spot where some water was dripping from the terrace to the floor. This spot was around 1.5 metres from the nest.

The wasp collect mud from a region around 2 metres far away from the nest.

Figure 79/NA-BHL water

Figure 78/ NA-BHL mud

Time Required;

Using a time recording device, I recorded the time required to collect water, mud and time taken for construction by the wasp. The data are given below,

Number of Observations	Time taken to collect mud and water (Seconds)	Time for construction (Seconds)
1	1.05	1.31
2	1.36	1.38
3	1.55	1.27
4	2.02	1.12
5	1.4	1.36
6	1.16	1.07
7	1.31	1.34
Average =	**1.41**	**1.26**

[Average time taken by the wasp is clearly mentioned in the given table]

Figure 80/ NA-BHL construction Time

Pictorial Representation;

Pictorial Representation of Nest Construction by *Phimenes*

Step I: Wasp collects water from water source

Step II: After collecting water, it moves to collect soil

Step III: Wasp moves towards the nest location with Boluses (Soil water mixture) …Then the cycle repeats.

Double Layered outer covering

Introduction;

From my observation and analysis, normally potter wasp makes only single layered outer covering nests. But I happened to observe two nests built by wasp having an extra outer covering.

Case 1: Nest Built by *Phimenes* sp.;

Nest code: **NA-BHL**

On **02-06-2023** I observed a *Phimenes* sp. wasp building a nest behind the wall of Hydraulics lab. Initially it was a normal nest but as it builds, I observed that it is trying to build an outer covering. Images of these phases are shown below,

Figure 83/NA-BHL (a) 02-06

Figure 82/NA-BHL (b) 02-06

Figure 81/NA-BHL (c) 02-06

On **03-06-2023**, The outer extra covering was almost closed;

Figure 84/ NA-BHL 03-06

On **06-06-2023**, The extra outer covering was completely closed;

Figure 85/NA-BHL 06-06

Strength of Extra outer covering;

The extra outer covering was very weak and quite fragile. On 07-06-2023, While I was making a hole in order to record the interior temperature, some part of the layer got damaged.

But interestingly, the wasp did not try to repair the whole layer.

In the Image below, the wasp repaired the hole I created but it left the damaged part as it was.

Figure 86/NA-BHL 08-06

Case 2: Looks like an abandoned nest;

Nest code: **NC-IMB**

There was a nest near Main building of IISc campus. Its looked like abandoned but the strange thing was that, there was evidences that the potter wasp tried making an extra outer layer. Normally in this type of nests (Pot shaped), the wasp usually covers just the top entry part but this case somewhat different. Image is attached below;

Figure 87/NC-IMB 06-07

Inferences and Assumptions;

- From these cases it can be stated that potter wasp tries to make an extra outer layer above the nests.
- Purpose of outer covering (Assumptions):
    1. Thermoregulation of nests
    2. Protection from parasitoid attack and other danger
- *Further research might be required in order uncoil this mystery!*

Nests Around IISc campus

Si No.	Image	Location	Dimension	More Info
1		# In CSA building https://maps.app.goo.gl/4fEGnBptkhxgLj8x8	6.5 x 6 x 2.1	# Nest code: **NB-CSA** #Attached on bottom surface of a window #Shape: Irregular #Closed and active #Different type of mud materials #Exposed surfaces
2		# Behind Hydraulics lab https://maps.app.goo.gl/S8D8PDNAfqMotbCq8	9.5 x 4.5 x 1.5	#Nest code : **NA-BHL** #Attached on a cement wall behind Hydraulics Lab #Shape: Elongated tubular #Closed and active nest #Double layered covering #Different type of mud
3		# In campus book house https://maps.app.goo.gl/eXT7W3uvmTFUhrEU7	7.5 x 2 x 2.5	#Nest code**: NB-NSO** #Surface: cement surface #Located on top of a window #Shape: Multitubular #One single hole present #Others closed and active

Si No.	Image	Location	Dimension	More Info
4		# In front of Main building https://goo.gl/maps/3jk1pkypXREfLJR4A	9 x 5 x 2.8	# Nest code: **NA-IMB** # Shape: Oval or irregular # Surface: Stone wall # Closed and active # presence of Ants (Parasitoids)
5		# In front of Main building https://goo.gl/maps/BPuGt2xr1ucQ1bNC9	1.8 x 2 x 1.4	# Nest code: **NB-IMB** # Shape: Pot # Surface: Stone wall # Closed and active
6		# In front of Main building https://goo.gl/maps/2xhVPTF2hc6ecknS8	5 x 2.3 x 1.5	# Nest code: **NB-IMB2** # Shape: Pot # Surface: Stone wall # 2 adjacent pot shaped nest # One inactive and single hole # Another one is active and closed
7		# In front of Main building https://goo.gl/maps/qxYfZcQ8L1yBD3fA6	2 x 2.2 x 1.3	# Nest code: **NC-IMB** # Shape: Pot # Surface: Stone wall # Looks like abandoned # Pot shaped with extra layer covering # 1 hole

Si No.	Image	Location	Dimension	More Info
8		# In Molecular biophysics building https://maps.app.goo.gl/mKqG4YUmGQabw7PPA	7 x 5 x 1.3	#Nest code: **NB-MBP** #Shape: Bow shaped #Surface: Window glass #One single hole present #Different materials on surface # Some part active
9		# In civil engineering building https://maps.app.goo.gl/9be2P6L9wfUiBQLw6	10 x 6.5 x 1.7	#Nest code: **NC-CE** #Shape: Wide and oval shaped #Surface: Stone wall #8 Holes #Top surface is very hard to break #inactive
10		# In Molecular biophysics building https://maps.app.goo.gl/mKqG4YUmGQabw7PPA	6.5 x 2.7 x 2	#Nest code: **NC-MBP** #Shape: Elongated tubular #Surface: Metal frame #Single hole #3 small holes can be seen #Looks like abondoned # inactive
11		# Near Instrumentation and applied physics building https://maps.app.goo.gl/R8DT2awjhjqjdpE79	3.4 x 1.5 x 1	#Nest code: **NC-IAP** #Shape: Pot #Surface: Stone wall #One hole # inactive

Si No.	Image	Location	Dimension	More Info
12		# Near hydraulics lab https://maps.app.goo.gl/F3RcBJDazCiAQLET8	2 x 1.3 x 0.5	#Nest code: **NB-ICDS** #Shape: Pot #Surface: Plastic surface #One hole #White coloured material present #In a light post #Active
13		# Near hydraulics lab https://maps.app.goo.gl/S8D8PDNAfqMotbCq8	6 x 3.2 x 2	#Nest code: **NB-BHL** #Shape: Oval shape #Surface: Cement surface #Attached on a wall behind hydraulics lab #Dark coloured substance present #Active
14		# Near hydraulics lab https://maps.app.goo.gl/S8D8PDNAfqMotbCq8	7 x 3.2 x 3.3	#Nest code: **NC-BHL** #Shape: Oval #Surface: Hanged on a metal wire #5 holes # inactive
15		# Near organic chemistry building https://goo.gl/maps/1xrY8wSDPUCCyLjP9		# Nest code: **NA-OCB** # Shape: Irregular # 3 holes # inactive

Si No.	Image	Location	Dimension	More Info
16		# In front of Main building https://goo.gl/maps/J7xmY3wVrjqNwbsg9	4.5 x 2.3 x 1.5	# Nest code: **NC-IMB2** # Shape : Pot # Surface: Stone wall # 2 adjacent pot shaped with one hole on each nest
17		# In front of Main building https://goo.gl/maps/dC3UxgtoYHJsb6KTA	11.2 x 3.5 x 2	# Nest code: NC-IMB3 # Shape : Irregular # Surface: Stone wall # 5 Holes observed # There is a pot shaped nest situated middle of the big nest # inactive
18		# In front of Main building https://goo.gl/maps/3ANiCBrfsMDXkty97		# Shape: Irregular # Surface: Stone wall # Multiple holes # Dark coloured substance all over the exterior part. # inactive

Si No.	Image	Location	Dimension	More Info
19		# In Neuroscience building https://goo.gl/maps/DU9tTHT6xnKF5Ajo8	Unable to access	# Shape : Irregular # Number of holes : 4 # inactive
20		# In Neuroscience building https://goo.gl/maps/DU9tTHT6xnKF5Ajo8	Unable to access	# Shape : Irregular # Many holes # inactive
21		# Behind CSA building https://goo.gl/maps/upvaoRx5LbXq6QJz8	Unable to access	# Shape : Tubular # Number of holes : 3 # inactive # At a certain height
22		# Near JNC https://goo.gl/maps/BXqivERofcCApuau9		# Nest code: NC-JNC # Shape: Irregular # Number of holes: 4 # Surface : Tiny Tree branch # Well exposed to sunlight # inactive # Plant:

Si No.	Image	Location	Dimension	More Info
23		# In main building https://goo.gl/maps/DMNrZQf7Jnz8nJCq5	Unable to access	# Shape: Irregular # Multiple small holes can be seen # Surface: Stone wall # Situated at a height attached to main building wall # Huge size compared to others
24		# In main building https://goo.gl/maps/DMNrZQf7Jnz8nJCq5	Unable to access	# Shape: more like tubular # Multiple small holes can be seen # Surface: Stone wall # Situated at a height attached to main building wall # Huge size compared to others
25		# In main building https://goo.gl/maps/DMNrZQf7Jnz8nJCq5	Unable to access	# Shape: Irregular # Multiple small holes can be seen # Surface: Stone wall # Situated at a height attached to main building wall # Huge size compared to others

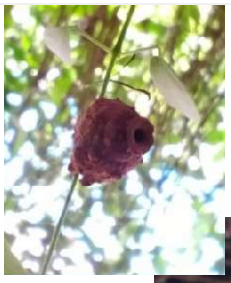
Si No.	Image	Location	Dimension	More Info
26		# Behind Civil engineering building https://goo.gl/maps/3gxoeAupWsZq8ipm6	Unable to access	# Shape: Tubular # Surface: Wooden window surface(Brown colour) # Multi tubular structures # 10 chambers # 6 are open and inactive # 4 of them are closed and Active # Situated at a certain height
27		# Behind Civil engineering building https://goo.gl/maps/3gxoeAupWsZq8ipm6	Unable to access	# Shape : Tubular # Surface: Stone wall # 3 chambers or tube structure # All closed and active # Situated at a certain height
28		# Behind Civil engineering building https://goo.gl/maps/3gxoeAupWsZq8ipm6	Unable to access	# Shape : Tubular # Surface: Stone wall # 4 chambers or tube structure # All closed and active # Situated at a certain height

Si No.	Image	Location	Dimension	More Info
29		# Behind Civil engineering building https://goo.gl/maps/3gxoeAupWsZq8ipm6	Unable to access	# Shape : Irregular # Surface: Stone wall # 1 hole can be seen # At a certain height
30		# Behind Civil engineering building https://goo.gl/maps/3gxoeAupWsZq8ipm6	Unable to access	# Shape : Tube # Surface: Stone wall and wood surface # 1 chamber # 1 hole can be seen # At a certain height
31		# Near Main building		# Shape: Pot # Surface: Stone wall # inactive

Si No.	Image	Location	Dimension	More Info
32		# In magnetic materials and switches building https://goo.gl/maps/PF5PTTk5hBL47v7Q6		# Shape: Tubular # Surface; Cement wall # Number of holes : 2 # Not sure about activity
33		# In electrical engineering https://goo.gl/maps/DU9tTHT6xnKF5Ajo8		# Shape: Spiral # Surface; Cement wall # Number of holes : 4 # Not sure about activity
34		# In electrical engineering https://goo.gl/maps/hxpXgFrS3jM7yPTF9		# Shape: Tubular # Surface; Cement wall # Number of holes : 1 # Active

Si No.	Image	Location	Dimension	More Info
35		# In magnetic materials and switches building https://goo.gl/maps/PF5PTTk5hBL47v7Q6		# Shape: Multi tubular # Surface: Cement wall # inactive
36		# In hydraulics Lab https://goo.gl/maps/nvX3C5GJwAU55Q7d6	Unable to access	***# Shape : Pot*** ***# Surface: Window side*** ***# 1 hole*** ***# inactive***
37		# Near to CSA https://maps.app.goo.gl/S8UytUtKxUZwsvru9	14 x 2.3 x 2.2	#Nest code: **NC-ICSA** #Shape: Elongated tubular #Surface: PVC Pipe #4 Holes
39		#Behind CSA https://goo.gl/maps/upvaoRx5LbXq6QJz8	Unable to access	# Shape : Tubular, pot (Top side) # Surface: Pipe # Closed and active # At a certain height # Top part contain a pot shaped nest
40		#In CSA https://goo.gl/maps/CLHezzBixjAsP32v8	Unable to access	# Shape: Tubular # Old nest # Surface: Window frame # White colured substance present

Si No.	Image	Location	Dimension	More Info
41		#Behind CSA https://goo.gl/maps/CLHezzBixjAsP32v8	Unable to access	# Shape: Tubular and L shape # Old nest # Surface: Window frame # White colured substance present
42		# In magnetic materials and switches building https://goo.gl/maps/PF5PTTk5hBL47v7Q6	Unable to access	# Shape: Pot # Active nest # Surface: Cement wall # Different material on surface # Well hidden from sunlight
43		# In materials engineering building https://goo.gl/maps/nkRjUsFedNE1fmND7	Unable to access	# Shape: Round # Surface: Stone wall # Closed and active # At a certain height
44		# In materials engineering building https://goo.gl/maps/nkRjUsFedNE1fmND7	Unable to access	# Shape: Round # Surface: Stone wall # Closed and active # At a certain height
45		# In neuroscience building	Unable to access	# Shape: Irregular # Surface: Stone wall # Old nest and damaged # inactive # Many chambers

Si No.	Image	Location	Dimension	More Info
46		# Inside swimming pool area https://goo.gl/maps/BUHY5sRU8Fr7sCQk7	***4.7 x 3.9 x 2.3***	# Nest code: **NB-SP** # Shape: Irregular, Pot # Surface: Brick wall wall # Closed and Active # Exposed
47		# Inside swimming pool area https://goo.gl/maps/rPe6Phd6TgG9Ueo69	***2 x 1.5 x 1.3***	# Shape: Pot # Surface: Rusted metal surface # Looks like abandoned # inactive
48	 	# Inside swimming pool area https://goo.gl/maps/rPe6Phd6TgG9Ueo69		# Shape: Pot # Surface: Plant thin stem # Looks like abandoned # inactive # Hanging on a plant
49		# Main building area https://goo.gl/maps/Ub2jGsJRba76uTBU8		# Shape: Irregular tubes # Surface: Tree branch # Tree : *Araucaria cookie* # Looks like abandoned # inactive # Hanging on a Tree # Number of holes: 4

Si No.	Image	Location	Dimension	More Info
50				# Shape: Tubular # Surface: Stone wall # Old nest and damaged # inactive # Around 7 chambers
51		# In magnetic materials and switches building https://goo.gl/maps/PF5PTTk5hBL47v7Q6		# Shape: Pot # Active nest # Surface: Cement wall # Different material on surface # Well hidden from sunlight
52		# In magnetic materials and switches building https://goo.gl/maps/PF5PTTk5hBL47v7Q6		# Shape: Oval # Surface: Metal window frame # Old nest # inactive # Number of holes: 2
53			Damged	# Shape: Tubular # Surface: Wooden window frame # Old nest and damaged # inactive # 6 chambers

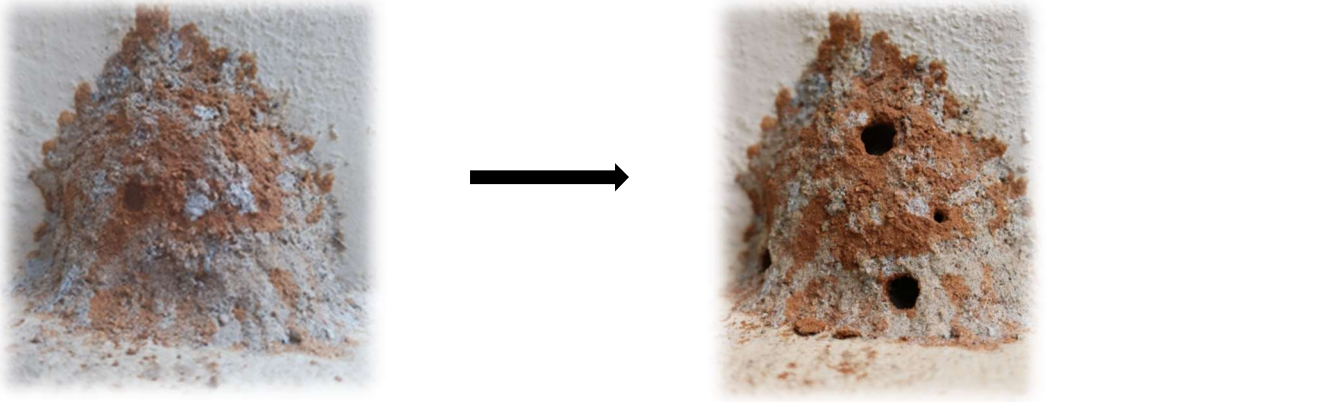
The above table contain various nest around IISc campus. Most of the nests are captured using **EOS 750 D Canon camera (Lab camera)** and Nest number 1,2,15,18,31,33,34,35,36,46,47,48,49,50,52 and 53 are captured using **Nokia 5.4 (Mobile camera)**.

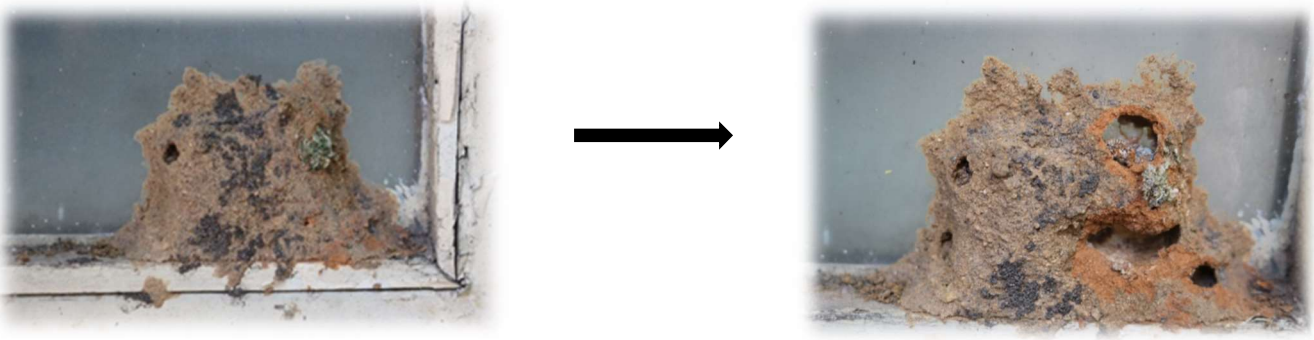
More Images

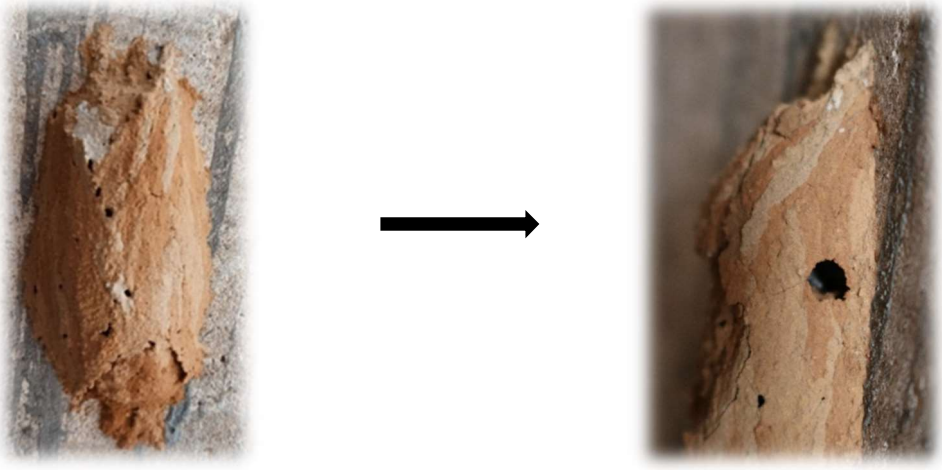
Nests before and after;

Here I am attaching some photos of nests: Which was once active but now wasp emerged out;

(The number of emergence holes can be visualized from these photographs)

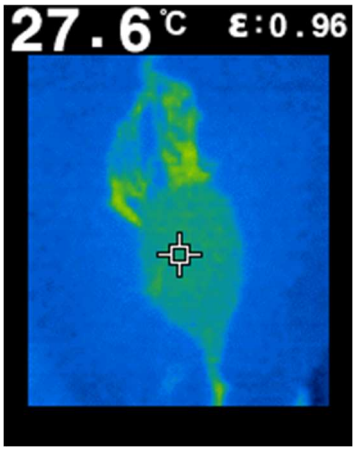
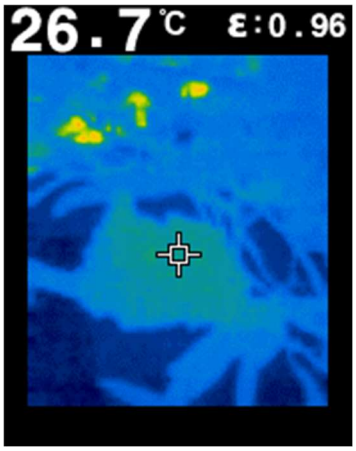
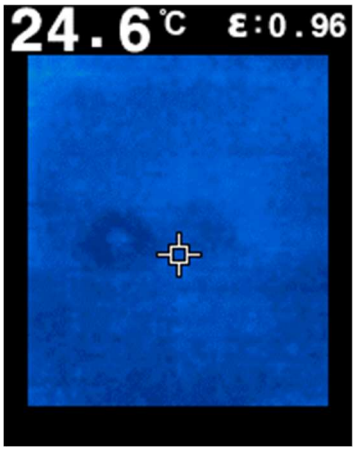
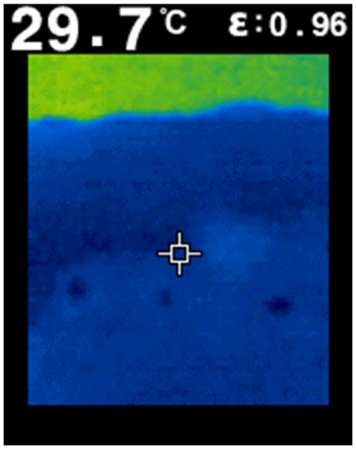
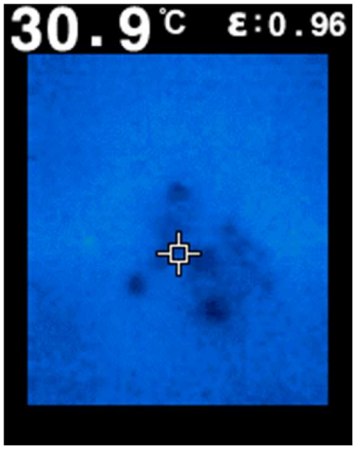
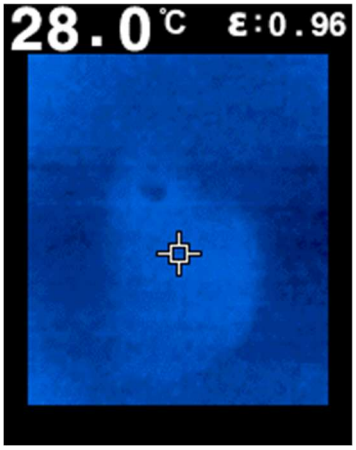
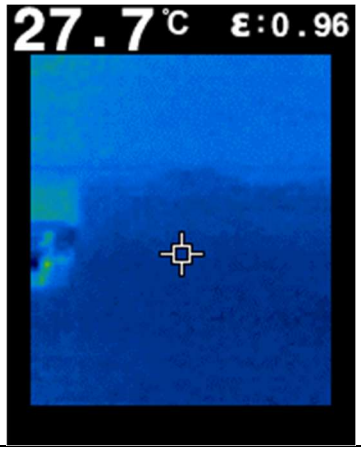
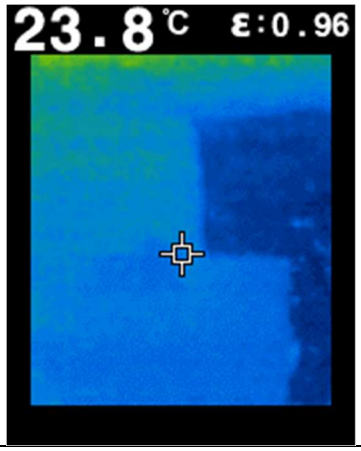






Images from IR Gun;

Thermal images of various nests captured using FLIR IR Thermometer is given below,

NC-BHL 	NC-JNC 	NB-IMB2 
NC-IMB3 	NB-CSA 	NC-CE 
NB-BHL 	NA-IMB 	NB-IMB 

Conclusion

In the following lines, I will provide a concise overview of my entire project.

- Homing behaviour in potter wasp is done by visual memory
- The potter wasp normally selects nesting locations where significant variation in ambient temperature are unlikely, and the chosen spot is positioned to avoid direct exposure to sunlight.
- During Hole repairing, there is no affinity towards the size of hole.
- Some *Eumenes* sp. species shows a peculiar behaviour of repeatedly returning to a nest without involving in any observable activities. This particular phenomenon has not been documented or mentioned by previous researchers studying potter wasps.
- From the comparison of temperature variation in active and inactive nests, it is crystal clear that active nests respond differently compared to inactive nests. From these instances and observation, it may indicate the presence of thermoregulation inside active nests.
- There are cases were potter wasp builds double layered outer covering for nests but its exact function is not known.
- A total of 53 potter wasp nests situated around the IISc campus are meticulously described, including their shape, locations, and distinctive characteristics.
- Thermal images of nests are provided.

The above-mentioned points summarize my entire summer project work. There are some cases where I couldn't reach the final result as further research might be required.

There were many challenges I faced during my entire fieldwork. Many nests including active ones were located at a certain height unable to gather the readings. During this small-time gap, I was unable to record readings of each data under observation. So, I began to categorize and partition my timing. I was able to monitor only 10 active and 9 inactive nests but it would have been better if I monitor more nests so that analysis might be better. The climate also affected me. Especially rain interrupted my data. Even though I tried my best to collect and analyse the data.

My ultimate aim was to compare the temperature variation in active and inactive nest. I was able to achieve my aim throughout this two-month internship period.

These results and observation that uncoiled here might enlighten some minds and ignite their soul to research further for the well-being of humanity.

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