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Studies on the foraging shift of bees and their negative consequences at urban ecosystems of Tamil Nadu, south India

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ABSTRACT:

Bees are indispensable pollinators being highly responsible for agricultural productivity and ecosystem sustainability. They are found to be declining across the world due to various factors such as habitat loss, habitat fragmentation, use of pesticides, diseases and urbanization. The cumulative impact of increased anthropogenic activities and urbanization are immediately visible as they exert negative consequences on bee populations. Foraging shift of honey bees from mutualistic (pollinator to flower) to a non-mutualistic object (disposed tea cups) caused by human activity. In order to analyze the non-mutualistic shift of honey bees and their negative consequences, the time of visiting, frequency, and mortality rate of bees were analyzed at different shops *viz.*, tea/coffee, flower market, fruit juice and cane juice at human dominated sites, Madurai, Tamil Nadu. Bee visitation data was collected from 06:00 to 18:00 with 1hour time interval for six months. Number of disposed cups, height of the dust bin and the volume of residual beverage left in the cups were considered for accounting the bee death. The relative frequency and death rate of bees was found to be comparatively higher (332.4 ± 13.8 and 126.4 ± 19.9 respectively) from 11.00 am to 12.00 pm at coffee/tea beverage bars then other foraging sites. Multiple factors such as number of disposed paper cups, bee competition and volume of the residual beverage in the disposed cups were found to have influence on bee death. Our study reveals that the foraging shift of honey bees from mutualistic (flower) to non-mutualistic is major threat to bees population at human dominated ecosystem. In conclusion, our study provides very essential data to make policies to curtail the bee's mortality on human dominated ecosystem.

KEYWORDS: Honey Bee, Urbanization, Foraging shift, Bee destruction

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INTRODUCTION

Bees are generalist pollinators for about 25,000 – 30,000 flowering species worldwide¹. They are responsible for agricultural productivity as it pollinates more than 70 important crops and ecosystem's sustainability. However, they are currently facing multiple stresses which include habitat loss and fragmentation, parasites and viral diseases, pesticide and herbicide uses, agriculture and grazing, invasive species^{1,2}. This can lead to global pollinator crisis causing vulnerability of crop as well as wild plants and economic losses³. Human developments such as urbanization have serious effects on bee diversity and distribution. Bee species richness and abundance are reported to be diminished in disturbed regions⁴⁻⁶. On other hand, disturbances have supported bees by increasing its species richness. However, the net impact of anthropogenic activities is not definite although the cases of negative impacts are more. Recently, through a study conducted by us in south India, we reported that foraging shift of honey bees towards disposed paper cups accumulating in commercial coffee bars has negative influences on adult bee workers. Bees are attracted to disposable cups containing residual sugary beverage and thus these cups act as death traps for bees killing about 168 bees/day/shop⁸. This reflects how bee's survival is affected in human dominated habitats. In this regard, here we aimed to assess the life of bees in regions having more human accessibility such as urban and semi urban areas in Madurai, Tamil Nadu of India.

MATERIALS AND METHODS

The study area Madurai is one among the southern districts of Tamil Nadu, India. According to a global estimate, Madurai holds 29th rank in population density (47,600 people/sq. mile), 306th rank in urban area cover and 684th rank in urban footprint⁹. We conducted preliminary survey to study the bees life in human dominated area in Madurai. On the basis of preliminary survey we selected four different bee foraging sites such as fruit juice centers, cane juice centers, flower markets and coffee/tea bars. Bee visitation data was collected from 06:00 to 18:00 with 1 hour time interval for six months. Number of bee visits and bee mortality were taken as parameters. Number of disposed cups, height of the dust bin and the volume of residual beverage left in the cups were considered for accounting the bee death. Human responses to get rid/kill honey bees were recorded. Dead samples of bees were collected and preserved in 80% ethanol and identified to species level.

RESULTS

Foraging shift of honey bees at human dominated ecosystem

From our extensive field survey, the influence of human activities on the foraging shift of honey bees at human dominated ecosystem was clearly revealed. From our study, it is understood that human activities tend to create new ecological niches for bee foraging. Coffee/ tea shops, flower markets, sugar cane and fruit juice centers were found to lure bee population in human dominated ecosystem. In specific, bee species such as *Apis indica*, *Apis dorsata*, *Apis florea* and *Melipona iridipennis* were found in common to shift to these human created niches. Out of these species, *Apis indica* was found to forage in all the human dominated sites.

Tea/ coffee shops

The foraging shifts of bees were observed from morning 6.00 am to 6.00 pm consistently. The relative frequency and death rate of bees was found to be comparatively higher (332.4 ± 13.8 and 126.4 ± 19.9 respectively) from 11.00 am to 12.00 pm (Table 1). The relative frequency was correlating directly with the death rate of honey bees at tea/coffee shops. Multiple factors such as number of disposed paper cups, bee competition and volume of the residual beverage in the disposed cups were found to have influence on bee death. Human tea/coffee consumption rate was found to higher during 11.00 am to 12.00 pm which had a direct role in the disposal of paper cups. The number of disposed cups ranged from 160 to 7000 approximately averaging about 1225 cups per day. The freshly disposed cups were more influential in luring the bees for foraging the residual sugar residue. The residual beverage makes a sticky fluid with the excess sugar which traps the bees due to its sticky nature and making them unable to fly (Plate 1 c). On an average 368 bees are killed per shop per day eventually the death rate was higher in the cups holding the residual beverage ranging from 3 to 6 ml (Figure 1). Based on our observations, we assumed that height of waste bin used for collecting disposed cups has impact on bee mortality. Bee deaths were arbitrarily noted at the height of 20 to 40 cm from the base of waste bins.

Juice/Cane juice centre's and flower markets

Relative frequency of honey bees was recorded maximum at cane juice center whereas death rate was found to be higher at fruit juice than cane juice center. The human plays a crucial role on killing of bees at fruit juice center. Human have suddenly poring hot water or putting fire on the bees to escape

from sting of bees which are resulted to increased death rate of bees (Plate 1 e & f). Relative frequency was observed very low when compared to other foraging site whilst bee mortality was not observed in the flower market (Table 2).

Mortality of bees was comparatively low in cane juice centers/fruit juice centers. In these sites, bees visit and take sufficient juice containing sucrose/fructose from freshly disposed bagasses/fruit wastes. Among the bees directly approaching the juice extractor, only few get trapped to death leading to low mortality in these centers. On an average 102 to 130 bees per day were killed in these foraging sites. Absence of mortality in flower markets is due to constant spraying of water over flowers and wrapping of garlands in polythene bags by shop keepers. It reduces the frequency of bee's direct contact with flowers.

Apart from these mortality causes, human activities also cause bee deaths in human dominated ecosystem. To avoid contact with bees, humans used various responses viz., pouring of hot water, putting fire over waste bins and beating bees with broomsticks and subsequently end in death of bees. Maximum mortality of bees was recorded for broomstick response followed by hot water and fire response (Plate 1e and 1f) and (Fig. 2). Besides during waste bin recycling, workers are forced to kill the bees which are escaping from the bins in order to protect them from bee sting.

DISCUSSION

This study clearly demonstrates the insecurity over honey bees' life in human dominated environment. The bee species here we reported to exhibit foraging shift are social bees and pollinators for wide range of plant species including wild and cultivators in India¹⁰⁻¹³. Hence loss of these bee populations in urbanized environments has significant impact on our agricultural productivity. High level of bee visitation in non-flower foraging sites (coffee/tea bars) implies their preference of non-floral reward (tea/coffee/milk/juice) over floral reward (nectar and pollen). This shift may be due to satisfaction of energy requirements from these non-floral resources since bees have ability to alter its foraging behavior according to source profitability¹⁴. Time of bees foraging depends on anthesis (flower opening) and nectar secretion period. Reports showed that in natural environment these bees hunt flowers during early morning or forenoon hours^{11,15}. In our study, *A. dorsata* only exhibit such foraging activity. *M. iridipennis* foraged juice centers during late forenoon to till evening and *A. indica* forage round all the daytime. It suggests that considerable populations of bees are not available to pollinate plants in urban ecosystem. Also such prolonged time of visitation increases the probability of bees to be

killed. If anthropogenic activities accompanied, huge population of worker bees have not able to return to their hives and thereby results in colony collapse disorder (CCD).

In an era of rapid and uncontrollable urbanization, many species will have to survive in anthropogenic habitats for their existence on earth¹⁶. It is important to monitor the life of ecologically important species such as bees in such ecosystems. While natural covers are diminishing and urban landscapes are increasing, role of honey bees is vital to maintain a rich floral biodiversity in urbanized habitats. Because movement of these pollinators will maintain genetic diversity of plant populations in human dominated ecosystem¹⁷. But foraging shift from usual mutualistic relationship (flowers – pollinators) to non-mutualistic association (sugar residual – pollinators) is a dangerous move and it may to lead to decline in crop productivity and collapse of entire ecosystem stability in urban and semi urban ecosystems. Usages of disposable cups are constantly increasing day-by-day and this means more and more bee foragers are prone to die. Urgent conservative measures have to be taken to conserve bees in the urban ecosystem. Contact of bee with these non-floral traps can be minimized by following proper waste disposal and planting bee-loving plants in these environments. Frequent monitoring has to be done in bee-lethal prone areas and other urbanized/semi-urbanized regions in order to reduce the pressure exert on bees in human dominated ecosystem. Awareness should be created among public not to consider bees as nuisance visitors but as valuable volunteers.

CONCLUSION:

Bees neglect visiting flowers and are attracted by the rich residual sugar in the cups as an alternative food resource in urban environment. These cups act as ‘death traps’ for them. The increasing drift in urbanization and subsequent increase in beverage bars may exacerbate the mortality of bees that inhabit in and around urban and semi-urban ecosystems. These foraging shifts of bees from usual – mutualistic relationship (flowers – pollinators) to unusual non-mutualistic association (sugar residual – pollinators) which may lead to bee collapse in future and reduction in agricultural productivity throughout the world. This can also lead to an irreversible ecological collapse and life threatening changes for local biodiversity. Our present work has given a clear understanding the colony collapse disorder through anthropogenic activities and controlling the behavioral shift of bees which can help in maintaining the ecosystem sustainability and agricultural productivity. Present study highlights the negative consequences of urban improvements exerted on vital pollinators. However intensive studies

are necessary to grasp knowledge on memory dynamics and behavioral evolution operating this recent foraging shift in bees through field and controlled experiments.

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Table 1 Bees mortality (number of bees died) recorded at various timing between 0600 – 1800 h in different study sites of Madurai district, Tamil Nadu

Time Interval	Coffee/Tea bars	Flower Market	Cane Juice Center	Fruit Juice Center
0600 - 0700 h	13.6 ± 4.1	0	NA	NA
0700 - 0800 h	28.8 ± 2.7	0	NA	NA
0800 - 0900 h	49.4 ± 5.8	0	NA	NA
0900 - 1000 h	73.4 ± 7.8	0	4.3 ± 1.5	6.0 ± 1.92
1000 - 1100 h	118.6 ± 13.0	0	7.0 ± 2.0	15.6 ± 2.3
1100 - 1200 h	126.4 ± 19.9	0	11.0 ± 1.7	23.2 ± 1.35
1200 - 1300 h	93.6 ± 10.8	NA	15.3 ± 3.5	34.0 ± 7.7
1300 - 1400 h	71.4 ± 18.3	NA	21.0 ± 4.5	28.0 ± 7.3
1400 - 1500 h	66.0 ± 7.4	NA	18.0 ± 2	17.2 ± 1.9
1500 - 1600 h	50.0 ± 5.55	NA	12.6 ± 0.5	13.2 ± 1.7
1600 - 1700 h	50.4 ± 12.3	NA	9.0 ± 1.0	8.4 ± 2.2
1700 - 1800 h	18.8 ± 3.8	NA	3.6 ± 0.5	NA

Data are represented in Mean ± SE (n = 10 for each site). NA – not available (due to closure of these centers at respective timings)

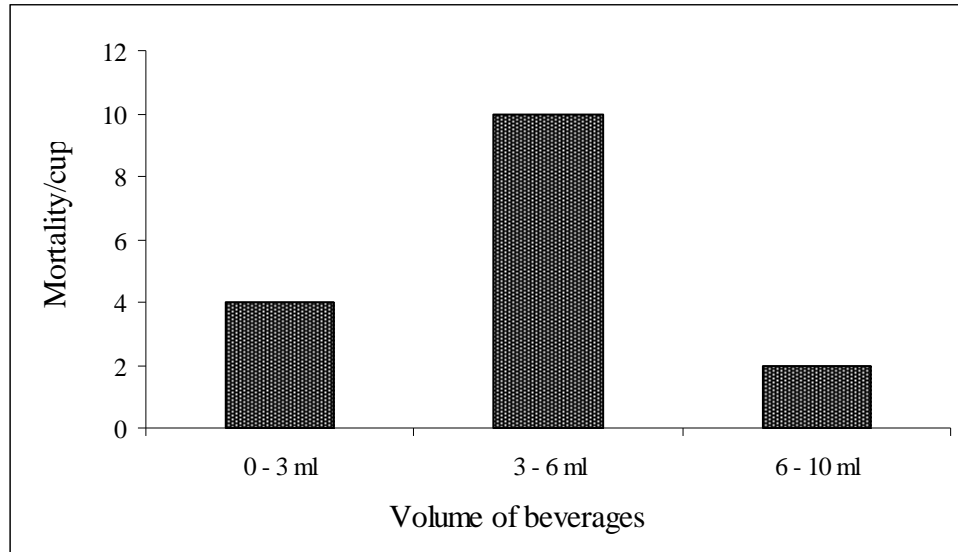


Fig. 1: Bee mortality observed at varied level of beverage remains in disposed cups observed in coffee/tea bars

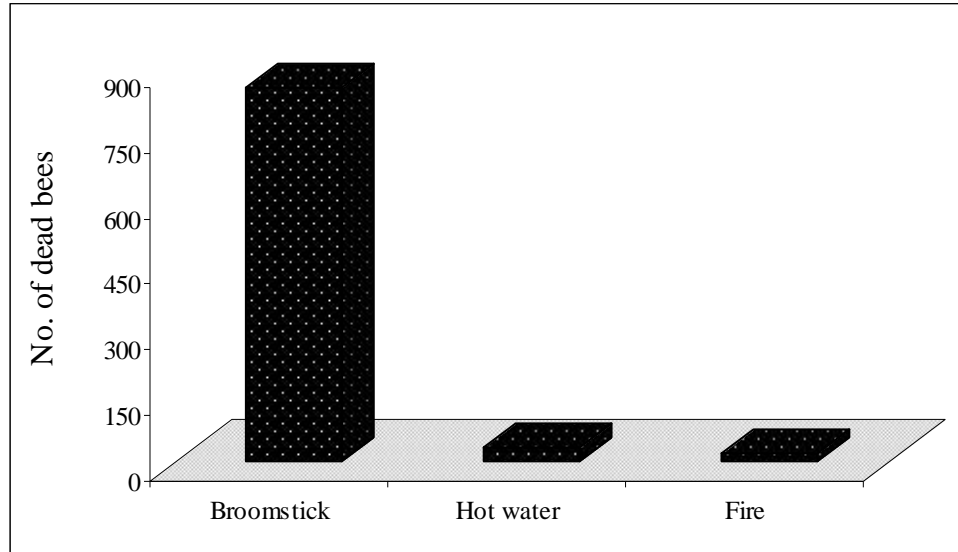


Fig. 2: Bee mortality resulted due to various human responses in studied bee foraging sites

Plate legends:

Plate 1 **a** and **b** Foraging shift bees in cane juice disposed bagasses center and in flower markets **c** and **d** Bees mortality in coffee/tea bars using paper and plastic disposable cups **e** and **f** Human responses to rid/kill honey bees by fire and pouring hot water.

