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Pests and predators interference on the stingless bee population inhabited at different habitats amidst south-eastern Karnataka, India

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Abstract
Stingless bees (Hymenoptera: Apidae: Meliponini) are called 'Dammar bees' live under cryptic conditions at diversified ecosystems. Stingless bees are one of the most important species, playing pivotal role as 'Keystone Pollinators' for various flowering plant species. Besides, they are cultured in the name of 'Meliponi culture' at various man-made agro-ecosystems. Reports on biological constraints of stingless bees is limited at south-eastern Karnataka, hence in the present study commonly occurring constraints and their per cent interference on stingless bee population under natural conditions from 2017 to 2019 in Bangalore Rural, Chikkaballapura and Kolar districts, Karnataka was made. The Megachile bee, *Megachile* (*Callomegachile*) *disjuncta*, beetle, *Bitoma siccana*, spider, *Menemerus bivittatus*, *Crossopriza lyoni* and *Pholcus phalangioides*, greater wax moth, *Galleria mellonella*, wall lizard, *Hemidactylus* species, garden lizard, *Calotis versicolar* and *Psammophilus dorsalis* acted as important constraints of stingless bee population and impacted more for their decline. Further, burning, hunting, closing their colony entrance by cow dung and cement, road construction and destruction of buildings and other man-made activities have created huge impact on stingless bee population. Stingless bee's conservation is required to restore for conservation of local vegetation, to produce medicinally important honey and hence their natural colonies need special attention cum protection at their preferred abode.

Keywords: stingless bees, biological constraints, *Megachile disjuncta*, *Bitoma siccana* south-eastern Karnataka, India

Introduction
Stingless bees are called 'dammar bees' in India [1, 2] and in Karnataka called 'Musare jenu'. These bees are most important, social corbiculate group of insects playing a major role as potential 'keystone pollinators' for 40 to 90% plants in agriculture and forest ecosystems. Stingless bees visit flowering plants include herbs, shrubs and trees [3]. Moreover, stingless bees are reared in the name of 'Meliponiculture' [4, 5, 6]. Interestingly, a stingless bee colony can live around 10 to 26 year [7, 10] at undisturbed habitats. Honey from stingless bees is typically less viscous, more acidic than the honey of *Apis* species [11] and has high medicinal value. Stingless bee honey is used for treating respiratory disorders and eye infections [12, 13]. Honey is rich with medicinal properties; villagers culture these bees for honey production [14]. Moreover, stingless bee's hive products are used to produce cold creams, shoe polish, wood polish, ointment, lipstick etc. Stingless bees wax is used in various industries as one of the raw materials to produce ink, candle, crayon, medicine coating material and in food industries as protecting material to preserve food items. Thus, stingless bee hive products have high demand in national and international markets [15]. Unfortunately, these valuable creatures are declining recent years throughout the world [16]. Most of the stingless bee species share natural and man-made habitats [17, 18] and continuously exposing themselves to various anthropogenic interferences such as habitat loss, pesticides application [19, 20], human interference in tropical and sub-tropical forest habitats [21, 23], which impacted the local biodiversity loss in general [24] and stingless bee population in particular [25, 27].
[19] Have reported the importance of pollinators in changing landscapes for various crops around the world. [22] Have reported the influence of the loss of Brazilian savanna vegetation and the occurrence of nests of stingless bees. [28] Have reported the crop pollination by stingless bees. In India, traditional beekeeping of stingless bee species (e.g. *Trigona* sp) is

Encouraged to Kani tribes of Western Ghats by the State Government of Tamil Nadu [14]. The stingless bees are rearing for honey production, as pets and pollination in a Uganda forest reserve [11]. However, presence of good food resource (e.g. honey, pollen and developing brood) found in stingless bee colony attracts several predators and pests [29, 30]. In Uganda, 12% bee colonies are declined due to predators [29]. The resin bee, *Megachile* and *Carinula* are infesting stingless bees in Thailand [31] and *Megachile* sub-genus *Callomegachile* is creating havoc at Chandigarh and Punjab plains [32], *Megachile (Callomegachile) disjuncta* parasitic activity was not reported on stingless bee *T. iridipennis* colony at Bangalore rural district of Karnataka [31]. Moreover, the sub cortical beetle, *Bitoma siccana* (Coleoptera: Zopheridae) is regularly intervened with the normal activity of stingless bees [33]. *B. siccana* predation was first reported in Korea by [34], in Andaman and Nicobar Islands by [35], in France by [33, 36].
[37] Have reported small hive beetle *Aethina tumida* found in stingless bee *Trigona carbonaria* hive. [38] Have reported a wasp, *Trachypus boharti* as a predator on male stingless bee *ScaptoTrigona postica*. The Chimpanzees predation on stingless bee was reported from Uganda by [29]. Mustelids, bears, primates and anteaters predation on stingless bees was reported [39, 40]. Moreover, anthropogenic interference on stingless bee diversity and distribution has been reported by [22]. All these interferences caused by different animal species have disturbed the normal survival of stingless bees at different habitats. Thus, stingless bees are facing continuous threat at both natural and man-made changing landscapes [19]. Published reports on animal's interferences on stingless bee colonies are diffuse in south-eastern Karnataka. Hence, the present study was conducted in Bangalore rural, Chikkabballapur and Kolar districts of south-eastern Karnataka.

Materials and Methods

Study area

Present study was conduct in three districts *viz*., Bangalore rural (12^{0}15' – 13^{0}31' N latitude to 77^{0}04'-77^{0}59' E longitude with an elevation 850-950m msl), Chickaballapur (13^{0}13'04" – 13^{0}58'29" N latitude to 77^{0}21'52"-78^{0}12'31" E longitude with an elevation 249-911m msl) and Kolar (12^{0}41'54" – 13^{0}35'47" N latitude to 77^{0}50'29"-78^{0}35'18" E longitude with an elevation range from 849-110 m msl) districts of south-eastern Karnataka. These three districts fall under eastern dry agro-climatic zone of Karnataka. This zone is experiencing semi-arid climate, with typical monsoon type weather [41, 42, 43, 44].

Methodology

Systematic survey was conducted using random sampling method during 2017 and 2019. Information on pests, predators and human interferences was collected by meeting local people with the help of pre-tested questionnaire. After collecting information on the stingless bee colonies from local villagers and farmers, 35 study areas were chosen from different taluks of Bangalore rural, Chikkaballapur and Kolar districts (Fig. 1). Moreover, from each study area, minimum five to maximum eight study sites were randomly selected based on the occurrence of stingless bee colonies at natural and man-made habitats. Further, each study site was visited two to three times during the study period by following standard methods. The stingless bee's colonies were searched using an all-out search method and visual count method as per [45, 46]. Pests, predator's interferences, old residential buildings destruction were recorded by spending one to 2 hours at each stingless bee colony at different habitats. The destroyed live nested material was collected in a sterile glass container and brought to the Laboratory for culture and study further. The workers and developing brood was cultured using 32 cm long and nine cm wide bamboo twig (Fig. 2 A to C) as per [14, 47]. The brood cells, pollen cells and few number of honey pots were introduced in a hollow bamboo box, managed and monitored for a period of three months under aseptic laboratory conditions. Forager bees were fed with 1:1 sugar solution during the time of need despite their regular, normal foraging activity. Incidence of pest's infestation and predators encounter was recorded even under laboratory conditions also. The pest's infestation and predators attack was recorded using Sony DSC-Wx7 digital still camera and photographed the pests and predators after the observation under stereo zoom research microscope - Stereo Discovery V20.

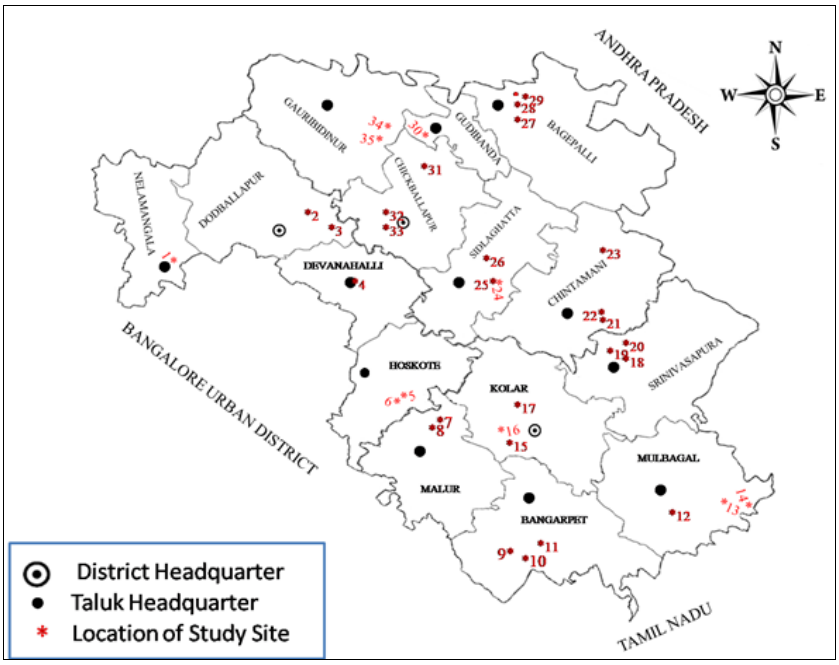
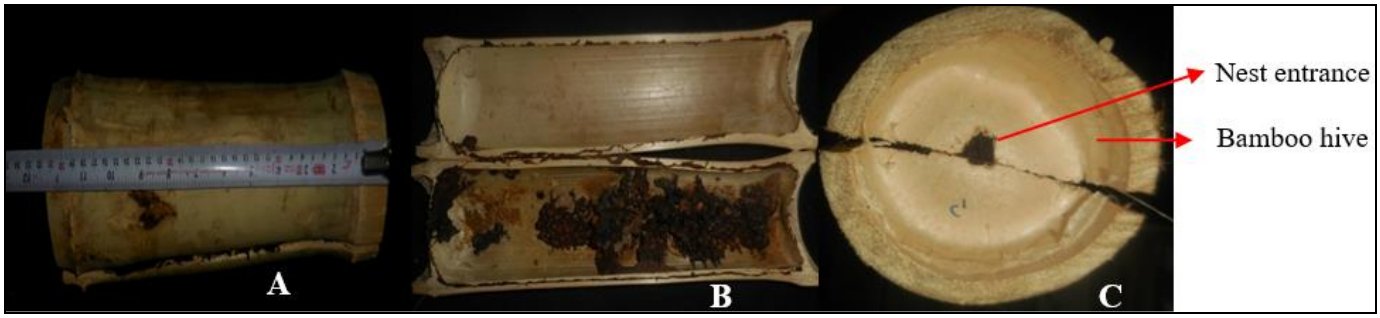


Fig 1: Map showing the study areas selected in different districts of south-eastern Karnataka



A. Hallow Bamboo box B. Cerumen and wax inside the bamboo box C. Bamboo box with nest entrance

Fig 2: Stingless bees rearing in the Laboratory

Statistical analysis

Collected data was compiled systematically by following standard methods. Per cent values, analysis of variance, Friedman-two-way analysis, Spearman's coefficient correlation and different graphical representation of the data are made using standard methods as per [48].

Results

Pests

Few commonly occurring pests recorded on stingless bee population at south-eastern Karnataka are depicted in Table 1. The resin bee, [*Megachile* (*Callomegachile*) *disjuncta*] (Fig. 3 A to D), barks beetle (*Bitoma siccana*) (Fig. 4 A & C) and wax moth (*Galleria mellonella*) (Fig. 5 A & D) which belong to the order Hymenoptera, Coleoptera and Lepidoptera respectively. The *M. disjucta* was collecting wax and cerumen especially from pollen and brood cells in the nest of stingless bees. The *B. siccana* infested pollen cells and causing damage in the nest of stingless bees. However, *G. mellonella* infest the brood and pollen cells to lay eggs and steal the developing brood for the growth and development of its larvae (Table 1).

Fig 3: Pests of Stingless bees, A. *Megachile* bee approaching to the stingless bee colony. B. *Megachile* bee holding cerumen ball. C. *Megachile* bee collecting wax on pollen. D. Dorsal view of *Megachile* (*Callomegachile*) *disjuncta*

Fig 4: Stingless bee nest infested by beetle, A(a). Pollen cells. A (b). *Bitoma siccana* cocoon present in between pollen cells B. Cocoon of beetle grub C. Dorsal view of *Bitoma siccana*

Fig 5: *Galleria mellonella* infesting to the stingless bee nest, A. Larvae on pollen pots. B. Adult larva. C. Pupa of *G. mellonella.* D. Adult moth, *Galleria mellonella*.

Table 1: Few commonly occurring pests recorded at stingless bee colonies at south-eastern Karnataka

Sl. No.	Common Name	Pests of stingless bee	Insect Type	Mode of threat
1.	Resin bees	*Megachile* (*Callomegachile*) *disjuncta*	Bee (Hymenoptera)	Collecting wax and cerumen from pollen and brood cells
2.	Cylindrical bark beetles	*Bitoma siccana*	Beetle (Coleoptera)	Infesting pollen cells area
3.	Honeycomb moth	*Galleria mellonella*	Moth (Lepidoptera)	Infesting brood cells area and pollen cells area

Predators

Total seven predatory animal's interferences were recorded at the nests of stingless bee population in south-eastern Karnataka (Table 2). The arachnids such as gray wall jumping spider (*Menemerus bivittatus*), tailed daddy long-legged spider (*Crossopriza lyoni*) and daddy long-legged spider (*Pholcus phalangioides*) were trapping the stingless bee foragers at the nest entrance using their web (Fig. 6 A to C). The lizards such as Bombay leaf-toed gecko (*Hemidactylus* sp.), eastern garden lizard (*Calotis versicolar*) and south Indian rock Agama (*Psammophilus dorsalis*) were entrapping the forager bees at the nest entrance (Fig. 7 A to C). Besides all these predatory animals, man (*Homo sapiens*) intervention was more on stingless bee nests at different places of south-eastern Karnataka (Table 2). Stingless bee colonies burning, hunting, pesticide spray on the nest entrance, pouring chemicals inside the nest, sealing of nest entrance using wet mud, cow dung, cement, stick, plastic cover, plastic and gunny bags, destruction of residential houses (Fig. 8 A to K) and cutting and trimming of trees on road side were few commonly occurring predatory interferences recorded at different places in south-eastern Karnataka. Further, heavy rain fall, uprooting of old trees, mud wall buildings and submergence of nest due to water were commonly occurred at stingless bee colonies at different places of south-eastern Karnataka (Table 2).

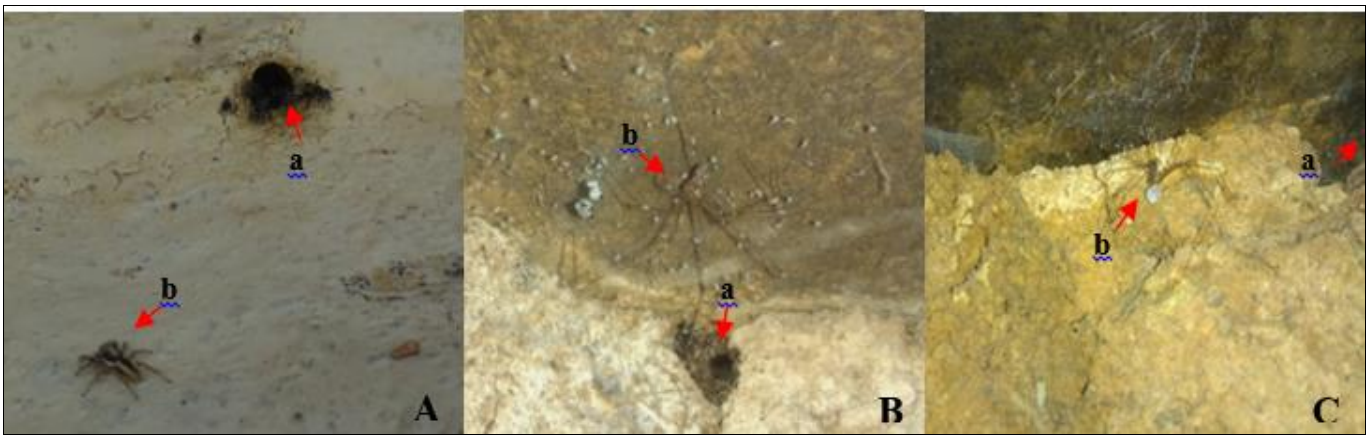


Fig 6: Predatory spiders nearby stingless bee nest entrance, A. *Menemerus bivittatus* capturing foraging bees at the nest entrance. A (a). Nest entrance, A (b). spider. B. *Crossopriza lyoni* a. Nest entrance b. Spider and C. *Pholcus phalangioides* C (a). Nest entrance. C (b). Spider constructs its web at the entrance of the stingless bee hives and trap stingless bees

Fig 7: Reptilian predators of stingless bee, A. *Hemidactylus* species B. *Calotis versicolar.* C. *Psammophilus dorsalis.*

Fig 8: Anthropogenic interferences on stingless bee nests, A. Plastic bag used to close stingless bee nest entrance. B. Plant twigs used to close nest entrance. C. Sticks used to close nest entrance. D & E. Cement used to close nest entrance. F&G. Polythene covers used to close nest entrance. H & I. Stingless bee nest entrance closed by cow dung. J. Man with iron road to destruction of nested building. K. Swarms of stingless are after building demolition.

Table 2: Few commonly occurring predators recorded at stingless bee colonies at south-eastern Karnataka

Sl. No.	Common name	Predators	Insect Type	Mode of threat
1.	Gray wall jumper spider	*Menemerus bivittatus*	Spider (Arachnida)	Eating foraging bees at the nest entrance
2.	Tailed daddy longlegs spiders	*Crossopriza lyoni*	Spider (Arachnida)	Trapping of foraging stingless bees by its web

3.	Daddy long-legs spider	*Pholcus phalangioides*	Spider (Arachnida)	Trapping of foraging stingless bees by its web
4.	Bombay leaf-toed gecko	*Hemidactylus* sp.	Gecko (Reptilia)	Eating foraging bees at the nest entrance
5.	Eastern Garden Lizard	*Calotis versicolar*	Lizard (Reptilia	Eating foraging bees at the nest entrance
6.	South Indian Rock Agama	*Psammophilus dorsalis*	Lizard (Reptilia)	Eating foraging bees at the nest entrance
7.	Human	*Homo sapiens*	Primate (Mammal)	Burning, hunting, pesticide spray on entrance, pouring of chemicals inside the hive, sealing of nest entrance by mud, cow dung, cement, stick and plastic covers, plastic bags, gunny bags, demolition of residential houses, cutting of trees at road side
8.	Natural Calamities	Other mode of distraction	-	Heavy rain fall, falling of old trees, falling of mud wall buildings, filling of water into the nest

Pest and predators interference

Interestingly, the pest's infestation and predatory activity by various animals was not evenly encountered at Bangalore rural, Chikkaballapura and Kolar districts (Table 3). Accordingly, analysis of variance of incidence of pests and predators on stingless bee nests at south-eastern Karnataka revealed considerable variations. Among the pests, resin bee [*Megachile* (*Callomegachile*) *disjuncta*] incidence was high in Bangalore rural district and it was followed by Kolar and Chikkaballapura districts compared to bark beetle (*Bitoma siccana*) and wax moth (*Galleria mellonella*) infestation (Table 3). However, among the predators, *Menemerus bivittatus* predation was more at Chikkaballapura and Kolar districts and it was followed by *Calotis versicolar* predation on stingless bees at Bangalore rural district compared to other predators (Table 3). Moreover, *Crossopriza lyoni*, *Pholcus phalangioides*, *Hemidactylus* sp., *Calotis versicolar* and *Psammophilus dorsalis* predatory interference was considerably less and there existed a significant difference ($F=3.784$; $p>0.05$) at different districts of south-eastern Karnataka (Table 3).

Table 3: Analysis of variance of incidence of pests and predators encountered at south-eastern Karnataka

Threat Due to	Sl. No.	Pests and Predators	Bangalore Rural	Chikkaballapura	Kolar	Total
Pest	1.	*Megachile* (*Callomegachile*) *disjuncta*	8.0	4.0	6.0	18.0
	2.	*Bitomasiccana*	1.0	2.0	1.0	4.0
	3.	*Galleria mellonella*	2.0	1.0	1.0	4.0
Predator	4.	*Menemerus bivittatus*	7.0	21.0	12.0	40.0
	5.	*Crossopriza lyoni*	5.0	12.0	6.0	23.0
	6.	*Pholcus phalangioides*	5.0	9.0	4.0	18.0
	7.	*Hemidactylus* sp.	2.0	5.0	3.0	10.0
	8.	*Calotis versicolar*	15.0	7.0	4.0	26.0
	9.	*Psammophilus dorsalis*	3.0	8.0	5.0	16.0
	10.	*Homo sapiens*	5.0	18.0	7.0	30.0
Total			53.0	87.0	49.0	189.0
Mean ± SD			5.3 ± 4.08	8.7 ± 6.60	4.9 ± 3.21	
'F' value			3.784*			-

Note: *Value is significant at 5% level

Per cent occurrence of pests and predators

Pests and predators per cent encounter on stingless bee colonies at different districts of south-eastern Karnataka is presented in Table 4. *M. disjuncta* infestation was more in Bangalore rural, Kolar and Chikkaballapura districts respectively 4.2, 3.2 and 2.1%. However, *B. siccana* and *G. mellonella* infestation was less than 2.0% in these districts. Altogether, *M. disjuncta* infestation was 9.5% and the *B. siccana* and *G. mellonella* infestation was 2.1% each at south-eastern Karnataka (Table 4). Among the predators, *Calotis versicolar* predation was high (7.9%) and it was followed by *Menemerus bivittatus* (3.7%), *Crossopriza lyoni* and *Pholcus phalangioides* (2.6% each) compared to other predators, where it was less than 2% predation on stingless bee population in Bangalore rural district. However, in Chikkaballapur district, *Menemerus bivittatus* predation was high (11.1%) compared to other predators namely: *Crossopriza lyoni*, *Pholcus phalangioides*, *Psammophilus dorsalis*, *Calotis versicolar* and *Hemidactylus* species respectively 6.3, 4.8, 4.2, 3.7 and 2.6% predation (Table 4). In Kolar district, *Menemerus bivittatus* (6.4%), *Crossopriza lyoni*, *Psammophilus dorsalis*, *Pholcus phalangioides* and *Calotis versicolar* and *Hemidactylus* species respectively 6.4, 3.2, 2.7, 2.1% each and 1.6% predation on stingless bee population in Kolar district (Table 4). Further, per cent occurrence of commonly infesting pests *viz*., *M. disjuncta*, *B. siccana*, *G. mellonella* and predators such as *M. bivittatus*, *C. lyoni*, *P. phalangioides*, *Hemidactylus* species, *C. versicolar*, *P. dorsalis* and human interference on stingless bee colonies at south-eastern Karnataka are depicted in Figure 7. Overall, *Menemerus bivittatus* predatory interference was high (21.2%) and it was followed by human interference (15.8%) on stingless bee population in south-eastern Karnataka. Moreover, *Calotis verrsicolar* (13.7%), *Crossopriza lyoni* (12.2%), *Pholcus phalangioides* predation and *M. disjuncta* pest infestation (9.5% each) and *Psammophilus dorsalis* (8.5%) and other pests and predators interference was less than 6% (Table 4). Based on the per cent interference of pests and predators on stingless bee population, the rate of encounter was graded as 1, 2, 3, 4, 5, 6, 7 and 8 respectively due to *Menemerus bivittatus*, *Homo sapiens*, *Calotis verrsicolar*, *Crossopriza lyoni*, *Pholcus phalangioides*,

Psammophilus dorsalis, *Hemidactylus* species and *Bitoma siccana* and *G. mellonella* at south-eastern Karnataka (Table 4). Further, overall incidences of different animal's interferences on stingless bee colonies in south-eastern Karnataka are depicted in Figure 9.

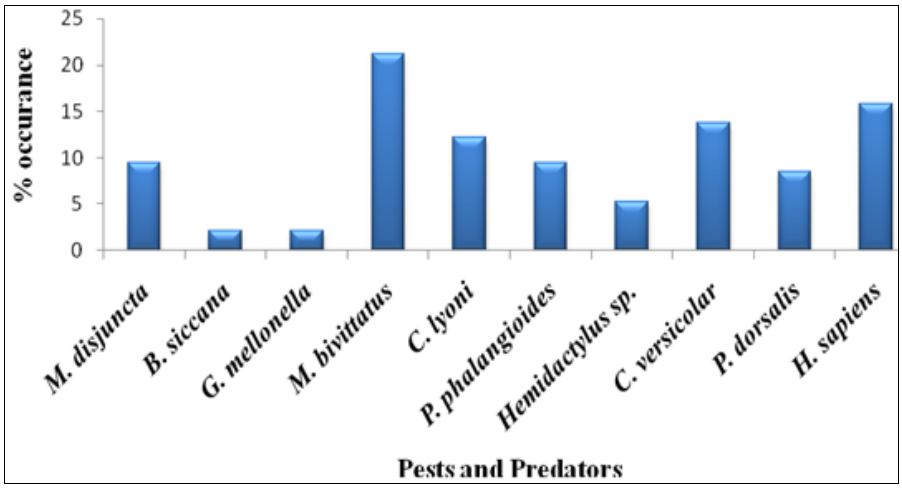


Fig 9: Per cent occurrence of pests and predators on stingless bee colonies at south-eastern Karnataka

Table 4: Per cent occurrence of pests and predators encountered in south-eastern Karnataka

Threat due to	Sl. No.	Pest and Predators	Bangalore Rural	Chikkaballapura	Kolar	Total	Rank
Pest	1.	*Megachile* (*Callomegachile*) *disjuncta*	4.2	2.1	3.2	9.5	5
	2.	*Bitoma siccana*	0.5	1.1	0.5	2.1	8
	3.	*Galleria mellonella*	1.1	0.5	0.5	2.1	
Predator	4.	*Menemerus bivittatus*	3.7	11.1	6.4	21.2	1
	5.	*Crossopriza lyoni*	2.6	6.3	3.2	12.2	4
	6.	*Pholcus phalangioides*	2.6	4.8	2.1	9.5	5
	7.	*Hemidactylus* sp.	1.1	2.6	1.6	5.3	7
	8.	*Calotis versicolar*	7.9	3.7	2.1	13.7	3
	9.	*Psammophilus dorsalis*	1.6	4.2	2.7	8.5	6
	10.	*Homo sapiens*	2.7	9.5	3.7	15.8	2
Total			28.0	46.0	26.0	100.0	-

Note: Data is based on Table

Seasonal incidence of pests and predators

Further, seasonal incidence of pests and predators on stingless bee population at south-eastern Karnataka are depicted in Table 5. During rainy season, *Menemerus bivittatus* predation was more (13.0) on stingless bee population and it was followed by human disturbance (9.0) and *Crossopriza lyoni* (6.0) compared to other pests and predators, where their interference was <4. However, *M. disjuncta*, *Calotis versicolar* and *Psammophilus dorsalis* interference on stingless bee population was not found during rainy season at south-eastern Karnataka (Table 5). In winter season, *Calotis versicolar* predation was more (14.0) and it was followed by *Menemerus bivittatus* predation (13.0) and predatory interference due to *Crossopriza lyoni*, *Psammophilus dorsalis* and *Homo sapiens* was 9.0 each on stingless bee population at south-eastern Karnataka (Table 5). The *G. mellonella* and *Hemidactylus* species infestation and predation was just one each on stingless bee population. However, *Bitoma siccana* infestation on stingless bees was not found during winter season at south-eastern Karnataka (Table 5). Further, during summer season, *Menemerus bivittatus* predation was high (14.0) and it was followed by *Calotis versicolar* and *Homo sapiens* was 12.0 each on stingless bee population at south-eastern Karnataka (Table 5). The other predators such as *Crossopriza lyoni* and, *Pholcus phalangioides*, *Psammophilus dorsalis Hemidactylus* species predation was respectively 8.0 each, 7.0 and 6.0 on stingless bee population during winter season. The pests such as *M. disjuncta*, *Bitoma siccana* and *G. mellonella* infestation was respectively 9, 3 and 2 on stingless bee population. Analysis of variance of incidence of infestation by pests and predation by predator's on stingless bee population didn't vary (F=0.466) between the seasons at south-eastern Karnataka. Thus, stingless bees are facing infestation and predation continuously by various insects, reptile species including man during different seasons at south-eastern Karnataka. Overall, per cent incidence of predation by predators and pest infestation by different insects on stingless bee population during rainy, winter and summer seasons are depicted in Table 6. Altogether, highest (42.8%) pests and predators interferences on stingless bee population was encountered in summer and it was followed by winter and rainy seasons respectively 38.1 and 19.1% at south-eastern Karnataka (Table 6).

Table 5: Analysis of variance of incidence of pests and predators encountered on stingless bee colonies during different seasons in south-eastern Karnataka

Sl. No.	Pest and Predators	Season			Total
		Rainy	Winter	Summer	
1.	*Megachile* (*Callomegachile*) *disjuncta*	-	9.0	9.0	18.0
2.	*Bitoma siccana*	1.0	-	3.0	4.0
3.	*Galleria mellonella*	1.0	1.0	2.0	4.0
4.	*Menemerus bivittatus*	13.0	13.0	14.0	40.0
5.	*Crossopriza lyoni*	6.0	9.0	8.0	23.0
6.	*Pholcus phalangioides*	3.0	7.0	8.0	18.0
7.	*Hemidactylus* sp.	3.0	1.0	6.0	10.0
8.	*Calotis versicolar*	-	14.0	12.0	26.0
9.	*Psammophilus dorsalis*	-	9.0	7.0	16.0
10.	*Homo sapiens*	9.0	9.0	12.0	30.0
Total		36.0	72.0	81.0	189
Mean ± SD		3.6 ± 4.4	7.2 ± 4.9	8.1 ± 3.8	-
'F' value		0.466NS			

Note: NS: Value is note significant

Table 6: Per cent occurrence of pests and predators on stingless bee colonies During different seasons in south-eastern Karnataka

Sl. No.	Pest and Predators	Season			Total
		Rainy	Winter	Summer	
1.	*Megachile* (*Callomegachile*) *disjuncta*	-	4.8	4.7	9.5
2.	*Bitoma siccana*	0.5	-	1.6	2.1
3.	*Galleria mellonella*	0.5	0.5	1.0	2.1
4.	*Menemerus bivittatus*	6.9	6.9	7.4	21.2
5.	*Crossopriza lyoni*	4.2	4.8	4.2	12.2
6.	*Pholcus phalangioides*	1.6	3.7	4.2	9.5
7.	*Hemidactylus* sp.	1.6	0.5	3.2	5.3
8.	*Calotis versicolar*	-	7.4	6.4	13.8
9.	*Psammophilus dorsalis*	-	4.8	3.7	8.5
10.	*Homo sapiens*	4.8	4.8	6.3	15.8
Total		19.1	38.1	42.8	100.0

Note: Data is based on Table 5

Human interferences on stingless bee population

The destruction of old residential houses, burning of nests, pesticides application, hunting and sealing of stingless bee nests entrance (Fig. 9 A to K) were commonly noticed at different districts of south-eastern Karnataka (Table 7). Human interference was high (3.6±3.1) in Chikkaballapura district compared to Kolar (1.4±1.1) and Bangalore rural (1.0 ±0.7) districts. However, analysis of variance of human activities between different districts didn't reveal significant difference (F=1.647) (Table 7) and indicated that various human activities regularly interfered on stingless bee population at different districts of south-eastern Karnataka. Accordingly, per cent occurrence of human activity encountered due to destruction of old residential houses, hunting, sealing of stingless bee nests entrance, burning of nests and pesticides application respectively 46.7, 20.0, 16.7, 13.3 and 3.3% at south-eastern Karnataka (Table 8). Moreover, at Chikkaballapura district these activities were high (60%) and it was followed by Kolar district (23.3%) and Bangalore rural district (16.7%) of south-eastern Karnataka. Moreover, per cent occurrence of human interference on stingless bee colonies at Bangalore rural, Chikkaballapur and Kolar districts is shown in Figures 9 and 10.

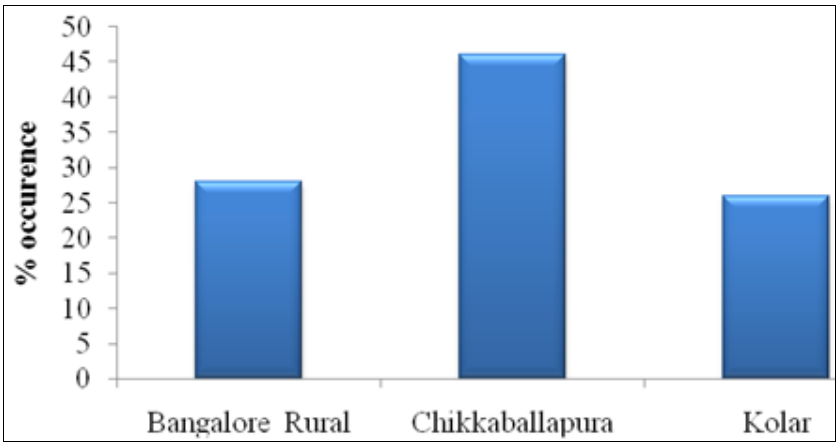


Fig 10: Overall incidences of different animal's interferences on stingless bee colonies at south-eastern Karnataka

Correlation coefficient

Spearman's correlation coefficient between human interference and stingless bee colonies decline at south-eastern Karnataka is depicted in Table 9. Stingless bee colonies destruction was high (103) in Chikkabalapura district and it was followed by Kolar and Bangalore rural districts respectively 73 and 43. It was related with the number of residential houses destructed in these districts. Surprisingly, there was a negative correlation (r = -0.443) existed between the stingless bee colonies destruction and the residential houses destruction at south-eastern Karnataka. Although, there was no significant correlation, but, 44% negative impact shouldn't be ignored (Table 9).

Thus, stingless bee colonies destruction and the rain fall impact on stingless bee population have revealed considerable variation existed at south-eastern Karnataka (Table 10). The usual and unusual rainfall severely affected the colonies (9.5%) by entering into the nests and 90.5% colonies were affected due to residential wall collapses at south-eastern Karnataka (Fig. 10 A to D). Overall, the stingless bee colonies damage due to rain water filling found only in Chikkabalapura district. Further, the 'basic Venn' diagram (MS-2007) indicated that *G. mellonella*, *M. bivittatus*, *C. lyoni*, *P. phalangioides*, *Hemidactylus* species and human interferences are commonly occurred during all the seasons and which becomes major biological constraints for the normal survival of stingless bees in south-eastern Karnataka (Figures 11 to 13). Moreover, *M. disjuncta*, *C. versicolar* and *P. dorsalis* are common only during winter and summer seasons. Further, *B. siccana* infestation was found both during rainy and summer seasons.

Fig 11: Rainfall affected the stingless bee colonies, A to C. Stingless bee colonies destroyed by residential wall fall D. Stingless bee nest filled with water.

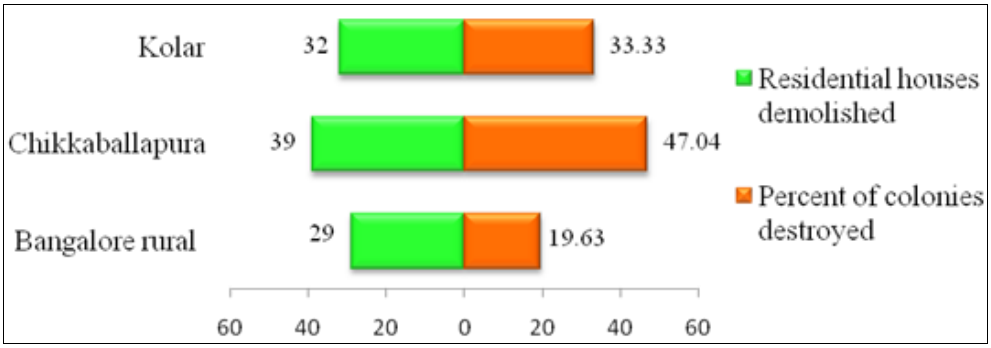


Fig 12: Per cent occurrence of human interference on stingless bee colonies in south-eastern Karnataka

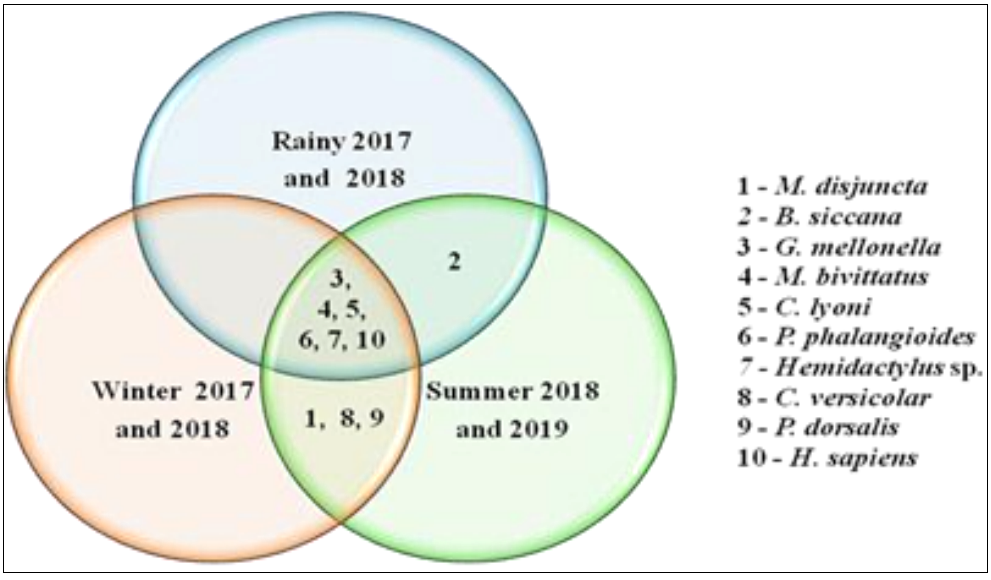


Fig 13: Van diagram showing the pests and predators encounter on stingless bee colony during different seasons in south-eastern Karnataka

Table 7: Analysis of variance of human activity encountered on Stingless bee colonies at south-eastern Karnataka

Sl. No.	Human activity	Bangalore Rural	Chikkaballapura	Kolar	Total
1.	Destruction	2.0	9.0	3.0	14.0
2.	Burring of nests	1.0	2.0	1.0	4.0
3.	Pesticides application	-	1.0	-	1.0
4.	Hunting	1.0	3.0	2.0	6.0
5.	Sealing of nest opening	1.0	3.0	1.0	5.0
Total		5.0	10.0	7.0	30.0
Mean±SD		1.0±0.7	3.6±3.1	1.4±1.1	-
'F' value		1.647NS			

Note: NS: Value is not significant

Table 8: Per cent occurrence of human activity encountered on Stingless bee colonies at south-eastern Karnataka

Sl. No.	Human activity	Bangalore Rural	Chikkaballapura	Kolar	Total
1.	Destruction	6.7	30.0	10.0	46.7
2.	Burring of nests	3.3	6.7	3.3	13.3
3.	Pesticides application	-	3.3	-	3.3
4.	Hunting	3.3	10.0	6.7	20.0
5.	Sealing of nest opening	3.3	10.0	3.3	16.7
Total		16.7	60.0	23.3	100.0

Note: Data is based on Tables

Table 9: Correlation coefficient of human interference and stingless bee Colony decline at south-eastern Karnataka

Sl. No.	District	No. of colonies destroyed	No. of residential houses destroyed
1.	Bangalore Rural	43	11
2.	Chikkaballapura	103	15
3.	Kolar	73	12
Total		219	38
Mean ± SD		73.0 ±	12.7 ±
'r' value		-0.443	
't' value		1.11NS	

Note: NS: Value is not significant

Table 10: Friedman two way analyses of stingless bee colonies destroyed Due to natural calamities at south-eastern Karnataka

Sl. No.	District	Damage due to		No. of nests destroyed
		Rain water filling into the nest	Residential houses wall collapse	
1.	Bangalore Rural	-	6.0	8.0
2.	Chikkaballapura	2.0	5.0	16.0
3.	Kolar	-	8.0	21.0
Total		2.0	19.0	45.0
Mean ± SD		0.66 ± 1.15	6.33 ± 1.52	15.0 ± 6.55

Discussion

Stingless bees evolved their nesting architecture beautifully to protect their colonies from pests and predators [40, 13, 9]. Nest is one of the examples for the amazing creation of engineering work made by stingless bees [23]. Stingless bees construct their nest in preexisting cavities [49], live in a perennial colony for longer period (e.g. up to 26 years if undisturbed). They play a pivotal role as 'keystone pollinator species' in wild and various man-made agro-ecosystems [19]. Around 40-90% crop pollination is directly or indirectly aided by stingless bees [4, 5] and more than 60 agricultural crops are depending on stingless bees for their pollination and propagation [28]. Since, these bees enter completely inside the flower and collect nectar and pollen, visit even very small sized flowers to large sized flowers in every ecosystem and helping the conservation of plant species at forests, agro-ecosystems and residential areas. However, pests and predators including man is playing a crucial role on stingless bee population, interfere with their normal survival by conducting various activities such as blocking the bee's colony entrance by cement, mud, cow dung, plastic papers or bags and also by sticks. Many farmers and villagers spray pesticides into the nest entrance and sometime pour crude oil or chemicals inside the colony to kill the stingless bees. Unfortunately, farmers and local villagers are unaware of about stingless bees, their role and influence on pollination and propagation of different plant species [19, 28] at local environment.

The pest, *B. siccana* is regularly intervening with the normal activity of stingless bees [33]. The sub cortical beetle, *Bitoma* incidence was first reported with the stingless bee colonies in Korea by [34] and other parts of the world [33, 36, 50]. Other three new species of Colydiidae (Coleoptera: Heteromera) are interfering with the stingless bees in Andaman and Nicobar Islands, India [35]. However, very few published reports are available on cylindrical bark beetle *Bitoma siccana*, as it is regularly found in tropical regions of the old world. It is distributed in India, Australia, New Caledonia, Nepal, China Japan, Africa North Africa, Algeria, Egypt and Yemen, America, Europe region Italy [36]. In Asia region, *Bitoma siccana* incidences reported by [51, 34]. In India, [35] has reported first time *Bitoma siccana* from Andaman and Nicobar Islands. Surprisingly, during the present study, *B. siccana* infestation was recorded. Further, resin bee, *Megachile* (*Callomegachile*) and *Carinula* were identified as new species infesting stingless bees in Thailand [31]. During the present study, *Megachile* sub-genus *Callomegachile*

(Hymenoptera, Megachilidae) is creating havoc at Chandigarh and Punjab plains [32]. The solitary Magachile bee, *Megachile (Callomegachile) disjuncta* predatory activity was recorded at stingless bee colonies in Bangalore rural, Chikkaballapura and Kolar districts under natural conditions and even under laboratory conditions as well. These observations are new to this part of the state and no such reports are available and deserve to be claimed this report as first of its kind from south-eastern Karnataka as on today.

Similarly way, the drone-preying wasp is predating on the stingless bees and disturbing them at their natural colonies [38]. Even, Apes including man are constantly creating threat to stingless bees in agriculture ecosystem and forest reserve [29]. Hence, stingless bees are facing continuous threat by biological agents such as insect pests and vertebrate predators at various ecosystems [19] and human and non-human primates also. In fact, to overcome pests, predators and enemies interferences, stingless bees exhibit specific defending behavior [8, 30]. Mummification is one such defending behavior exhibited by stingless bees. Stingless bees mummify predators like spiders using nesting material [37] (Greco *et al.*, 2010). Although, stingless bees exhibit specific defending behavior [8, 30], but, the constant threat prevailed at various crop lands and residential areas severely progressing the population decline of stingless bees. It is one of the drawbacks with stingless bee population at different habitats. Further, man is hunting stingless bee colonies for extracting the honey and hive products [11] such as honey, pollen and cerumen which are used for various purposes including in the preparation of medicine. Similar type of observations were reported by [8, 21, 23, 29 to 38, 50] at different parts of the world. Pollinators like stingless bees are playing important role in changing landscapes at various crop lands [19]. Stingless bees influence the propagation of various crops [28] and improve the vegetation [22]. Hence, traditional beekeeping using stingless bee (e.g. *Trigona* sp) should be encouraged to farmers [14] to rear stingless bees for honey production, as pets and pollinators [11] amidst croplands and forest reserves. Despite all these constant interferences by pests and predators, Meliponiculture at human inhabited conditions and protecting stingless bee colonies in the wild is a challenging task. On this line, present investigation help provide useful scientific information to focus on these biological constraints to keep them away [15] from stingless bee population. In this regard, our observations are on par with the observations of [8, 21, 23, 29-32, 34-38, 50, 51].

Recommendations

- Stingless bees are keystone pollinator species at various agro-ecosystems and at human inhabited places, their conservation is very essential to restore the local biodiversity.
- Karnataka Biodiversity Board should take measures to create awareness about stingless bees among the farmers and villagers.
- Role of stingless bees should be conveyed to local Grama Panchayath level.
- Rearing of stingless bees should be demonstrated to farmers and villagers and
- Destruction of colonies should be prevented.

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