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A pilot study of honey samples from different mangrove plants of Sundarban forest: Making a case for *Aegiceras corniculatum* (khalsi) honey as a potential therapeutic agent

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Keywords: Sundarban; mangrove; honey; therapeutic; antioxidant, antimicrobial

Abstract

West Bengal has a unique ecosystem which is rich in bio-diversity and natural resources. Prominent features include a part of the world's largest ecosystem including the Sundarban mangrove forests. Although many reports have emphasized the immense value of this mangrove ecosystem, many of its natural products, like the 'Sundarban Honey', have not been characterized systematically and scientifically. Commercially available 'Sundarban honey' is not a single source product, but usually a blended sample. This pilot work presents preliminary results obtained from four mangrove floral sources that show significant anti-oxidant potential based on standard tests like estimation of their polyphenol and flavonoid content, FRAP value, DPPH assay. The average total polyphenol content of uni-floral honey samples varied from 26.5 ±1.0 mg (for khalsi) to 15.2 ± 1.2 mg (for gewa) while that of blended multi-floral honey was around 18 ± 3 mg of gallic acid equivalent. Flavonoid content of uni-floral honey ranged from 18.55 ± 0.79 mg (for khalsi) to 9.6 ± 1.05 mg (for gewa) while that of blended multi-floral honey was around 13-14 mg of quercetin per 100 g of honey. FRAP (ferric reducing ability of plasma) values ranged from 375 to 475 µM Fe (II) which is highly significant as compared to similar studies done by other groups. DPPH free radical scavenging assay showed khalsi honey giving considerable percent inhibition (42±2) which is close to that given by standard ascorbic acid. Honey samples also exhibit significant antimicrobial

efficacy against different bacteria even when diluted to 50-25%. Honey sample of khalsi plant seems to be most promising and consistent in its potential role as therapeutic agent, as per result of this pilot study. Batch-to-batch comparative analysis over a few seasons can further confirm consistency and sustainability.

Introduction:

Honey has been used in traditional medicine since ancient ages in many early civilizations. Currently, honey is used in industry mostly as a cheap source of sweetening agent. Its therapeutic value is severely underestimated, although it has been known to possess antimicrobial property and wound-healing activity, as well as anti-inflammation, anti-oxidant and anti-tumor effects (Goswami *et al*. 2017). Unfortunately, honey is used only as a last-resort medication, e.g. in the treatment of wound infections when antibiotics and other modern medicines fail. Its use in modern medicine is limited mainly due to lack of thorough scientific evidence of its therapeutic efficacy.

Commercially available 'Sundarban honey', sold under various names, is a wild multi-floral honey produced mostly by *Apis dorsata* bees (Mitra *et al* 2018). Some of the unique mangrove trees of the region include sundari (*Heritiera fomes*), gewa (*Excoecaria agallocha*), goran (*Ceriops decandra*), keora (*Sonneratia apetala*), khalsi (*Aegiceras corniculatum*) etc. (Barik and Chowdhury, 2014; Islam, 2016; https://naturewildlife.org/flora-of-sundarbans/).

According to West Bengal Forest Department, local honey collectors and bee-keepers association of Sundarban region, honey collection usually starts in March and continues intensely till May-June, every year. Major harvesting occurs in April-May (Mitra *et al* 2018). As a usual practice, the initial verification of the floral origin of each honey sample is provided by the beekeepers or honey collectors on the basis of corresponding hive location, season and available floral sources (Das *et al* 2013). The first blooms come in Khalsi trees. So, honey collected in early March is usually pure Khalsi honey (Chakraborti *et al*, 2019; Rahman *et al*, 2015). After that, blossoms start coming up **one by one** in other mangrove trees as well (like goran, keora, gorjon, pusur, kankra, gewa, etc); and after mid-May, as time progresses**,** the honey collected from different hives usually becomes a mixture from diverse floral sources. It is difficult to differentiate or separate them.

The composition and beneficial properties of each honey variety are reflections of its floral origin (Beretta *et al.,* 2005; Küçük *et al.,* 2007; Castro-Vázquez *et al.,* 2009; Goswami *et al*. 2017). It is important that honey samples from different plant sources in Sundarban be individually studied for their prophylactic, therapeutic and associated impact on health and the present work aims to do the same through systematic studies.

Materials and Methods:

Reagents and chemicals used were either bought from reputed companies like SRL/Himedia/Merck or were of analytical grade procured from local sources. Raw honey samples (total 100) from different individual floral sources like khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H) have been collected from Sundarban mangrove region, with help of local honey collectors, licensed traders and beekeepers, over two seasons. As mentioned before, initial identification of natural raw honey variety was made by the collectors. Confirmatory results of the floral origin were later obtained by pollen assay following standard protocol (Das et al, 2013), which was analyzed as the ratio of frequency of each pollen type in honey with respect to the total number of identified pollens (data not shown). Processed mutifloral 'Blended Sundarban Honey' (BSH) was purchased from West Bengal Forest Department, Aranya Bhawan, Bidhan Nagar , Block - LA, No - 10A, Sector –III, Kolkata - 700 106, and also from South 24-parganas Beekeeper' Cooperative Society Limited at Baruipur (Blended Apiary Honey or BAH). All the samples were stored at 0-4ºC and were analyzed within 3 months of storage period. The honey samples were kept at room temperature overnight before the analyses were performed. Experiments were performed with different percentage of aqueous solution of the honey samples (e.g. 10%, 20% etc.) as mentioned.

To measure the **total polyphenol content** of honey samples, Folin–Ciocalteu assay was employed as described previously (Meda *et al.,* 2005; Dhar *et al.,* 2011; Das *et al.,* 2013). For each honey sample, 0.5 ml of aqueous honey solution (20%) was added with 1 ml of Folin–Ciocalteu's phenol reagent (10-fold diluted). Next, 0.8 ml of 2% sodium carbonate and 60% methanol were successively added to the mix. Then the reaction mixture was incubated at room temperature for 30 min

and were analyzed in UV-Visible spectrophotometer at 740 nm. The calibration curve was plotted as per protocol, using gallic acid (0–100 mg/ml) as standard. The result of polyphenol content was represented as mg of gallic acid equivalents (GAE) per 100 g of honey. Formation of blue or green colour indicated the presence of phenols.

To quantify **total flavonoid content** of each of the honey samples, Aluminium chloride method was used as described before (Meda *et al.,* 2005; Das *et al.,* 2013). In each case, equal volume of 10% honey solution was combined with 2% aluminium trichloride ($AlCl_3$) dissolved in methanol. After 10 min of incubation at room temperature, absorbance was measured at 415 nm using a standard curve of quercetin (0-50 mg/ml). The results were expressed as mg of quercetin equivalent (QE) per 100 g of honey.

FRAP (ferric reducing ability of plasma) **assay** is a reliable test that is widely used for measuring total antioxidant capacity and is based on the capability of the sample to reduce the Fe^{3+} to Fe^{2+} in the presence of TPTZ (2,4,6-Tri[2-pyridyl]-1,3,5-triazine), forming a blue colored Ferrous - TPTZ complex with an absorption maxima at 593 nm (Das *et al.,* 2013; Goswami *et al*. 2017). To prepare fresh working FRAP reagent, as described before, 50 ml of 300 mM acetate buffer (pH-3.6) was mixed with 5 ml of 40 mM TPTZ dissolved in 40 mM HCl and 5 ml of 20 mM ferric chloride. With each honey sample, 400 µl of its 10% aqueous solution was added to 3 ml of freshly prepared working FRAP reagent. The absorbance at 593 nm was spectrophotometrically measured immediately and after 4 min of incubation at 37ºC. The change in absorbance was recorded as the final absorbance. For plotting calibration curve, ferrous sulphate ($FeSO_4.7H_2O$) was used as standard at various concentrations (100-500 µM). The ferric reducing ability of each honey sample was expressed as FRAP value (µM of FeII) of 10% honey solution.

Free radical scavenging assay was measured using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical test as described before (Das *et al.,* 2013). DPPH is stable nitrogen-centered free radical, extensively used for determining antioxidant activity. DPPH assay measures hydrogen (or electron) donating ability of the samples thereby decolourising DPPH radical from purple to yellow converting it to its reduced form. DPPH solution (0.1 mM) was mixed with either honey samples or standard solution and the decrease in absorbance of the mixture after 20 minutes of incubation in the dark was monitored at 517 nm. Results were expressed as % inhibition, which was calculated as [(Absorbance of Blank – Absorbance of sample)/ Absorbance of Blank] X 100. Distilled water was the control and ascorbic acid served as the standard.

Antimicrobial activity ~ Determination of minimum inhibitory concentration (MIC): The MIC value is defined as the lowest concentration of the test antimicrobial agent that inhibits the visible growth of the microorganism used in the assay (Balouiri *et al*. 2016; Wasihun *et al.* 2016). The different bacteria used in the study were *Escherichia coli, Bacillus subtilis, Staphylococcus aureus, Klebsiella pneumoniae*. The minimum inhibitory concentration of every honey sample was determined using broth tube dilution method following usual procedure of two-fold serial dilutions of each test sample (Wasihun *et al.* 2016). Briefly, for each honey sample and each bacterium, sterile test tubes were placed in rack, labeled as 'Test1', 'Test 2' and so on, containing serially diluted test honey sample (concentrations of 100%, 50%, 25%, 12.5%, 6.25%, 3.125% v/v). Honey control tube (HC) and growth control tube (GC) were also prepared. The GC tube received no honey (0%) and served as a positive growth control while the HC tube received no bacterial inoculums and served as a 100% honey control or negative growth control. Except the HC tube, each tube was inoculated with culture of respective prepared microorganism. After overnight incubation at 37ºC, the tubes were examined for turbidity indicating growth of the microorganisms. The lowest concentration of the test honey sample that inhibited growth of the microorganism as detected by the lack of visual turbidity (matching the negative growth control) was designated the minimum inhibitory concentration (Balouiri *et al*. 2016; Wasihun *et al.* 2016; Goswami *et al.* 2017).

Antimicrobial activity ~ Determination of minimum bactericidal concentration: MBC is defined as the lowest concentration of antimicrobial agent needed to kill 99.9% of the final inoculum after incubation for 24 h under a standardized set of conditions (Balouiri *et al*. 2016). In this method, the MBC can be determined after broth MIC assay, by sub-culturing a sample from tubes, yielding a negative visible microbial growth, on the surface of non-selective agar plates that do not contain the test

antimicrobial agent. The MBC is thus considered to be complementary to the MIC; whereas the MIC test demonstrates the lowest concentration of antimicrobial agent that inhibits growth, the MBC demonstrates the lowest concentration of antimicrobial agent that results in microbial death. This means that even if a particular MIC shows growth inhibition, plating the bacteria onto agar might still result in organism resuming its proliferation because the antimicrobial did not cause death. So, to determine bactericidal potential, the honey samples were subjected to MBC assay following MIC determination, using standard protocol, as described before (Balouiri *et al*. 2016; Wasihun *et al.* 2016). Then inoculated plates can be scored as bactericidal if no growth; bacteriostatic if there is light to moderate growth.

Results and Discussion:

All honey samples tested positive for flavonoid and phenolic compound content, as expected. The total phenolic content of different Sundarban honey samples followed the order: khalsi > goran > keora > gewa. Flavonoid content also followed the same order. Values are represented as mean ± SD (Figure 1; Table 1). The antioxidant activity seems to strongly correlate with this result (shown below).

The FRAP Test values reflect their reducing and hence anti-oxidant property (Figure 2). Values are represented as mean ± SD. (Table 1). The result of FRAP assay indicated that khalsi honey had higher ferric reducing potential in comparison to others, in agreement with its total phenolic and flavonoid content.

It is to be noted that the commercially available blended honey samples show higher range of deviation from respective mean value, suggesting higher variation in composition in different samples, which can be attributed to their multi-floral origin. (Figures 1, 2).

All the honey samples also showed significant radical scavenging activities, khalsi being the most significant (Figure 3).

All honey samples exhibited bacteriostatic and bactericidal activities in different dilutions, against the bacterial species tested, the effect being most pronounced against *E. coli* and least pronounced against *Staphylococcus aureus* (Figures 4, 5), thus suggesting considerable therapeutic potential. Khalsi honey seems to be most potent against *E. coli*.

This pilot project aimed to carry out a comparative study and understanding of the individual efficacy of different varieties of natural honey from different mangrove plants to estimate their potential to be regularly used in therapeutics or to make honey-based value-added products. Preliminary study indicates that the four tested honey samples possess significant and consistent antioxidant and antibacterial properties, the most promising being khalsi honey. So, the future plan is to carry out a more in-depth study on a larger scale for potential drug development using these natural products, with special focus on khalsi honey.

Acknowledgement:

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TABLE 1

Floral origin of honey	Total polyphenol content (mg of Gallic acid equivalent/100g of honey)	Flavonoid content (mg of quercetin equivalent/100g of honey)	FRAP Values [µM Fe (II) equivalence]
Khalsi (K1H)	26.5 ±1.0	18.55 ± 0.79	475 ±4.5
Goran (G1H)	18 ± 0.8	11.65 ± 1.0	410 ± 3.23
Keora (K2H)	16.5 ±1.5	10.4 ± 0.82	382 ±3.66
Gewa (G2H)	15.2 ± 1.2	9.6 ± 1.05	377 ± 4.57
Blended Sundarban Honey (BSH)	18 ± 3.1	13.4 ± 2.19	412 ±7.8
Blended Apiary Honey (BAH)	18.5 ± 2.8	14.2 ±1.59	415± 7.0

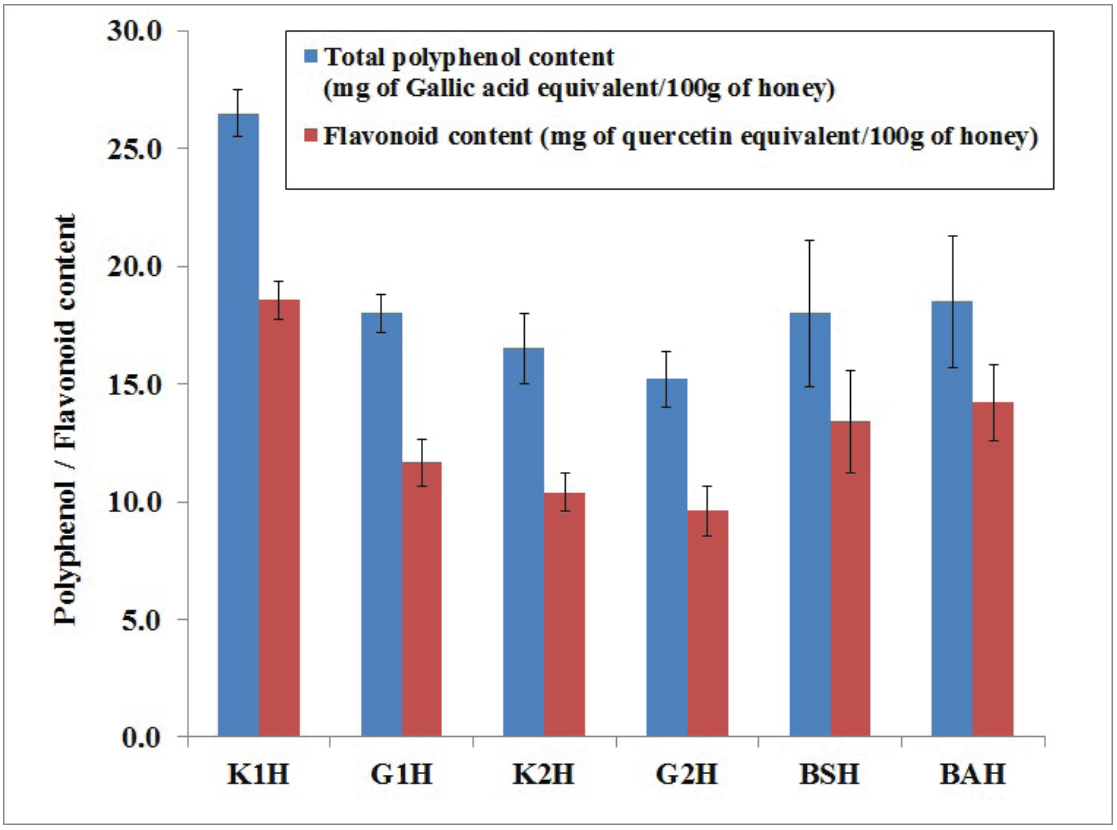

Figure 1: Total polyphenol and flavonoid content of different honey samples: khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H), Blended Sundarban Honey' (BSH), Blended Apiary Honey (BAH).

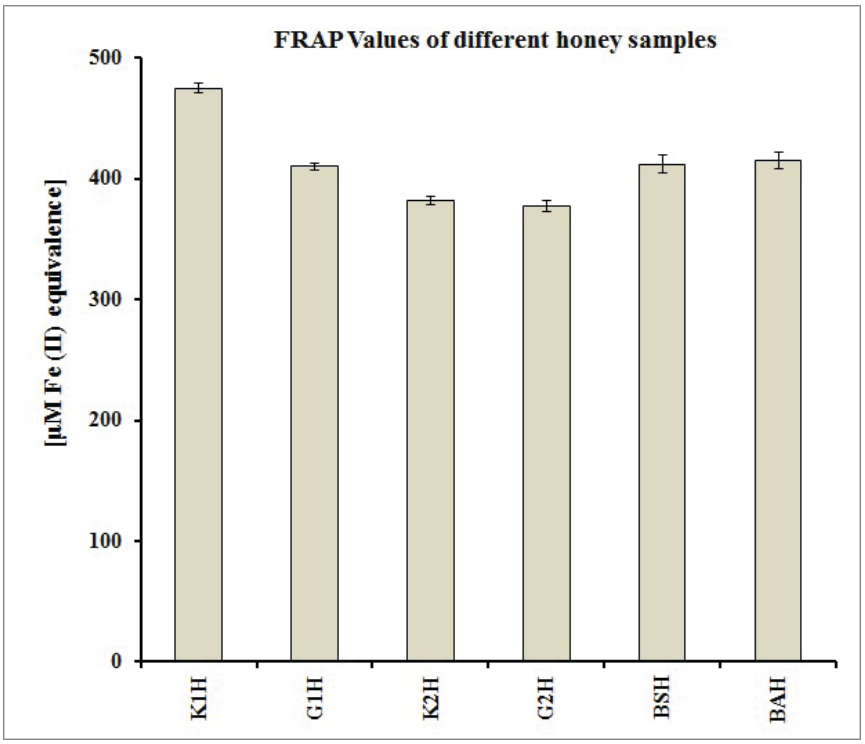

Figure 2: FRAP Values of different honey samples: khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H), Blended Sundarban Honey' (BSH), Blended Apiary Honey (BAH).

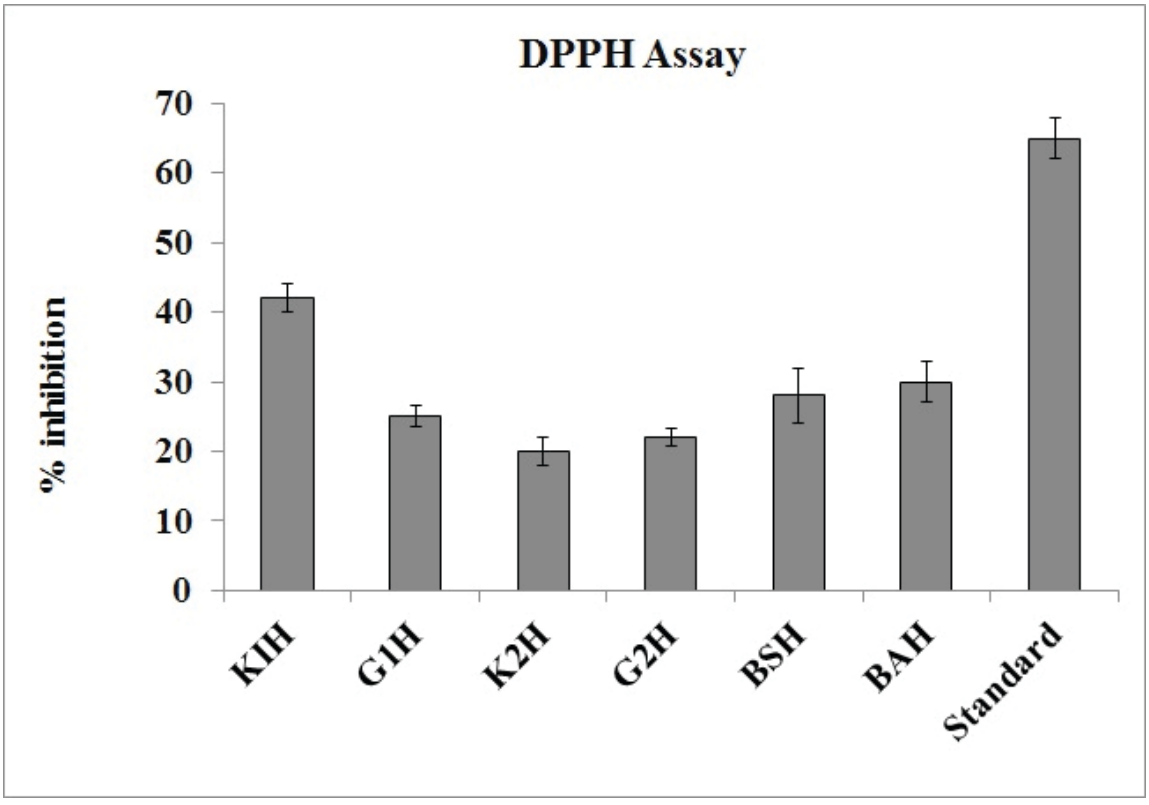

Figure 3: DPPH Assay result of different honey samples: khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H), Blended Sundarban Honey' (BSH), Blended Apiary Honey (BAH).

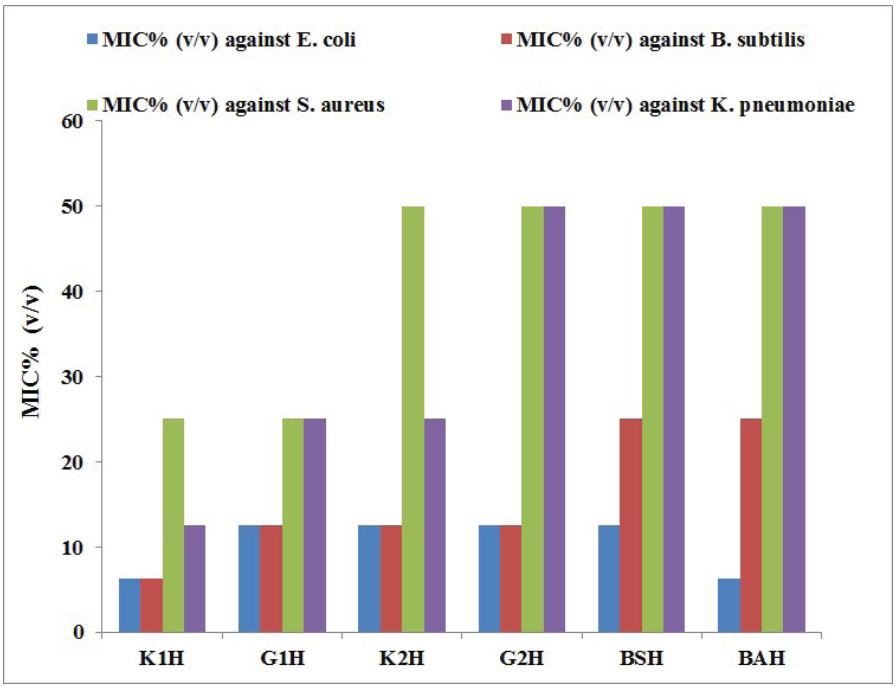

Figure 4: MIC Determination Assay Result of different honey samples: khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H), Blended Sundarban Honey' (BSH), Blended Apiary Honey (BAH) against different bacteria.

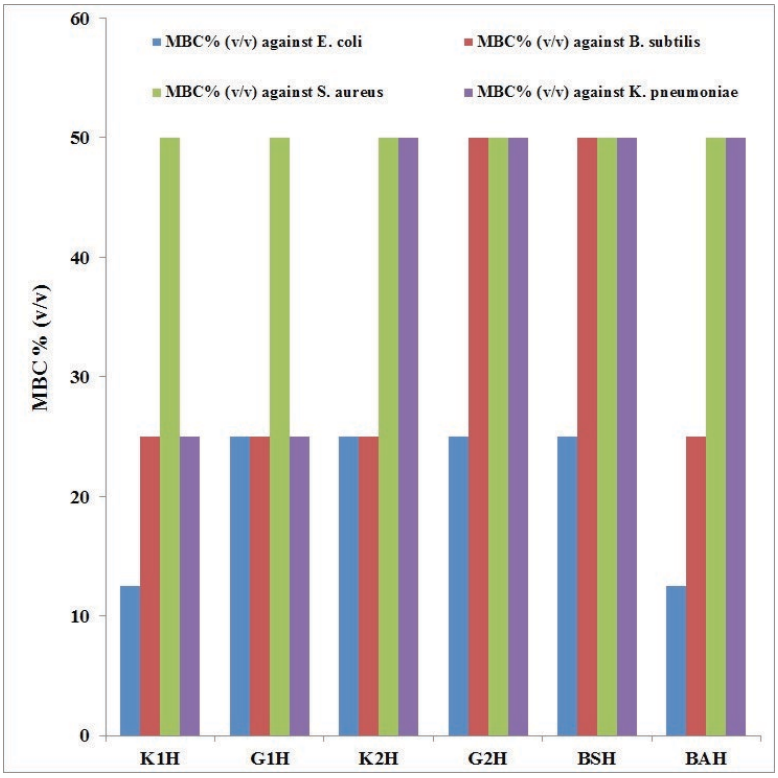

Figure 5: MBC Determination Assay Result of different honey samples: khalsi (K1H), keora (K2H), goran (G1H), gewa (G2H), Blended Sundarban Honey' (BSH), Blended Apiary Honey (BAH) against different bacteria.

Study of Birds in Unprotected Grassland Patches of South Solapur, District Solapur, Maharashtra State, India

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Abstract

The present study was conducted on the avifaunal diversity of unprotected grasslands patches in South Solapur tehsil, Solapur District and Osmanabad district, Maharashtra. The study shows that the major ground nesting birds included Ashy-crowned Sparrow Lark, Sykes Lark, Yellow-wattled Lapwing, Chestnut-bellied Sandgrouse, Indian Courser. The study also found that out of the 39 bird families Muscicapidae and Accipitridae contributed highest percentage (13% and 11%) followed by Alaudidae (6%), Cuculidae (6%), Phasianidae (5%), Columbidae (4%), Hirundinidae (4%) Laniidae (4%), Falconidae (4%) and all together these 9 families contributed 57% and remaining 27 families contribute 43% . Study recorded 94 bird species, out of which, 89 species (95%) are categorized as Least Concern, 4 species (4%) fall under the Near Threatened category, and 1 species (1%) is classified as Vulnerable. Study also found that there are 20 endemic species.

The grassland is facing shortage of rainfall, habitat fragmentation, overgrazing and other anthropogenic pressures.

Keywords: Avifaunal diversity, Grassland, Ground nesting birds, South Solapur

Introduction

Grassland birds are those birds that rely on grassland habitat for nesting and roosting and feeding. (Vickery *et al*., 1999) Solapur district is situated on the Southeast periphery of Maharashtra state. It is adjoining to Osmanabad district. The grassland ecosystem contains a diverse grouping of resident and migratory birds. The birds use the area for nesting, foraging, molting and wintering purposes. The breeding season of majority of

grassland birds starts with approaching summer season. Birds are exposed to human disturbance as farmers, poachers; cattle and visitors access the nest sites during the breeding season (Hippargi *et al., 2012)*

Grasslands are either overgrazed or considered as wastelands in need of expansion, industrial development, afforestation, and have been largely ignored in most governmental and conservation plans. (Rahmani 1988) Grassland birds are stated to be declining in many countries, largely due to habitat loss and degradation (Group *et al*., 1991; Knopf, 1994; Sauer *et al*., 2008; Tucker, 1991; Vickery *et al*., 1999). The situation of Indian grasslands is serious because India with just a fortieth of the total land mass of the world supports more than 50% of its buffaloes, 15% of its cattle, 15% of its goats and 4% of its sheep, and additionally, lacks a grazing policy (Rahmani, 1988). It is important to measure conservation issues of Indian grasslands at a landscape level, since these mainly fall under human-impacted landscapes and will eventually be influenced by the support and land-use practices of local communities, especially in the light of the problems arising from the growing human population and its impacts (Ranjit Manakadan, 2014). The study records the diversity of bird species in these grassland patches.

Materials and Methods

Study area

Solapur is located between 17.10 to 18.32 degrees north latitude and 74.42 to 76.15 degrees east longitude. The region is situated on the south east border of Maharashtra State and lies completely in the Bhima and Seena basins. Whole of the region is drained either by Bhima river or its tributaries. The region is bounded on the north by Ahmednagar and Osmanabad districts, on the east by Osmanabad and Gulbarga (Karnataka State) districts, on the south by Sangli and Bijapur (Karnataka State). Our study area is situated at the fringe of Solapur and Osmanabad district at south tehsil, . According to topography entire region divided into three natural zones Eastern zone, Central zone, Western zone (https://solapur.gov.in/en/geography/). The present study was carried out in unprotected grassland patches of south tehsil of Solapur district and Osmanabad district during the year 2019 to 2020 Study site included two sq.km.

Figure 1: Google earth image of Study area

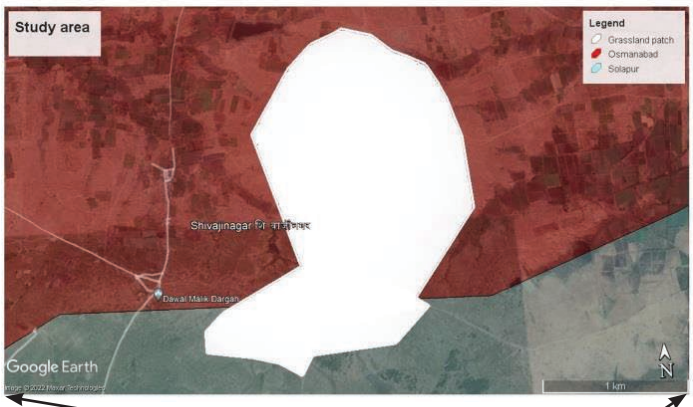

Image 3: Map showing boundaries of study site

Image 1: Map of Maharashtra

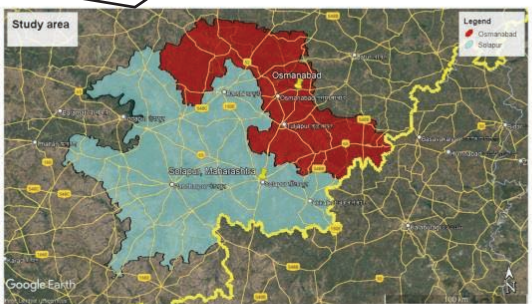

Image 2: Map of Solapur and Osmanabad district

area of unguarded grassland that is about 19 km, south of Solapur city (site 17°45'46.34"N and 17°45'46.34"N).

Survey methodology

Point count and line transect method was used record the bird diversity in the study area, surveys were carried in the morning session (7.00AM to 10.00AM) every month regularly during 2019 to 2020. Study area mainly consisted of grassland ecosystem with sporadic bushes, shrubs and herbs. Birds were observed by using Olympus and Nikon binoculars with magnification of 10X50, and photographs were taken for identification of birds. For photography Nikon D7500 camera was used with Nikkor 70-300mm VR lens and Tamron 150-600 mm Zoom lens. Based on photography and field observations, birds were identified using the field guides (Ali, 2006; Grimmete, 2008; Pande *et al* 2017).

Results and Discussion:

A total of 94 bird species belonging to 39 families were recorded. This study revealed that resident birds (n= 66, 71%) were higher in comparison to migrant (n=18, 19%) and local migrant (n=10, 10%) species. Ground nesting bird species included Ashy-crowned Sparrow Lark, Sykes Lark, Yellow-wattled Lapwing, Chestnut-bellied Sandgrouse, and Indian Courser. The study recorded that out of the 39 avian families, Muscicapidae and Accipitridae contributed highest percentage (13% and 11%) followed by Alaudidae (6%), Cuculidae (6%), Phasianidae (5%), Columbidae (4%), Hirundinidae (4%) Laniidae (4%), Falconidae (4%) and all together these 9 families contributed 57% and remaining 27 families contribute 43%.

Out of 94 species 20 species are endemic as per (Jathar and Rahamani 2006). Which contribute 18.8 % of total number of species. Among 94 (100%) bird species 89 (95%) species are Least concern, 4 (4%) species are Near threatened 1 (1%) species is Vulnerable.

The grassland is facing shortage of rainfall, habitat fragmentation, overgrazing and other anthropogenic pressures.

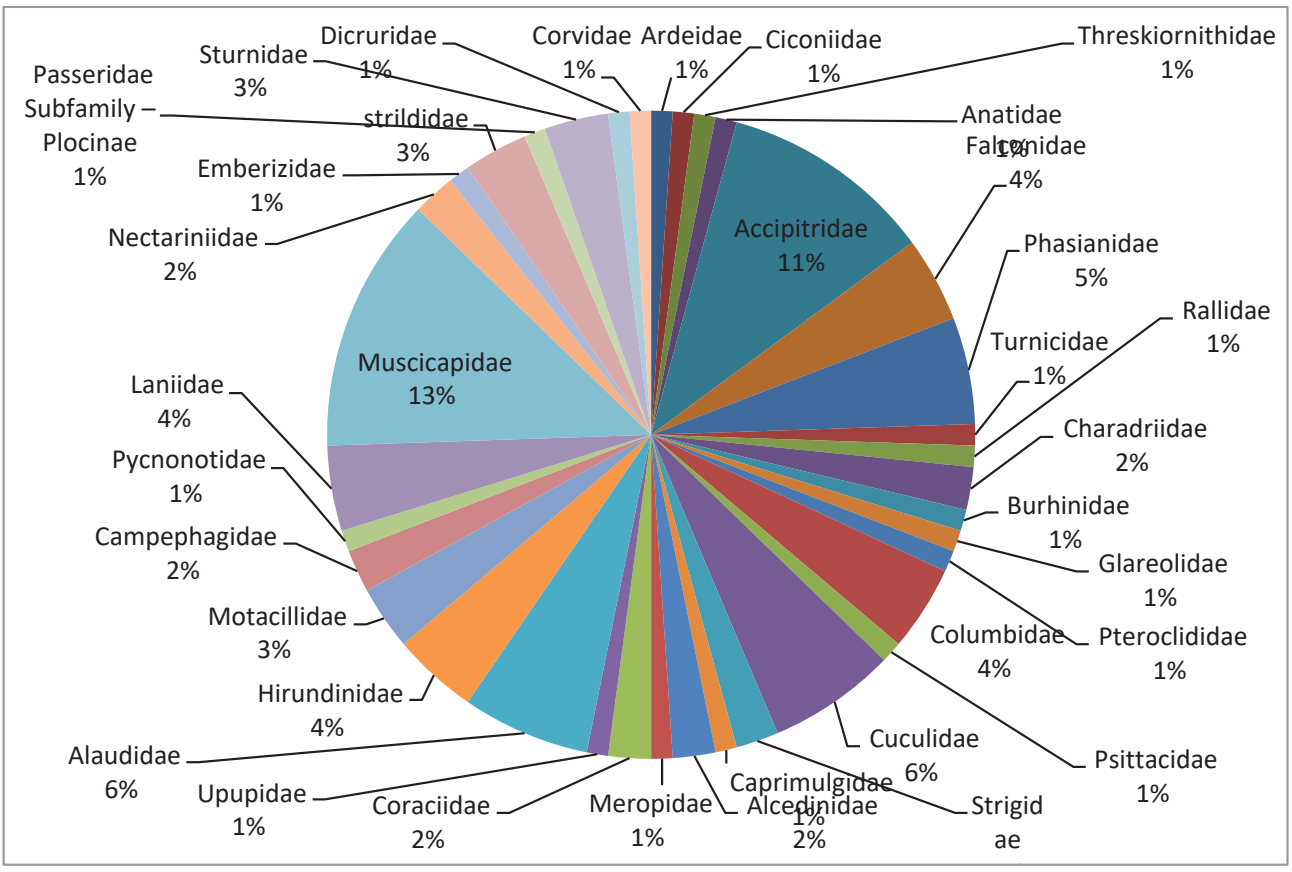

Figure 2 : Family level percentage composition of birds from grassland patches of south Solapur.

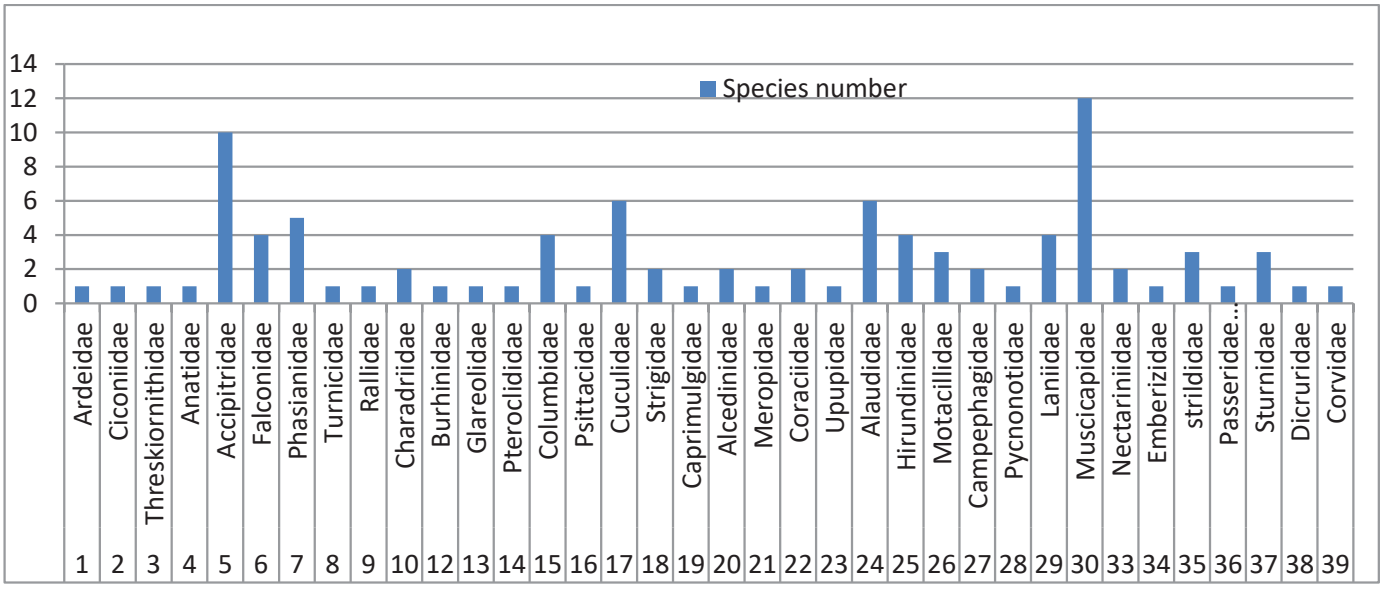

Figure 3: Graph showing Family wise species count of Bird found in grassland patches of south Solapur.

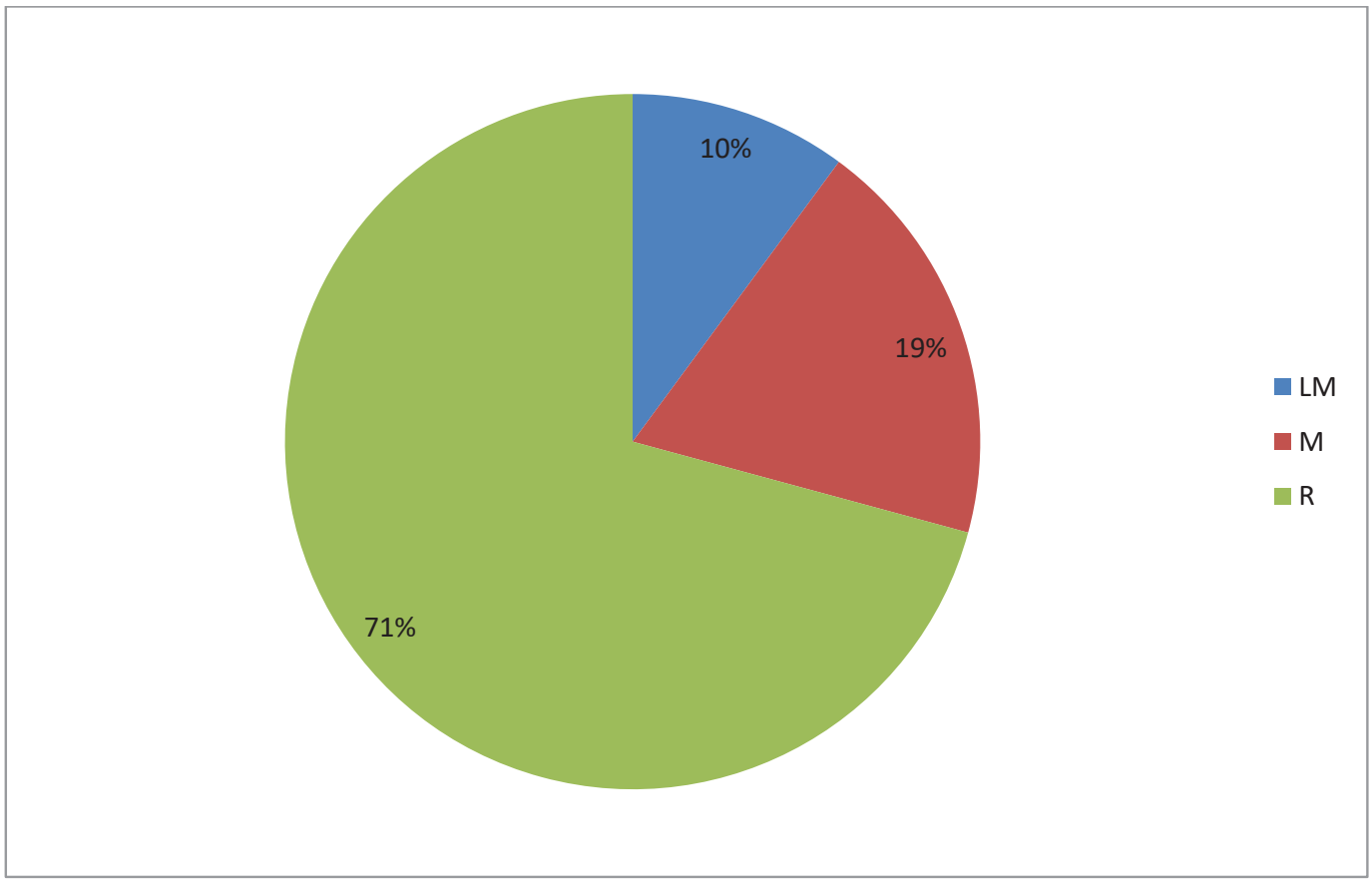

Figure 4: Bird status ratio of Resident (R), Local migrant (LM), Migrant (M) found in grassland patches of south Solapur.

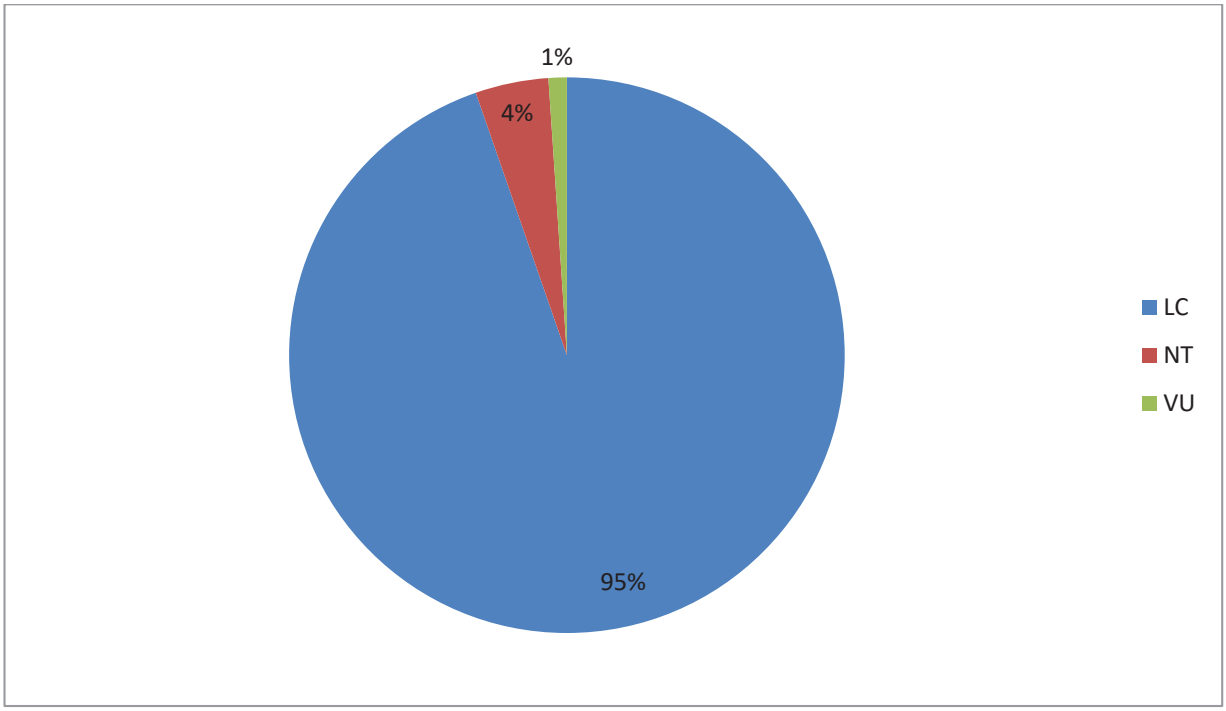

Figure 5: According to IUCN red list category Bird status ratio found in grassland patches of south Solapur.

Bay-backed Shrike *Lanius vittatus*

Black Drongo *Dicrurus macrocercus*

Little Green Bee-eater
Merops orientalis

Yellow-wattled Lapwing
Vanellus indicus

Indian Courser
Cursorius coromandelicus

Annexure 1 Check list of Birds found in study area.

Sr. no.	Family	Sr. No.	Common and scientific names	Status	R/ LM/ M	Endemism	IUCN Status
1.	**Ardeidae**		Indian Pond Heron *Ardeola grayii*	Common	R	_	LC
2.	**Ciconiidae**		Woolly-necked Stork *Ciconia episcopus*	Common	LM	_	**NT**
3.	**Threskiornithidae**		Indian Black Ibis *Pseudibis papillosa*	Common	R	**E SAM**	**LC**
	Anatidae		Indian Spot-billed Duck *Anas poecilorhyncha*	Common	R	_	**LC**
4.	**Accipitridae**		Black-Winged Kite *Elanus caeruleus*	Common	R	_	**LC**
			Black Kite *Milvus migrans*	Common	R	_	**LC**
			Brahminy Kite *Haliastur indus*	Common	R	_	**LC**
			Shikra *Accipiter badius*	Common	R	_	**LC**
			White-eyed Buzzard *Butastur teesa*	Common	R	_	**LC**
			Pallid Harrier *Circus macrourus*	Common	M	_	**NT**
			Montagu's Harrier *Circus pygargus*	Common	M	_	**LC**
			Pied Harrier *Circus melanoleucos*	Uncommon	M	_	**LC**
			Short-toed Eagle *Circaetus gallicus*	Common	R	_	**LC**
			Bonelli's Eagle *Aquila fasciatus*	Common	R	_	**LC**
			Tawny Eagle *Aquila rapax*	Rare	R	_	**VU**
	Falconidae		Eurasian Kestrel *Falco tinnuncullus*	Common	M	_	**LC**
			Laggar Falcon *Falco jugger*	Rare	LM	**NE SAM**	**NT**
			Red-necked Falcon *Falco chicquera*	Common	LM	_	**NT**
5.	**Phasianidae**		Painted Francolin *Francolinus pictus*	Common	R	**E SAM and SL**	**LC**
			Gray Francolin *Francolinus pondicerianus*	Common	R	**NE SAM**	**LC**
			Rain Quail *Coturnix coromandelica*	Common	R	_	**LC**
			Rock Bush-quail *Perdicula argoondah*	Common	R	**E SAM and SL**	**LC**
			Indian Peafowl *Pavo cristatus*	Common	R	**E SAM and SL**	**LC**
6.	**Turnicidae**		Barred Buttonquail *Turnix suscitator*	Common	R	_	**LC**
7.	**Rallidae**		White-breasted Waterhen *Amaurornis phoenicurus*	Common	R	_	**LC**

8.	**Charadriidae**		Red-wattled Lapwing *Vanellus indicus*	Common	R	_	**LC**
			Yellow-wattled Lapwing *Vanellus malabaricus*	Common	LM	**E SAM and SL**	**LC**
9.	**Recurvirostridae**		Black-winged Stilt *Himantopus himantopus*	Common	R	_	**LC**
10.	**Burhinidae**		Eurasian Stonecurlew *Burhinus oedicnemus*	Common	R	_	**LC**
11.	**Glareolidae**		Indian Courser *Cursorius coromandelicus*	Common	R and LM	**E SAM and SL**	**LC**
12.	**Pteroclididae**		Chestnut-bellied Sandgrouse *Pterocles exustus*	Common	R	_	**LC**
13.	**Columbidae**		Blue Rock Pigeon *Columba livia*	Common	R	_	**LC**
			Eurasian Collared-dove *Streptopelia decaocto*	Common	R	_	**LC**
			Laughing Dove *Spilopelia senegalensis*	Common	R	_	**LC**
			Red Collared-dove *Streptopelia tranquebarica*	Common	R	_	**LC**
			Spotted Dove *Spilopelia chinensis*	Common	R	_	**LC**
14.	**Psittacidae**		Rose-ringed Parakeet *Psittacula krameri*	Common	R	_	**LC**
15.	**Cuculidae**		Jacobin Cuckoo *Clamator jacobinus*	Common	M	_	**LC**
			Grey-bellied Cuckoo *Cacomantis passerines*	Uncommon	LM	**E SAM and SL**	**LC**
			Common Hawk Cuckoo *Hierococcyx varius*	Common	R	**E SAM and SL**	**LC**
			Indian cuckoo *Cuculus micropterus*	Uncommon	LM	_	**LC**
			Asian Koel *Eudynamys scolopaceus*	Common	R	_	**LC**
			'Southern' Coucal *Centropus [sinensis] parroti*	Common	R	_	**LC**
16.	**Strigidae**		Spotted Owlet *Athene brama*	Common	R	_	**LC**
			Short-eared Owl *Asio flammeus*	Uncommon	M	_	**LC**
17.	**Caprimulgidae**		Indian Little nightjar *Caprimulgus asiaticus*	Common	R	_	**LC**
18.	**Alcedinidae**		White-throated Kingfisher *Halcyon smyrnensis*	Common	R	_	**LC**
			Common Kingfisher *Alcedo atthis*	Common	R	_	**LC**
19.	**Meropidae**		Little Green Bee-eater *Merops orientalis*	Common	R	_	**LC**

	Coraciidae		European Roller *Coracias garrulous*	Common	M	_	**LC**
			Indian Roller *Coracias benghalensis*	Common	LM	_	**LC**
	Upupidae		Common Hoopoe *Upupa epops*	Common	LM	_	**LC**
	Alaudidae		Indian Bush Lark *Mirafra erythroptera*	Common	R	**E SAM and SL**	**LC**
			Ashy-crowned Finch-lark *Eremopterix griseus*	Common	R	**E SAM and SL**	**LC**
			Rufous-tailed Lark *Ammomanes phoenicura*	Common	R	**E SAM and SL**	**LC**
			Sykes's Lark *Galerida deva*	Common	R	**E SAM and SL**	**LC**
			Oriental Skylark *Alauda gulgula*	Uncommon	R	_	**LC**
			Greater Short-toed Lark *Calandrella brachydactyla*	Common	M	_	**LC**
	Hirundinidae		Barn Swallow *Hirundo rustica*	Common	M	_	**LC**
			Wire-tailed Swallow *Hirundo smithii*	common	R	_	**LC**
			Streak-throated Swallow *Petrochelidon fluvicola*	Fairly common	R	_	**LC**
			Red-rumped Swallow *Cecropis daurica*	Common	R	_	**LC**
	Motacillidae		Tree pipit *Anthus trivialis*	Common	M	_	**LC**
			Paddyfield Pipit *Anthus rufulus*	Common	R	_	**LC**
			Richard's Pipit *Anthus richardi*	Common	M	_	**LC**
	Campephagidae		Common Woodshrike *Tephrodornis pondicerianus*	Uncommon	R	_	**LC**
			Small Minivet *Pericrocotus cinnamomeus*	Common	LM	_	**LC**
	Pycnonotidae		Red-vented Bulbul *Pycnonotus cafer*	Common	R	_	**LC**
	Laniidae		Great Gray Shrike *Lanius excubitor*	Common	M	_	**LC**
			Bay-backed Shrike *Lanius vittatus*	Uncommon	M	_	**LC**
			Long-tailed Shrike *Lanius schach*	Common	R	_	**LC**
			Isabelline Shrike *Lanius isabellinus*	Common	M	_	**LC**
	Muscicapidae **Subfamily – Turdinae**		Common Stonechat *Saxicola maurus*	Common	M	_	**LC**
			Pied Bushchat *Saxicola caprata*	Common	R	_	**LC**
			Indian Robin *Copsychus fulicatus*	Common	R	**E SAM and SL**	**LC**
			Isabelline Wheatear *Oenanthe isabellina*	Uncommon	M	_	**LC**

	Subfamily – Timalinae		Large Grey Babbler *Turdoides malcolmi*	Common	R	**E SAM and SL**	**LC**
			Yellow-eyed Babbler *Chrysoma sinense*	Common	R	_	**LC**
	Subfamily – Silvinae		Zitting Cisticola *Cisticola juncidis*	Common	R	_	**LC**
			Plain Prinia *Prinia inornata*	Common	R		**LC**
			Ashy Prinia *Prinia socialis*	Common	R	**E SAM and SL**	**LC**
			Common Tailorbird *Orthotomus sutorius*	Common	R	_	**LC**
	Nectariniidae		Purple Sunbird *Cinnyris asiatica*	Common	R	_	**LC**
			Purple-rumped Sunbird *Leptocoma zeylonica*	Common	R	_	**LC**
	Emberizidae		Grey-necked Bunting *Emberiza buchanani*	Common	M	_	**LC**
	Estrildidae		Indian Silverbill *Euodice malabarica*	Common	R	_	**LC**
			Tricoloured Munia *Lonchura malacca*	Common	R	**E SAM and SL**	**LC**
			Scaly-breasted Munia *Lonchura punctulata*	Common	R	_	**LC**
	Passeridae Subfamily – Plocinae		Baya Weaver *Ploceus philippinus*	Common	R	_	**LC**
	Sturnidae		Rosy Starling *Pastor roseus*	Common	M	_	**LC**
			Brahminy Starling *Sturnia pagodarum*	Common	R	**E SAM and SL**	**LC**
			Common Myna *Acridotheres tristis*	Common	R	_	**LC**
	Dicruridae		Black Drongo *Dicrurus macrocercus*	Common	R	_	**LC**
	Corvidae		Large-billed Crow *Corvus [macrorhynchus] culminatus*	Common	R	**E SAM and SL**	**LC**

*** E SAM and SL -** Endemic to the South Asian mainland and Sri Lanka
*** NE SAM -** Near Endemic to mainland South Asia

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All Photos : Balasaheb Lambture

Grassland habitat

Butterflies of Urban Landscape: A Review on Conservation Ecology of Diurnal Lepidoptera

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Abstract

The Anthropocene is leading to environmental disturbances that affect biodiversity. Butterflies are often considered as bio-indicatorsof environmental changes. In order to determine the status quotient of the ecology of butterflies in urban areas, we compiled exactly 106 published papers, publications focussed on butterflies, of which 95 (the remaining 11 papers were for references only), are from 2000 to 2020 from 20 states of India, relating to urban ecology and conservation practices and management. We have classified 95 review papers into three broad categories, 46 paper addressed ecological topics (48.42%), 27 papers (28.42%) were focused on species list/checklist and 22 papers (23.15%) corresponded to the biological conservation studies. The monitoring of Lepidopterans can thus be used to improve the strategies of planning, management and conservation of urban biodiversity.

Keywords:

Urbanization, Diurnal Lepidoptera, Bio-indicator, Conservation Management, Bio-diversity.

Introduction

Biodiversity provides various ecosystem services such as purifying air and water, regulation of water flows, modification of regional and local climate change and rainfall (Bolund and Hunhammer 1999); aesthetic gratification and recreation (Miller 2005, 2006) andplays a role in conservation education of human population (Miller and Hobbs 2002). Today,

in view of high rate of urbanization, the fundamental challenge for planning conservation is to understand how it isinfluencing the biodiversity (McKinney 2002; Hansen et al. 2005; Fragkias et al. 2013). Currently half of total human population resides in cities and it is estimated that by 2030 approximately 5 billion of human population will reside in urban areas (UN DESAPD, 2015). Rapid urbanization in developed and developing countries like America and India is leading to severe changes in environment (UN DESAPD, 2015). Unlike habitat modification leading to water logging, where forests may rejuvenate over time through ecological succession (Sheil and Burslem 2003), urbanization often irreversibly modifies natural habitats by replacing primary forests with artificial ones which ultimately results in long lasting negative impacts such as species extinctions (Stein et al. 2000). Thus, urbanization has been recognized as one of the major negative causes of biodiversity threat (Czech et al. 2000; McKinney 2002; Berkowitz et al. 2003; Alberti 2008; Shochat et al. 2010; Kowarik 2011).

Various studies have addressed this issue for the past seven decades (McDonnell et al. 2009; Gaston 2010; Aronson et al. 2014), evaluating both increase and decrease in richness of wildlife species depending on numerous variables such as taxonomic group, intensity of urbanization and spatial scale (McKinney 2002, 2006, 2008; Kowarik 2011; Jones and Leather 2012; Soga et al. 2015, Moreno et al. 2007). Butterflies are highly susceptible to environmental changes such as change in temperature, solar radiation, humidity, wind speed and air quality, hence, butterfly richness, is a suitable tool for assessing impact of modification of habitats particularly urbanization and pollution on biodiversity (Kremen 1993; Wagner et al. 2003; Garćia et al. 2007; Settele et al. 2008; Li et al. 2009). Butterflies have extremely selective diet and host plant specificity during their developmental stages and most butterfly species primarily depends upon robustness of surroundings (Kocher and Williams, 2000; Thomas et al., 2001; Eichel and Fartmen, 2008; Garcia-Barros and Fartmann, 2009). Their population in metropolitan and polluted areas is decreasing (Thomas et al., 2005) hence they are useful and rapidly responding bio-indicators for monitoring conservation strategies (Watt and Boggs, 2003; Ehrlich and Hanski, 2004, Rouquette et al. 2013; MacGregor-Fors et al. 2015; Lee et al. 2015; Sing et al. 2016a, b; Tam and Bonebrake 2016, Hanski, 1999, Grimm et al., 2008; Shochat et al., 2010).In this paper, we compiled published papers on urbanization and urban butterflies to determine various ecological patterns of butterflies in urban areas such as butterflies in metropolitan areas, major studied topics about butterflies in urban areas, global ecological patterns and response of butterflies towards the urbanization. We compiled all accessible urban butterfly publications and classified them in broad topics.

Methods

We compiled published studies focused on butterflies of urban areas from India. We searched academic databases such as ResearchGate (www.researchgate.net), Google Scholar (www.scholar.google.com), Academia (www.academia.edu), Wiley Online Library (http://onlinelibrary.wiley.com/) and Web of Science (www.webofscience.com); Journals were searched using keywords like diurnal Lepidoptera,urbanization, "Urban" AND "Butterflies", "Industrialization" AND "Effect" AND "Butterflies", "Urban" AND "Butterflies" AND "India", "Urbanization" AND "Diurnal" AND "Lepidoptera", Conservation AND UrbanButterflies.

We classified the papers by location (i.e., region/district/city and state), year of publication, and three common themes: (1) *Ecological Prototypes*– publications that explored correlation of butterflies with other organisms or natural variables; (2) *Species records* – publications where fundamental objective was to record butterfly species of a given locality; and (3) *Conservation biology* – publications focused on conservation status or conservation activities including one or more butterfly species. When more than one point was addressed in the publicationwe considered the main objective in that paper.

Results

Our investigation on urban ecology of butterflies allowed us to assemble 92 publications focused exclusively on butterflies of urban areas. **State and region-wise publications** are as follows; West Bengal: (*n = 12*); Maharashtra: (*n = 12*); Uttrakhand (*n = 6*); Madhya Pradesh (*n = 5*); Karnataka (*n = 5*); Uttar Pradesh (*n = 8*); Tripura (*n = 4*); Tamil Nadu (*n = 5*); Western Ghats (*n = 4*); Himachal Pradesh (*n = 3*); Assam (*n = 6*); New Delhi (*n = 4*); Odhisa (*n = 4*); Kerala (*n= 2*); Gujarat (*n = 5*); Western Himalayas (*n

= *2*); Punjab (*n = 3*); Meghalaya (*n = 1*); Ranchi (n = 1); Arunachal Pradesh (n = 3) (Table1). Ecological prototypes top the list (48.42%) followed by Species list/ Checklist (28.42%) and biological conservation studies (23.15%) (Fig 1).

1] Ecological prototypes

Most studies in this category (n = 46) mainly centred on diversity, abundance, richness, of urban butterflies. More than half of the regained publications were from West Bengal, Maharashtra, Uttrakhand, Madhya Pradesh, New Delhi, Gujarat, Karnataka and Tamil Nadu. According to their occurrence in time, we classified them as Pioneer studies (2000-2010) and modern studies (2011-2020)

1 a) Pioneer Studies (2000-2010)

From 95 publications foremost urban butterfly study with an ecological priority was performed in Pune city, Maharashtra (Kunte, 2000) who calculated the butterfly diversity along the human impact gradient and found that around 170 species of butterflies out of which 103 are so far reported from urban area of Pune within a radius of 20km. Enduring species are predominantly forest dwellers. Sharma and P.C Joshi in their survey of 2002-04 and published in 2009, concluded a total 41 species of butterflies belonging to 5 families in their survey area of Dholbaha dam (District Hoshiarpur) in Punjab Shivalik. In 2005, Bhardwaj and Uniyal (2009) conducted survey in Kullu, Himachal Pradesh at proposed hydroelectric project area from five study sites (Deodar Forest, Blue Pine Forest, Alpine Pastures and Human Degraded Forest) and concluded that Human degraded forest (HDF) was dominated by more number of ordinary species. Gosh and Siddiqui (2005); (conducted field survey from April 2002 to May 2004) explored 11 sites out of which 5 sites were considered as "Influenced" (Human interferences and activities) zone. They found total 68 species of butterflies, least from urban areas; the species ranged from 28-38. Uniyal (2007) studied butterflies in the Great Himalayan Conservation Landscape in Himachal Pradesh, Western Himalayas and reported 75 species of butterflies belonging to 48 genera from different elevation and watershed. In 2007, Tiple, Khurad and Dennis carried out an investigation in Sant Gadge Baba Amravati University, Maharashtra, contrasting on butterfly diversity related to human impact gradient and availability of human resources on the site. They found that the area in and around buildings of the university campus harboured 35 species in which none of them was unique. Arun P. Singh 2010, conducted a survey in 2008 in Anuka Reserve Forest, Jharkhand where the total 999.9ha of area was proposed for lease under an iron ore mining project. He indicated high beta diversity of butterflies and recorded 71 species of butterflies; however, most of them were common and species. Tiple and Khurad 2009, estimated 145 species of butterflies in and around Nagpur City, Central India and concluded Nagpur area was rich in diversity probably due to the favourable tropical climatic conditions and also stated that few butterflies which were previously recorded from study area was not seen in their study period probably because of habitat loss by ever increasing urbanization. Ramesh *et al.,* (2010), conducted a study in DAE (Department of Atomic Energy) campus at Kalpakkam, Tamilnadu and recorded 55 species of butterflies belonging to 5 families, out of which family Nymphalidae was dominant with 20 species and concluded that species recorded from highly disturbed area was less than species recorded ingarden and scrub forest.

1 b) Modern Studies (2011-2020)

In this category studies were found from West Bengal (n = 7), Maharashtra (n = 4); Uttar Pradesh (n = 3); Madhya Pradesh (n = 3); Uttrakhand (n = 2); Karnataka (n = 2); Western Himalayas (n = 2); Tamil Nadu (n = 1); Gujarat (n = 1). The focus of these studies included five categories. 1. Diversity of butterflies in Urban and suburban habitats; 2. Utilization of resources; 3. Threats of urbanization; 4. Seasonal dynamics and 5.Developmental biology and eco-ethology. In order to understand alteration in the responses of butterfly diversity at changed intensities of urbanization several studies have been performed in urban gradients such as urban fragments, urban-rural habitats, and urban exurban gradient.

Although most of the reviewed publications reported a negative effect of urbanization on the butterfly population, one study from Madhya Pradesh found a strong positive effect of urbanization on the butterfly diversity in that particular study area.

Nimbalkar et al., (2011), studied the response of butterflies in relation to nectar plants in urban areas of Pune district, from August 2007 to August 2009. 64

species of butterflies were recorded belonging to five families. Study from Tropical Forest Research Institute, Madhya Pradesh, Tiple (2012), reported 66 species of butterflies belonging to 47 genera and 5 families. The findings of the presented study says that the site was in constant disturbances due to various human activities which may be the reason of overall reduction of the number of species, it also underlined the significance of institutional buildings as preferred habitats of butterflies. Sarma et al. (2012), studied the diversity and habitat association of butterfly species in foothills of Arunachal Pradesh (Itanagar) by choosing the human impacted site which is North Eastern Regional Institute of Science and Technology (NERIST) and recorded 63 species of butterflies. Open grassland site was found to have high species richness followed by forest patch and lowest in roadside plantation and home gardens. In 2013 Reddy and Ravikantha chari carried out a study on Effect of Induced Environmental Stress on the Butterfly, *Catopsilia pomona*. (Lemon Emigrant). One of the objectives of this study was developmental biology of the species. They showed that phytochemicals affected development of butterflies. Arya et al., (2014), monitored species richness of butterflies in and around Kumaun University, Nainital, Uttrakhand based on seasonal pattern and found maximum numbers of individuals of butterflies were present in rainy season followed by summer and winter. In Assam, Bora and Meitei (2014), highlighted the diversity of butterflies in university campus of Cachar district and recorded total 96 species from different habitat types. Kumar and Murugesan (2014), carried out survey around 30 km of Kudankulam Nuclear Power Plant area, Tirunelveli, Tamil Nadu, and yielded 6347 individuals of 64 species and stated that studies on monitoring the species diversity and abundance of butterflies gives valuable information on their population dynamics. Kumar(2014), surveyed urban areas of Jhansi, Uttar Pradesh and recorded 38 species of butterflies, as a baseline data for that region. In 2016, Chaudhuri and Basu, studied butterfly diversity along the urban and rural gradient in fiveurban sites of Kolkata and recorded 925 butterflies belonging to 28 species. Saraf and Jadesh (2016) conducted a systematic survey and recorded a total 52 species from 29 genera and 5 families. They suggested that control and prevention of fire and grazing in green patches could be the first positive step to sustain butterfly diversity. Gosh and Mukherjee (2016), studied butterfly diversity in Sreampore, West Bengal and identified 38 species of butterflies and mentioned the conservation of flora in a sustainable manner to increase the richness of butterflies. Mehra et al., (2017) recorded 493 species from 219 genera from western Himalayas out of which 89 species were found to be endemic. Thakur and Chaudhuri (2017), performed eco-ethological studies of butterfly species of a garden in urban area of Kolkata and observed that a suitable habitat including host and nectar food plants led to higher number and activity of butterfly species including basking, resting, hovering, chasing, courtship flight, mud puddling, and feeing. A butterfly park or garden helps to maintain the diversity of natural pollinators because there are many environmental stresses in urban areas and gardens can reinstate and sustain the healthy ecosystem for butterflies. Their study also emphasized the importance of weed as a part of butterfly conservation strategies. In 2018 Kumar and Rana, carried out a survey on species diversity in urban forest fragments of Lucknow, Uttar Pradesh and recorded 30 species belonging to 26 genera and 5 families. Gandhi et al., (2018) studied butterfly diversity around an irrigation reservoir in the semi-arid zone of Gujarat and recorded total 42 species of butterflies dominated by family Nymphalidae (38%) over Pieridae (31%), Lycaenidae (21%) and Papilionidae (10%). Patil et al., (2019) presented a paper on butterflies in and around Vita City, Sangli, Maharashtra and reported 33 species belonging to 24 genera and 5 families and found highest number of butterflies from vegetated or grassland area and least in human disturbed area. Gupta et al., (2019) studied the effect of temperature and humidity gradient on butterfly assemblages in sub-tropical urban landscape of National Capital Region (NCR)/ New Delhi and found that butterfly community showed a biannual peak of abundance and species richness in pre-monsoon period (April and May) unlike most other studies from India which reported these months as of lowest diversity. Meshram et al., (2020) found 42 species of butterflies in Mahatma Phule A.S.C College Campus, Panvel, Maharashtra. The area was highly affected by various anthropogenic activities including the ongoing construction of Navi Mumbai International Airport. Laghude et al., (2020) conducted a study in the moderately disturbed forests and along forest edges of Karjat, Maharashtra, India, and recorded 45 species of butterflies belonging to 33 genera in 5 families.

2] Species List/Checklist

We compile 27 publications of butterfly species lists/ checklist from urban landscape (Panda et al., 2016; Mukherjee et al., 2016; Kumar 2020; Sidat et al 2020; Buragohain et al., 2018; Biswas et al., 2017; Padhye et al., 2012; Gandhi et al., 2017), intra or semi urban and non-urban habitats such reserves, sanctuaries, wetlands etc., (Chowdhury et al., 2011; Kumar et al., 2014, 2018; Amala et al., 2011; Tiple et al., 2009; Deokar et al., 2015; Kanaujia et al., 2015; Gandhi et al., 2017) and butterfly parks, botanical gardens and University campuses (Sushmita et al., 2021; Kumar 2012; Mohapatra et al., 2013; Kumar Adesh et al., 2016); Anila et al., 2017; Saini et al., 2017). The urban butterfly species diversity changed with study site, sampling effort and survey method

3] Biological Conservation

In Biological Conservation we compiled 22 research papers. Soumyajit Chowdhary (2014), studied taxonomic diversity, ecology and conservation of butterflies in Sundarban Reserve, West Bengal and recorded 76 species of butterflies and concluded that current scenario of increased pressure towards deltaic mangrove ecosystems, exploration specific larval host plants and niche specifications of some exclusive species may help in the long run for conservation programmes and ecosystem management of highly threatened and bio diverse deltaic area of Sundarban Reserve. Mukherjee, et.al., (2015), conducted a study on conservation management of butterfly diversity in Kolkata and encountered 96 species of butterflies in and around Kolkata, with shifting relative abundance in the urban, rural and sub-urban landscapes, and concluded that the occurrence of species diversity were high in sub-urban area followed by rural and urban area. In 2015 Khan and Rastogi, studied impact of mining activity on butterfly population and community composition in Singrauli, Madhya Pradesh and found a strong positive impact of mining activity and butterfly diversity due to the revegetation around the mining site. The overall abundance, richness and diversity of butterfly assemblages increased with increase in mineregionrestoration.Further, they concluded that correspondence study divulges that most species of family Nymphalidae showed a strong positive relationship with the extremely disturbed sites and are consequently disturbance tolerant. Shukla and Maini (2015), suggested few measures to reduce the impact of urbanization and development on butterflies by planting more endemic trees and plants, maintenance and landscaping of forest regions and careful planning of plantation. Thakur et al., (2017) suggested that setting up of butterfly garden in urban areas could minimise the effect of urbanization on butterfly diversity and help them to thrive better. Mukherjee et al., (2018), reported total 48 species of butterflies linked to 30 different flowering plants of one year survey in Kolkata. Further analysis showed that apart from shrubs, various herbaceous plants were also helpful in nourishing butterfly population. Sharma et al, 2021 conducted a survey in Butterfly Garden of Nawab Wajid Ali Shah Zoological Garden, Lucknow, Uttar Pradesh and reported 62 butterflies and stated that the environment and availability of nectar and host plants in butterfly park of Lucknow Zoo was suitable for butterflies.

Discussion

We have classified 95 review papers into three broad categories, 46 paper addressed ecological topics (48.42%), 27 papers (28.42%) were focused on species list/checklist and 22 papers (23.15%) corresponded to the biological conservation studies. The monitoring of Lepidopterans can thus be used to improve the strategies of planning, management and conservation of urban biodiversity. Due to the risks from urbanization to butterflies and the global heterogeneity of urban zones, it is vital to extend the number of biological ponders in a bigger cluster of urban scenarios considering their geographic area, year of foundation, size, demography, history, economy, open legislative issues, and urban administration activities (MacGregor-Fors and Ortega-Álvarez 2013). In spite of the fact that a few patterns have developed, there's still a shortage of information on the way butterflies react to urbanization. If we proposed to oversee, arrange, and create urban zones considering a biological approach that seems to improve both natural life and human quality of life, we have to grow the number of multidisciplinary inquire groups conducting inquire about ventures pointed at portraying urban butterfly populaces and communities, and their relationship with territory highlights (e.g., host plants, nectar sources, arrive utilize, trophic networks) in urban situations (Alberti et al. 2003; Grimm et al. 2000). It would be prudent to centre inquire about endeavours in understudied biodiversity hotspot zones (Myers et

al. 2000; Fisher and Christopher 2007), as urbanization will tend to extend in creating nations where biodiversity crests (United Nations 2014). At last, we recognized a few understudied common points, ineffectively or unrepresented within the reviewed publications, that seem to move forward our comprehension of the response of butterflies to urbanization (1) demographic designs; (2) physiological reactions; (3) genetics; (4) evolution; (5) multitrophic intuitive; (5) biotic homogenization; and (6) resource preservation and management. It has been recommended to move from depicting environmental patterns to determining environmental forms (Shochat et al. 2006), prioritizing understudied locales. In spite of the fact that urban butterfly biology is beginning to move towards that heading, current distributions still reflect an inclination towards fundamental ecological pattern studies.

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Author's Contributions

This work was carried out in collaboration among all authors. Author Sushmita, designed the study, carried out all the work, wrote protocol and first draft of manuscript, designed all the graphs, performed the basic analysis of the study and managed the literature searches. Author Babita Sharma managed references section. All authors read and approved the final manuscript.

Table1. Number of urban butterfly publications by States and general topic.

S. No.	State	Publications	Ecological Prototypes	Checklist	Biological Conservation
1	West Bengal	12	5	2	5
2	Maharashtra	12	7	1	4
3	Uttarakhand	6	3	1	2
4	Madhya Pradesh	5	3	1	1
5	Karnataka	5	2	2	1
6	Uttar Pradesh	8	2	6	-
7	Tripura	4	1	2	1
8	Tamil Nadu	5	3	2	-
9	Western Ghats	4	3	-	1
10	Himachal Pradesh	3	2	-	1
11	Assam	6	2	2	2
12	New Delhi	4	2	1	1
13	Odhisa	4	1	2	1
14	Kerala	2	1	1	-
15	Gujarat	5	3	1	1
16	Western Himalayas	2	-	1	1
17	Punjab	3	2	1	-
18	Meghalaya	1	1	-	-
19	Ranchi	1	1	-	-
20	Arunachal Pradesh	3	2	1	-
	Total	95	46	27	22

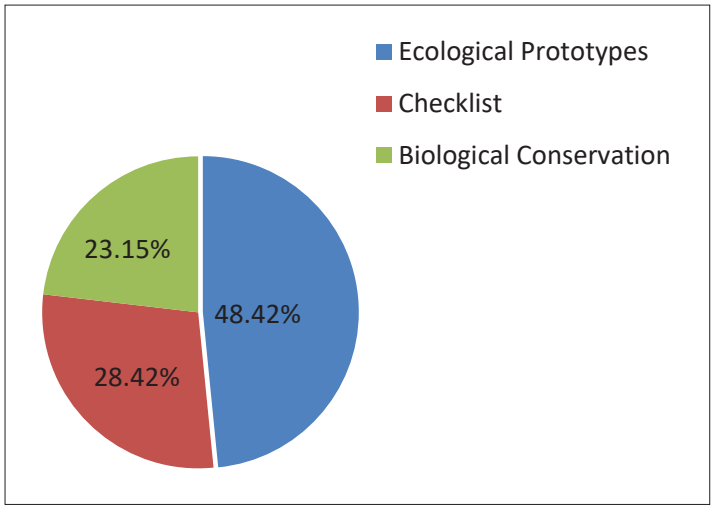

Fig1: Percentage Composition of three broad topics based on reviewed publications

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An unsuccessful attempt of predation of a Monitor lizard by a Bonelli's Eagle *Hieraaetus fasciatus*

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Solapur sub-region is covered with thorny forest patches. Land is covered with Babhul *Acacia nilotica* and Hivar *Acacia leucophloea* sporadically. There are small streams arising from seasonal medium sized ponds and lakes. Land patches ranging from one to two acres surrounding human settlements are being used for cultivation. Grass species like *Melanocenchris jacquemontii*, *Heteropogon contortus* and *Chrysopogon spp*. dominate the landcover. Short grasses fulfil the needs of canids, bovids and wild cats along with the winter visitors including raptors.

On 12 November 2019 authors witnessed an unexpected incident while birding near village Dhotri (17.811953, 76.036957) in the outskirts of the city adjoining the area of Jawaharlal Nehru bustard sanctuary Solapur, Maharashtra. An individual from a pair of Bonelli's eagle *H. fasciatus* launched an attack from a high voltage electric tower on a Monitor Lizard *Varanus bengalensis* which was basking on an ant hill. The two feet longer lizard started running when it saw the predator. Eagle chased the running lizard grasped it in the talons and lifted the lizard. A lizard bit the leg of the eagle and it released the lizard from its claws. The fallen lizard escaped successfully. The lizard retreated beneath the stones. Eagle could not get another chance to catch the monitor lizard. According to Ali (1997) and Naoroji (2006) monitor lizards are one of the food preferences of Bonelli's eagle.

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