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A Preliminary Assessment of the Urban Butterfly Diversity of Powai Lake and Hiranandani Township, Mumbai.

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Introduction

The butterflies of Mumbai are well documented, with at least 172 species recorded in the region (Kasambe et al., 2012). However, most recording efforts are focused on more 'natural', i.e. non-urban/non-suburban environments, such as the Sanjay Gandhi National Park, a moist mixed deciduous forest, Yeoor hills (Thane district), and to a lesser degree, Aarey Milk Colony – an altered grass and scrub habitat, harboring a variety of different ecosystem types, and recently declared a reserve forest.

While these natural environments are essential to conservation efforts, being invaluable as species repositories, the importance of urban and suburban green spaces in biodiversity conservation should not be underestimated, especially those public parks and gardens intentionally cultivated with flowering plants that attract and sustain pollinators (Aronson et al., 2017) and other fauna. Furthermore, non-bee pollinators, such as butterflies, are not as dependent on the presence of natural and semi-natural environments, being more resilient to modified habitats and landscapes, and, therefore, are particularly important as pollinators in the urban matrix (Rader et al., 2015).

Background to the study area

Powai Lake, an artificial urban wetland located in Central Mumbai, is one of Mumbai's largest lakes, surrounded by the suburb of Powai, and located near the township of Hiranandani, an upscale and affluent hub of commercial and social activity. While generally recognized as an urban biodiversity hotspot, the butterflies of the lake and its surrounding landscape remain largely understudied.

The last attempt to document the biodiversity of this area was in 2009, in the form of a WWF India report on the biodiversity of the Indian Institute of Technology (IIT) Bombay Campus, which documented 86 different species of butterflies from the campus grounds (Quadros et al., 2009). It should be noted that this study was focused solely on the biodiversity of the sprawling IIT Bombay campus, spanning an area 566 acres, with a mix of different habitat types, ranging from woodland, scrub, freshwater marshland, and large areas of the lake itself. No further attempts were made to document the biodiversity of the Powai suburbs, and very little other published material, except the odd newspaper article, exists on the terrestrial biodiversity of this area.

In order to fill this gap, and especially given the importance of butterflies as non-bee pollinators in urban ecosystems, the butterflies of the Powai suburbs were recorded in a pilot study, over a period of two years, from February 2021 until January 2023. (all local quarantine protocols were followed, including following COVID-19 appropriate behaviour, with field surveys suspended during periods of temporary local lockdowns and travel prohibitions. Some of the months during which field visits were suspended in 2021 were covered in 2022, when restrictions were relaxed and subsequently lifted, thereby ensuring a certain consistency in survey spread across two years.)

Methodology

The study period spanned two years, from February 2021, until January 2023. Urban green spaces, including the Powai Lakeside Promenade, Nirvana Park, at the Hiranandani Township, and Powai Garden, were all prioritized (Figure 1, points 1 and 2). Butterflies were also recorded along tree-lined avenues in the Hiranandani township (Figure 1, point 3), particularly around Technology Street (Figure 1, point 4) where flowering trees such as *Millettia pinnata* (L.) were observed to be utilized by butterflies as a source of nectar, when in bloom. Five visits were also made to the IIT Bombay Campus grounds (by invitation, courtesy Ms. Maithreyi). A total of fifty (50) field visits were made to the study area, overall, with at least two researchers recording butterflies in the field, during any given field visit.

Butterflies were also recorded at different time periods, in the morning, afternoon and late evening, to ensure better coverage, and were photographically recorded using a Nikon B500 digital camera, a Nikon D5600 with a Nikon DX AF-P 70-300mm f/4.5-6.3G ED VR zoom lens and a pair of Olympus Tracker PC I binoculars (10x25). Smartphone cameras were also used, especially in situations where any delay would have resulted in a missed record. The following references were utilized for butterfly species identification: Evans (1949), Hirowatari (1993), Kaur et al. (2023), Kunte (2023), Toussaint et al. (2015), Wynter-Blyth (1957).

Observations and data

A total of 84 different species of butterflies (Table 1) from five families and 64 genera were recorded in the area and identified to species level. Additionally, another 10 butterflies were observed, but only identified to genus, and in 2 cases tribe level (Table 2). Comparing our results with the WWF India report (Quadros et al., 2009) that reported 86 species, we find that a similar level of biodiversity is apparent, despite the difference in location and habitat types – the WWF report focused on the more 'natural', non-urban areas, such as the forest still extant inside the IIT Bombay campus, while our own observations were largely made in urban and suburban areas, such as public parks, gardens, tree-lined avenues and the Powai Lakeside Promenade.

A comparison of butterfly genera between the WWF India report, and our own data shows a sum total of 73 genera recorded, with 57 being common to both datasets, 9 unique to the WWF report and 7 unique to our records (Table 4 and 6). Furthermore, 5 families were observed in both studies, with 18 species unique to the WWF report, 17 unique to ours, and 67 species common to both studies). This makes for a sum-total of 102 different species of butterflies observed (Tables 3 and 5) near Powai lake, and the surrounding forested areas.

Concluding comments

Lowe et al. (2017) note that while urban development can negatively impact biodiversity, resulting in local extinctions, modified habitats in the form of urban and suburban green spaces have the potential to sustain biodiversity to varying degrees, depending upon the characteristics of the local environments. In other words, the right mix of microhabitats and flora (both native and non-native) may enable sustainable, and perhaps increased biodiversity in areas where invertebrates in particular were negatively impacted through urbanization and urban sprawl.

The Powai area contains a large artificial wetland body (Powai Lake), and an ecologically suave township in the form of Hiranandani Gardens, richly planted with a plethora of native, and exotic flora. Additionally, it lies in close proximity to other cornerstone natural habitats of Mumbai, such as Aarey Milk Colony, Vihar Lake and the Sanjay Gandhi National Park.

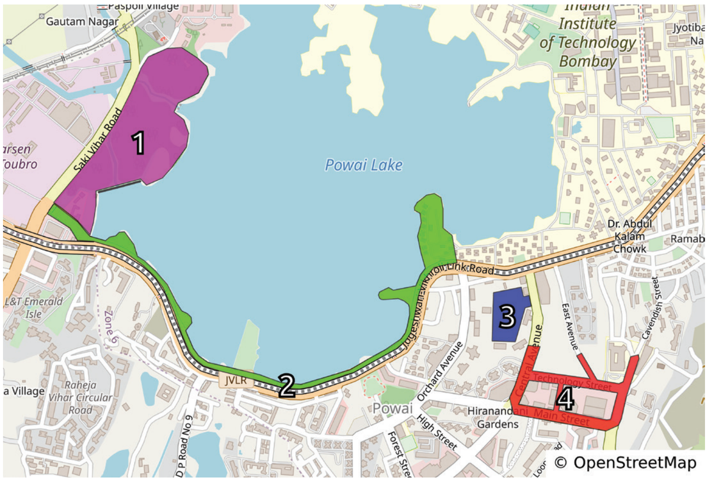
Given the results of our study spanning a two year period, as well as the 2009 WWF India report, it is clear that this area is able to sustain a rich diversity of butterflies, despite being in a very highly developed, populous and busy suburb and, as such, is an important urban biodiversity hotspot, especially for butterflies.

Further research is needed to better understand the ecology of butterflies, as important non-bee native pollinators of urban ecosystems, in townships across Mumbai. Perhaps the greatest threat to semi-urban mosaic habitats is the ephemeral nature of these transient ecosystems, which are forever at the mercy of stake holders, and risk being altered, modified or even completely obliterated, in event of a development project requiring it. Steps must be taken to ensure the sanctity of areas designated as urban green zones, in order to ensure the continued survival of the remarkable biodiversity these altered habitats are able to sustain, and support.

Additional Remarks

Possibly worthy of note is that the species *Abisara echerius* recorded in the WWF India report is somewhat contentious in its classification, with some sources considering it part of the Riodinidae family and others considering it part of the Lycaenidae family with Riodininae being a sub-family of Lycaenidae (Zhao et al., 2013). Bearing this fact in mind, we have opted to not reclassify this record under Riodinidae, leaving it under Lycaenidae.

In comparing butterfly diversity records between



the WWF India report (Quadros et al., 2009) and our own study, we excluded those observations for which identification to species level was not possible, hence only 85 of the 86 records from the WWF report, and 84 of the 94 records from the present study were used for drawing comparisons. We chose to do so to prevent ambiguity between records identified to the same tribe or genus between the two studies, but which may or may not be the same actual species.

Acknowledgments

This paper is fondly dedicated to the memory of our beloved friend, the late-great Dr. Krishna Mohan: physician, wildlife photographer, educator, and brilliant naturalist – lost, but never forgotten. The late Dr. B.F. Chhapgar, Marine Biologist extraordinaire, and Mr. Sunjoy Monga, India's leading Ornithologist, are both gratefully acknowledged for being constant sources of inspiration. Javed Ahmed would like to thank Caledonian Conservation Ltd. (Scotland), for their generous financial aid, which enabled the successful completion of this study. All images © Javed Ahmed/curiocritters/ The Urban Bestiary Project/Wild Megapolis Project/ The Misplaced Menagerie Project.

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Table 1. All butterflies observed and identified to species level, with months where one or more of them were observed, marked as 1, and months where surveys were conducted but none observed, marked as 0. Gray columns indicate months where no surveys were conducted.

Family	Common Name	Scientific Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hesperiidae	Vindhayan bob	Arnetta vindhiana	0	0	0				0	0	1	0	0	0
Hesperiidae	Brown awl	Badamia exclamationis	0	0	0				0	0	1	0	0	0
Hesperiidae	Rice swift	Borbo cinnara	0	0	0				1	1	1	0	0	0
Hesperiidae	Blank swift	Caltoris kumara kumara	0	0	0				0	1	0	0	0	0
Hesperiidae	Philippine swift	Caltoris philippina philippina	0	0	0				0	1	0	0	0	0
Hesperiidae	Tricoloured pied flat	Coladenia indrani indra	0	0	0				0	0	1	0	0	0
Hesperiidae	Giant redeye	Gangara thyrsis thyrsis	0	0	1				0	0	0	0	0	0
Hesperiidae	Common awl	Hasora badra badra	0	0	0				0	0	1	0	0	0
Hesperiidae	Common banded awl	Hasora chromus chromus	0	0	0				0	0	1	0	0	0
Hesperiidae	Common redeye	Matapa aria	0	0	0				0	1	1	0	0	0
Hesperiidae	Conjoined swift	Pelopidas conjuncta narooa	0	0	1				0	0	0	0	0	0

Family	Common Name	Scientific Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hesperiidae	Small branded swift	Pelopidas mathias mathias	0	0	0				1	1	1	0	0	0
Hesperiidae	Common small flat	Sarangesa dasahara dasahara	0	0	0				0	0	1	1	0	0
Hesperiidae	Indian palm bob	Suastus gremius gremius	0	0	1				0	0	0	0	0	0
Hesperiidae	Dark palm dart	Telicota bambusae bambusae	0	0	0				0	1	0	0	0	0
Lycaenidae	Common hedge blue	Acytolepis puspa gisca	0	1	1				0	1	1	0	1	0
Lycaenidae	Pointed ciliate blue	Anthene lycaenina lycaenina	0	0	1				0	0	0	0	0	0
Lycaenidae	Large oakblue	Arhopala amantes amantes	0	1	0				0	0	0	0	0	0
Lycaenidae	Angled pierrot	Caleta decidia	0	0	0				1	0	1	0	0	0
Lycaenidae	Common pierrot	Castalius rosimon rosimon	0	0	1				1	0	1	0	0	0
Lycaenidae	Forget-me-not	Catochrysops strabo strabo	1	1	1				0	0	0	0	0	0
Lycaenidae	Lime blue	Chilades lajus lajus	0	0	0				1	0	1	0	0	0
Lycaenidae	Plains cupid	Chilades pandava pandava	0	0	1				0	0	1	0	0	0
Lycaenidae	Common silverline	Cigaritis vulcanus vulcanus	0	0	0				1	0	0	0	0	0
Lycaenidae	Indian sunbeam	Curetis thetis	0	0	0				1	0	1	0	0	0
Lycaenidae	Gram blue	Euchrysops cnejus cnejus	0	0	1				0	0	0	0	0	0
Lycaenidae	Dark cerulean	Jamides bochus bochus	0	1	1				0	0	0	0	0	0
Lycaenidae	Common cerulean	Jamides celeno celeno	0	0	1				0	1	1	1	1	0
Lycaenidae	Pea blue	Lampides boeticus	0	0	1				0	0	0	0	0	0
Lycaenidae	Zebra blue	Leptotes plinius plinius	0	1	1				0	0	1	0	0	0
Lycaenidae	Tailless lineblue	Prosotas dubiosa indica	0	1	1				0	0	0	0	0	0
Lycaenidae	Common lineblue	Prosotas nora ardates	0	0	1				0	0	0	0	0	0
Lycaenidae	Apefly	Spalgis epius epius	1	0	0				0	0	0	0	0	0
Lycaenidae	Red pierrot	Talicada nyseus nyseus	0	0	1				0	0	1	0	0	0
Lycaenidae	Dark grass blue	Zizeeria karsandra	1	1	0				1	0	0	0	0	0
Lycaenidae	Tiny grass blue	Zizula hylax hylax	1	1	0				0	0	1	0	0	0
Nymphalidae	Tawny coster	Acraea terpsicore	0	1	1				0	0	0	0	0	0
Nymphalidae	Common castor	Ariadne merione merione	0	1	1				1	1	1	0	0	0
Nymphalidae	Black rajah	Charaxes solon solon	0	0	0				1	1	0	0	0	0
Nymphalidae	Plain tiger	Danaus chrysippus chrysippus	0	0	1				1	1	0	0	0	0
Nymphalidae	Striped tiger	Danaus genutia genutia	0	1	1				1	1	1	0	0	0
Nymphalidae	Common palmfly	Elymnias hypermnestra undularis	0	1	1				0	1	1	0	0	0
Nymphalidae	Common crow	Euploea core core	0	0	1				1	1	1	0	0	0
Nymphalidae	Brown king crow	Euploea klugii kollari	0	0	0				0	1	1	0	0	0
Nymphalidae	Common baron	Euthalia aconthea meridionalis	0	0	0				1	1	1	0	0	0
Nymphalidae	Great eggfly	Hypolimnas bolina jacintha	0	0	0				1	1	1	0	0	0
Nymphalidae	Danaid eggfly	Hypolimnas misippus	0	0	0				1	1	1	0	0	0
Nymphalidae	Peacock pansy	Junonia almana almana	0	0	0				1	1	1	0	0	0
Nymphalidae	Grey pansy	Junonia atlites atlites	0	0	0				1	1	1	0	0	0
Nymphalidae	Chocolate pansy	Junonia iphita iphita	0	1	0				1	1	1	0	0	0

Family	Common Name	Scientific Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nymphalidae	Lemon pansy	Junonia lemonias lemonias	0	0	1				1	0	0	0	0	0
Nymphalidae	Blue oakleaf	Kallima horsfieldii	0	0	1				0	0	1	0	0	0
Nymphalidae	Common evening brown	Melanitis leda leda	0	1	0				0	1	1	0	1	0
Nymphalidae	Commander	Moduza procris undifragus	0	1	0				0	0	0	0	0	0
Nymphalidae	Common sailer	Neptis hylas varmona	0	1	1				0	0	1	0	0	0
Nymphalidae	Chestnut-streaked sailer	Neptis jumbah nalanda	0	1	0				0	0	0	0	0	0
Nymphalidae	Glassy tiger	Parantica aglea aglea	0	0	0				1	1	1	0	0	0
Nymphalidae	Common leopard	Phalanta phalantha phalantha	0	0	1				1	1	1	0	0	0
Nymphalidae	Indian nawab	Polyura bharata	0	0	0				1	0	0	0	0	0
Nymphalidae	Baronet	Symphaedra nais	0	0	0				1	0	0	0	0	0
Nymphalidae	Blue tiger	Tirumala limniace exoticus	0	1	1				1	1	1	0	0	0
Nymphalidae	Dark blue tiger	Tirumala septentrionis dravidarum	0	1	1				1	0	0	0	0	0
Nymphalidae	Common fourring	Ypthima huebneri	0	0	0				0	0	1	0	0	0
Papilionidae	Tailed jay	Graphium agamemnon menides	0	1	1				1	1	1	0	0	0
Papilionidae	Common jay	Graphium doson eleius	0	0	1				1	0	0	0	0	0
Papilionidae	Common bluebottle	Graphium sarpedon sarpedon	0	0	0				1	0	0	0	0	0
Papilionidae	Crimson rose	Pachliopta hector	0	0	0				0	0	1	0	0	0
Papilionidae	Lime swallowtail	Papilio demoleus demoleus	0	0	1				1	1	0	0	0	0
Papilionidae	Blue mormon	Papilio polymnestor polymnestor	0	0	0				1	1	1	0	1	0
Papilionidae	Common mormon	Papilio polytes romulus	0	0	1				1	1	1	0	0	0
Pieridae	Common albatross	Appias albina swinhoei	0	0	0				1	0	0	0	0	0
Pieridae	Striped albatross	Appias libythea	0	1	0				0	1	0	0	0	0
Pieridae	Common emigrant	Catopsilia pomona pomona	0	1	1				0	1	1	0	0	0
Pieridae	Mottled emigrant	Catopsilia pyranthe pyranthe	0	0	0				1	0	1	0	0	0
Pieridae	Common gull	Cepora nerissa phryne	0	0	1				1	1	1	0	1	0
Pieridae	Small salmon arab	Colotis amata	0	0	0				1	0	0	0	0	0
Pieridae	Jezebel	Delias eucharis	0	0	1				0	1	0	0	0	0
Pieridae	Small grass yellow	Eurema brigitta rubella	0	1	1				1	0	0	0	0	0
Pieridae	Common grass yellow	Eurema hecabe hecabe	0	1	1				1	1	1	0	1	0
Pieridae	Great orange tip	Hebomoia glaucippe australis	0	0	0				1	1	1	0	0	0
Pieridae	White orange tip	Ixias marianne	0	0	0				1	0	1	0	0	0
Pieridae	Yellow orange tip	Ixias pyrene sesia	0	0	0				1	0	1	0	0	0
Pieridae	Psyche	Leptosia nina nina	0	1	1				1	1	1	0	1	0
Pieridae	Common wanderer	Pareronia hippia	0	0	1				1	1	1	0	0	0
Monthly Totals			**4**	**25**	**39**				**43**	**37**	**50**	**2**	**7**	**0**
Total Taxa Recorded														**84**

Table 2. Butterflies only identified to the genus or tribe level (see Table 1 description for notes about format).

Family	Common Name	Scientific Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hesperiidae	Swift	*Baorini sp. (tribe)*	0	0	0				0	1	0	0	0	0
Hesperiidae	Swift	*Borbo sp.*	0	0	0				0	0	1	1	0	0
Hesperiidae	Awl	*Hasora sp.*	0	0	0				0	0	1	0	0	0
Hesperiidae	Swift	*Parnara sp.*	0	0	0				1	1	0	0	0	0
Hesperiidae	Branded swift	*Pelopidas sp.*	0	0	0				0	0	1	0	0	0
Lycaenidae	Lineblue	*Polyommatini sp. (tribe)*	1											
Lycaenidae	Lineblue	*Prosotas sp.*	0	1	1				0	0	0	0	0	0
Nymphalidae	Bushbrown	*Mycalesis sp.*	0	0	1				0	0	0	0	0	0
Nymphalidae	Sailer	*Neptis sp.*	0	1	0				0	0	0	0	0	0
Pieridae	Grass yellow	*Eurema sp.*	1	1	1				1	1	0	0	0	0
Monthly Totals			2	3	3				2	3	3	1	0	0
Total Taxa Recorded														10

Table 3. Comparison between our study and the WWF report (Quadros et al., 2009) of butterflies identified to species level (1 indicates one or more found, 0 indicates no). Only includes butterflies identified to species level. In 4 cases the scientific name differs from the name used in the WWF report (see footnotes for rationale), in those cases the name they used was added in brackets.

Family	Common Name	Scientific Name	Found in this Study	Found in WWF Report
Hesperiidae	Vindhayan bob	*Arnetta vindhiana*	1	1
Hesperiidae	Brown awl	*Badamia exclamationis*	1	1
Hesperiidae	Rice swift	*Borbo cinnara*	1	1
Hesperiidae	Blank swift	*Caltoris kumara*	1	0
Hesperiidae	Philippine swift	*Caltoris philippina*	1	0
Hesperiidae	Tricoloured pied flat	*Coladenia indrani*	1	1
Hesperiidae	Giant redeye	*Gangara thyrsis*	1	0
Hesperiidae	Common awl	*Hasora badra*	1	0
Hesperiidae	Common banded awl	*Hasora chromus*	1	1
Hesperiidae	Chestnut bob	*Iambrix salsala*	0	1
Hesperiidae	Common redeye	*Matapa aria*	1	1
Hesperiidae	Conjoined swift	*Pelopidas conjuncta*	1	1
Hesperiidae	Small branded swift	*Pelopidas mathias*	1	0
Hesperiidae	Common small flat	*Sarangesa dasahara*	1	1
Hesperiidae	Spotted small flat	*Sarangesa purendra*	0	1
Hesperiidae	Indian palm bob	*Suastus gremius*	1	1
Hesperiidae	Dark palm dart	*Telicota bambusae (Telicota ancilla)**	1	1
Hesperiidae	Grass demon	*Udaspes folus*	0	1
Lycaenidae	Plum Judy	*Abisara echerius*	0	1
Lycaenidae	Common hedge blue	*Acytolepis puspa*	1	1
Lycaenidae	Pointed ciliate blue	*Anthene lycaenina*	1	0
Lycaenidae	Large oakblue	*Arhopala amantes*	1	0
Lycaenidae	Angled pierrot	*Caleta decidia (Caleta caleta)***	1	1
Lycaenidae	Common pierrot	*Castalius rosimon*	1	1
Lycaenidae	Forget-me-not	*Catochrysops strabo*	1	1
Lycaenidae	Lime blue	*Chilades lajus*	1	1
Lycaenidae	Plains cupid	*Chilades pandava*	1	0
Lycaenidae	Common silverline	*Cigaritis vulcanus*	1	1

Family	Common Name	Scientific Name	Found in this Study	Found in WWF Report
Lycaenidae	Indian sunbeam	*Curetis thetis*	1	0
Lycaenidae	Gram blue	*Euchrysops cnejus*	1	1
Lycaenidae	Grass jewel	*Freyeria trochylus*	0	1
Lycaenidae	Dark cerulean	*Jamides bochus*	1	1
Lycaenidae	Common cerulean	*Jamides celeno*	1	1
Lycaenidae	Pea blue	*Lampides boeticus*	1	1
Lycaenidae	Zebra blue	*Leptotes plinius*	1	1
Lycaenidae	Tailless lineblue	*Prosotas dubiosa*	1	0
Lycaenidae	Common lineblue	*Prosotas nora*	1	1
Lycaenidae	Pale grass blue	*Pseudozizeeria maha*	0	1
Lycaenidae	Slate flash	*Rapala manea*	0	1
Lycaenidae	Apefly	*Spalgis epius*	1	1
Lycaenidae	Peacock royal	*Tajuria cippus*	0	1
Lycaenidae	Red pierrot	*Talicada nyseus*	1	1
Lycaenidae	Rounded pierrot	*Tarucus nara*	0	1
Lycaenidae	Dark grass blue	*Zizeeria karsandra*	1	1
Lycaenidae	Tiny grass blue	*Zizula hylax*	1	1
Nymphalidae	Tawny coster	*Acraea terpsicore*	1	1
Nymphalidae	Angled castor	*Ariadne ariadne*	0	1
Nymphalidae	Common castor	*Ariadne merione*	1	1
Nymphalidae	Black rajah	*Charaxes solon*	1	1
Nymphalidae	Plain tiger	*Danaus chrysippus*	1	1
Nymphalidae	Striped tiger	*Danaus genutia*	1	1
Nymphalidae	Common palmfly	*Elymnias hypermnestra*	1	1
Nymphalidae	Common crow	*Euploea core*	1	1
Nymphalidae	Brown king crow	*Euploea klugii*	1	0
Nymphalidae	Common baron	*Euthalia aconthea*	1	1
Nymphalidae	Gaudy baron	*Euthalia lubentina*	0	1
Nymphalidae	Great eggfly	*Hypolimnas bolina*	1	1
Nymphalidae	Danaid eggfly	*Hypolimnas misippus*	1	1
Nymphalidae	Peacock pansy	*Junonia almana*	1	1
Nymphalidae	Grey pansy	*Junonia atlites*	1	1
Nymphalidae	Chocolate pansy	*Junonia iphita*	1	1
Nymphalidae	Lemon pansy	*Junonia lemonias*	1	1
Nymphalidae	Blue oakleaf	*Kallima horsfieldii*	1	1
Nymphalidae	Common evening brown	*Melanitis leda*	1	1
Nymphalidae	Commander	*Moduza procris*	1	1
Nymphalidae	Common bushbrown	*Mycalesis perseus*	0	1
Nymphalidae	Long-brand bushbrown	*Mycalesis visala*	0	1
Nymphalidae	Common sailer	*Neptis hylas*	1	1
Nymphalidae	Chestnut-streaked sailer	*Neptis jumbah*	1	0
Nymphalidae	Glassy tiger	*Parantica aglea*	1	1
Nymphalidae	Common leopard	*Phalanta phalantha*	1	1
Nymphalidae	Indian nawab	*Polyura bharata (Polyura athamas)******	1	1
Nymphalidae	Baronet	*Symphaedra nais*	1	0

Family	Common Name	Scientific Name	Found in this Study	Found in WWF Report
Nymphalidae	Blue tiger	*Tirumala limniace*	1	1
Nymphalidae	Dark blue tiger	*Tirumala septentrionis*	1	0
Nymphalidae	Common fourring	*Ypthima huebneri*	1	1
Papilionidae	Tailed jay	*Graphium agamemnon*	1	1
Papilionidae	Common jay	*Graphium doson*	1	1
Papilionidae	Common bluebottle	*Graphium sarpedon*	1	1
Papilionidae	Common rose	*Pachliopta aristolochia*	0	1
Papilionidae	Crimson rose	*Pachliopta hector*	1	0
Papilionidae	Lime swallowtail	*Papilio demoleus*	1	1
Papilionidae	Blue mormon	*Papilio polymnestor*	1	1
Papilionidae	Common mormon	*Papilio polytes*	1	1
Pieridae	Common albatross	*Appias albina*	1	0
Pieridae	Striped albatross	*Appias libythea*	1	1
Pieridae	Pioneer	*Belenois aurata*	0	1
Pieridae	Common emigrant	*Catopsilia pomona*	1	1
Pieridae	Mottled emigrant	*Catopsilia pyranthe*	1	1
Pieridae	Common gull	*Cepora nerissa*	1	1
Pieridae	Small salmon arab	*Colotis amata*	1	0
Pieridae	Little orange tip	*Colotis etrida*	0	1
Pieridae	Jezebel	*Delias eucharis*	1	1
Pieridae	Three spot grass yellow	*Eurema blanda*	0	1
Pieridae	Small grass yellow	*Eurema brigitta*	1	1
Pieridae	Common grass yellow	*Eurema hecabe*	1	1
Pieridae	Spotless grass yellow	*Eurema laeta*	0	1
Pieridae	Great orange tip	*Hebomoia glaucippe*	1	1
Pieridae	White orange tip	*Ixias marianne*	1	1
Pieridae	Yellow orange tip	*Ixias pyrene*	1	1
Pieridae	Psyche	*Leptosia nina*	1	1
Pieridae	Common wanderer	*Pareronia hippia (Pareronia valeria)******	1	1
Total Count	102		84	85

* Telicota ancilla does not occur in India, we've presumed it to be a misidentified Telicota bambusae as they have the same common name, a similar appearance and are the closest species that does occur in the region (Evans, 1949).
** Similarly Caleta caleta does not occur in India, we believe it to be mistaken for Caleta decidia for the same reasons as above footnote (Hirowatari, 1993; Wynter-Blyth, 1954).
*** The subspecies of these which occur in the region (Polyura athamas bharata and Pareronia valeria hippia) were raised to species level in current taxonomy (Kaur et al, 2023; Toussaint et al, 2015).


Apefly (Spalgis epius epius)


Black rajah (Charaxes solon solon)


Indian sunbeam (Curetis thetis)


Blue oakleaf (Kallima horsefieldii)


Common silverline (Cigaritis vulcanus vulcanus)


Pointed cilate blue (Anthene lycaenina lycaenina)


Dark palm dart (Telicota bambusae bambusae)


Giant redeye (Gangara thyrsis thyrsis)


Striped albatross (appias libythea)


Jezebel (Delias eucharis)


Small salmon arab (Colotis amata)


Tricoloured pied flat (Coladenia indrani indra)

Table 4. Comparison between our study and the WWF report (Quadros et al., 2009) of genera observed (1 indicates one or more found, 0 indicates no).

Family	Scientific Name	Found in this Study	Found in WWF Report
Hesperiidae	*Arnetta*	1	1
Hesperiidae	*Badamia*	1	1
Hesperiidae	*Borbo*	1	1
Hesperiidae	*Caltoris*	1	0
Hesperiidae	*Coladenia*	1	1
Hesperiidae	*Gangara*	1	0
Hesperiidae	*Hasora*	1	1
Hesperiidae	*Iambrix*	0	1
Hesperiidae	*Matapa*	1	1
Hesperiidae	*Parnara*	1	0
Hesperiidae	*Pelopidas*	1	1
Hesperiidae	*Sarangesa*	1	1
Hesperiidae	*Suastus*	1	1
Hesperiidae	*Telicota*	1	1
Hesperiidae	*Udaspes*	0	1
Lycaenidae	*Abisara*	0	1
Lycaenidae	*Acytolepis*	1	1
Lycaenidae	*Anthene*	1	0
Lycaenidae	*Arhopala*	1	0
Lycaenidae	*Caleta*	1	1
Lycaenidae	*Castalius*	1	1
Lycaenidae	*Catochrysops*	1	1
Lycaenidae	*Chilades*	1	1
Lycaenidae	*Cigaritis*	1	1
Lycaenidae	*Curetis*	1	1
Lycaenidae	*Euchrysops*	1	1
Lycaenidae	*Freyeria*	0	1
Lycaenidae	*Jamides*	1	1
Lycaenidae	*Lampides*	1	1
Lycaenidae	*Leptotes*	1	1
Lycaenidae	*Luthrodes*	1	0
Lycaenidae	*Prosotas*	1	0
Lycaenidae	*Pseudozizeeria*	0	1
Lycaenidae	*Rapala*	0	1
Lycaenidae	*Spalgis*	1	1
Lycaenidae	*Tajuria*	0	1
Lycaenidae	*Talicada*	1	1
Lycaenidae	*Tarucus*	0	1
Lycaenidae	*Zizeeria*	1	1
Lycaenidae	*Zizula*	1	1
Nymphalidae	*Acraea*	1	1
Nymphalidae	*Ariadne*	1	1
Nymphalidae	*Charaxes*	1	1
Nymphalidae	*Danaus*	1	1
Nymphalidae	*Elymnias*	1	1
Nymphalidae	*Euploea*	1	1
Nymphalidae	*Euthalia*	1	1

Family	Scientific Name	Found in this Study	Found in WWF Report
Nymphalidae	*Hypolimnas*	1	1
Nymphalidae	*Junonia*	1	1
Nymphalidae	*Kallima*	1	1
Nymphalidae	*Melanitis*	1	1
Nymphalidae	*Moduza*	1	1
Nymphalidae	*Mycalesis*	1	1
Nymphalidae	*Neptis*	1	1
Nymphalidae	*Parantica*	1	1
Nymphalidae	*Phalanta*	1	1
Nymphalidae	*Polyura*	1	1
Nymphalidae	*Tirumala*	1	1
Nymphalidae	*Ypthima*	1	1
Papilionidae	*Graphium*	1	1
Papilionidae	*Pachliopta*	1	1
Papilionidae	*Papilio*	1	1
Pieridae	*Appias*	1	1
Pieridae	*Belenois*	0	1
Pieridae	*Catopsilia*	1	1
Pieridae	*Cepora*	1	1
Pieridae	*Colotis*	1	1
Pieridae	*Delias*	1	1
Pieridae	*Eurema*	1	1
Pieridae	*Hebomoia*	1	1
Pieridae	*Ixias*	1	1
Pieridae	*Leptosia*	1	1
Pieridae	*Pareronia*	1	1
Total Count	73	64	66

Table 5. Number of different species identified in both the present study, the WWF report (Quadros et al., 2009) and the combined data. Excludes observations where only the genus or tribe is known.

Family	Our data		WWF data		Common	Combined
	Total	Unique	Total	Unique		
Hesperiidae	15	5	13	3	10	18
Lycaenidae	21	5	22	7	16	27
Nymphalidae	27	4	27	4	23	31
Papilionidae	7	1	7	1	6	8
Pieridae	14	2	16	4	12	18
Total Counts	84	17	85	19	67	102

Table 6. Number of different genera identified in both the present study, the WWF report (Quadros et al., 2009) and the combined data.

Family	Our data		WWF data		Common	Combined
	Total	Unique	Total	Unique		
Hesperiidae	13	3	12	2	10	15
Lycaenidae	19	4	21	7	15	25
Nymphalidae	19	0	19	0	19	19
Papilionidae	3	0	3	0	3	3
Pieridae	10	0	11	1	10	11
Total Counts	64	7	66	10	57	73

Diversity and Distribution of Coleopteran and Hemipteran Insects in Five Rivers of Maharashtra, India.

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Abstract

The present investigation deals with the diversity and distribution of aquatic beetles and bugs inhabiting five Rivers in Maharashtra, India. The study was conducted from October 2020 to June 2022. The collection of freshwater aquatic insects was done during the early hours of the day, following the standard sampling protocol. Total number of 29 species belonging to 18 genera, 12 families (Gyrinidae, Hydrophilidae, Dytiscidae, Notoridae of the order Coleoptera; and Corixidae, Naucoridae, Gerridae, Nepidae, Belostomatidae, Notonectidae, Pleidae, Aphelocheiridae of the order Hemiptera), and 2 orders (Coleoptera and Hemiptera) were recorded. Among the aquatic insects (beetles and bugs) population studied, Hemiptera was recorded as the most abundant insect order constituting 85%, whereas order Coleoptera constituted 15% composition. Among the water bodies studied, low diversity was indicated at all the five sampling stations, as per the values resulting from Simpson's Diversity Index calculation. The Station 2 (on Tapi River) had the highest value of Shannon-Weiner Diversity Index, indicating moderate diversity; whereas remaining four stations showed less diversity. Further, all the five stations showed moderate water quality status. Highest Evenness and Dominance values were observed at Station 5 (on Ulhas River).

Keywords:

Aquatic Insects, Coleoptera, Hemiptera, Rivers, Diversity, Distribution.

Introduction:

Among the living organisms found in freshwater ecosystems, insects are the most diverse group. It is estimated that approximately 45000 insect species all around the world live in such ecosystems. (Balaram, 2005) It is believed that India alone is home to around 5000 species of aquatic insects that inhabit inland wetlands (Subramanian and Sivaramakrishnan, 2007). The aquatic insects play a crucial role in ecosystem functioning due to their taxonomic diversity, numerical abundance, and trophic significance (Abhijna et al., 2013). Fernandez and Ruf (2006) studied aquatic and semiaquatic Coleoptera and Heteroptera species in four limnotopes across the different water bodies in Partido de Berisso of Buenos Aires Province; while comparing the frequency, abundance, species richness, and diversity of these insects.

Aquatic beetles are found in a variety of habitats, but they are most diverse in lentic environments such as wetlands and pond edges (Dash and Roy, 2017). In India, greater attention on aquatic Coleoptera was drawn by the work of Biswas et al. (1995), who conducted a thorough investigation of the Dytiscidae, Gyrinidae, and Hydrophilidae families of water beetles in West Bengal. Pahari et al. (1997; 1999) studied the taxonomic aspects of the aquatic insects from order Coleoptera in two wetlands in West Midnapur Districts. Thakare and Zade (2011) worked out the species composition, abundance, and diversity of aquatic beetles in the Kolkas region from Melghat Tiger Reserve, Amravati District, Maharashtra, India. Jaiswal et al. (2022) documented 41 species of aquatic beetle fauna belonging to 4 families such as Dytiscidae, Hydrophilidae, Gyrinidae, and Noteridae; from the Kawal Tiger Reserve, Telangana, India. Pir et al. (2022) assessed diversity and species composition of aquatic beetles in the Narmada River; documenting 17 species belonging to 5 families.

There are 23 families, 343 genera, and 4810 species of Hemiptera all over the world; out of which, 20 families, 326 genera, and 4656 species inhabit freshwater habitats in India (Polhemus et al., 2008). Hemiptera is a large insect group that always plays an important role in freshwater ecosystems. The aquatic and semiaquatic Hemiptera, commonly known as aquatic bugs (suborder Heteroptera), are among the primary predators of freshwater bodies. They exhibit remarkable diversity, which has been extensively documented in India. (Thirumalai, 1999; 2002) Deepa and Rao (2007) documented the diversity of aquatic Hemiptera in Pocharam Lake, Andhra Pradesh.

The present study recorded the diversity and distribution of aquatic Coleopteran and Hemipteran insects from five sampling stations on five geographically significant Rivers flowing through the Districts of Satara, Jalgaon, Ahmednagar, Pune, and Raigad; of Maharashtra, India.

Material and Methods:

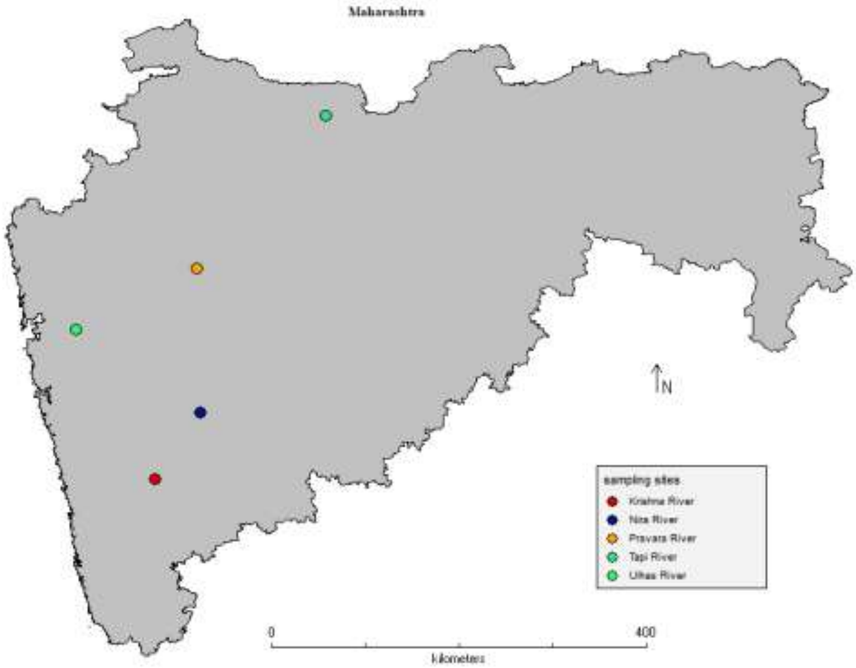
Period of Investigation: The study was conducted from October 2020 to June 2022. Sampling was done from October 2020 to September 2021, followed by taxonomic inspection of the collected specimens.

Study Area: Five sampling stations located on two major rivers (Krishna and Tapi) and three minor rivers (Pravara, Nira, and Ulhas) from Maharashtra, India; were selected for the present study, as they represented various regions of the State (See Table 1 and Map 1).

Sample Collection: Random sampling method was applied for collection of the aquatic insects. Aquatic insect samples were collected from the five sampling stations, during the sampling seasons: Post-monsoon (October to January), Pre-monsoon (February to May); and Monsoon (June to September); paying three visits per sampling season. Sampling was conducted preferably in the morning hours: from 8.00 a.m. to 11.00 a.m., according to local time. Aquatic insects

Sr. No.	Sampling Station	Location	Water body	Latitude	Longitude
1	Station-1	Umbraj, Satara	Krishna River	17° 23’ 55.428” N	74° 6’ 49.4496” E
2	Station-2	Bhusawal, Jalgaon	Tapi River	21° 4’ 3.558” N	75° 46’ 36.8868” E
3	Station-3	Kolhar, hmednagar	Pravara River	19° 31’ 39.5868” N	74° 30’ 56.106” E
4	Station-4	Sangavi, Pune	Nira River	18° 4’ 7.8672” N	74° 33’ 35.2548” E
5	Station-5	Karjat, Raigad	Ulhas River	18° 54’ 30.1104” N	73° 19’ 48.162”E

Table 1: Geographical Details of Aquatic Insect Sampling Stations across Maharashtra



Map 1: Location of the Riverine Sampling Stations across Maharashtra

were collected, as per Meritt and Cummins (1988): with a 500 µm mesh size D-frame dip net, trapping the insect specimens suspended in water and those attached to vegetation along the banks of the water bodies.

Sample Preservation: The collected and trapped aquatic insect specimens were preserved in 70% ethanol in sample bottles, each carrying label denoting Code Name of Sampling Station, Date of Visit, and Initials of Name of Collector.

Sample Identification: The collected/preserved specimens were identified on the basis of morphological characteristics, using standard identification keys/ manuals/guides by Richards and Davis (1977), McCafferty (1981), Dudgeon (1999), and Subramanian and Sivaramakrishnan (2007). Confirmation of identification was done with the taxonomical support of entomology experts from Zoological Survey of India (ZSI), Freshwater Biology Regional Centre, Hyderabad (Telangana), India.

Data Analysis: The Simpson's Diversity Index was worked out for indicating species diversity; whereas Shannon-Weiner Diversity Index was calculated to understand the diversity of aquatic beetles and bugs; as well as the pollution status of water at each sampling station. Further, Dominance, and Evenness were also worked out for each sampling station.

Results & Discussion:

The sampling stations on selected rivers flowing through various regions of Maharashtra were surveyed to study the diversity and distribution of aquatic insects, most specifically - the beetles and bugs. Although, aquatic entomofauna belonging to various other orders might have been part of the collection during the random sampling procedure; the central focus was directed on the two orders Coleoptera and Hemiptera, considering their greater ecological importance as vital constituents of the aquatic food web; and considerable economic importance as 'bioindicators' of water quality.

The present study recorded a total of 685 individuals of aquatic insects which belonging to 2 orders namely Coleoptera and Hemiptera, 12 families (Gyrinidae, Hydrophilidae, Dytiscidae, Noteridae of order Coleoptera; and Corixidae, Naucoridae, Gerridae, Nepidae, Belostomatidae, Notonectidae, Pleidae, Aphelocheiridae of order Hemiptera), 18 genera and 29 species.

In the present investigation; 9 genera, 7 families, and 2 orders of aquatic insects were documented at Station 1 (on Krishna River); while Station 2 (on Tapi

River) showed 10 genera, 8 families, and 2 orders. 9 genera, 7 families, and 2 orders of aquatic insects were observed at Station 3 (on Pravara River). Station 4 (on Nira River) showed 5 genera, 5 families, and 2 orders; while 5 genera, 4 families, and 2 orders were recorded at Station 5 (on Ulhas River). The maximum number of aquatic insects was recorded at Station 2 (on Tapi River) with 268 individuals, while the minimum was recorded at Station 4 (on Nira River) with only 63 individuals.

The Percent Composition of the two insect orders recorded from the sampling stations on five rivers of Maharashtra are shown in Figure 1 (of Coleoptera) and Figure 2 (of Hemiptera). Figure 1 shows that the highest percentage of Coleopteran insects were recorded from Station 3 (on Pravara River) and the lowest percentage of Coleopteran insects were recorded from Station 5 (on Ulhas River). Figure 2 shows the Percent Composition of Hemipteran insects, which were highest at Station 2 (on Tapi River) and lowest at the Station 4 (on Nira River). Figure 3 shows the Generic Richness of aquatic insect specimens studied. The Generic Richness of order Coleoptera was highest (4) at Stations 1 (on Krishna River) and 3 (on Pravara River); while the highest Generic Richness (8) of order Hemiptera was observed at Station 2 (on Tapi River). The lowest Generic Richness (1) of order Coleoptera was at Station 5 (on Ulhas River) and lowest (2) of order Hemiptera was at Station 4 (on Nira River).

Dabhade et al. (2012) carried out similar work in Mangrulpir Tahsil, Washim District of Maharashtra; identifying 25 beetle species belonging to 8 superfamilies and 11 families. In a survey conducted by Moreno et al. (2018), aquatic and semiaquatic bugs (Insecta, Hemiptera, Heteroptera) belonging to 8 families, 20 genera, and 32 species were documented; out of which, 11 species were recorded for the first time from the Sucre Department, 8 from the Colombian Caribbean region, and 4 from Colombia. Hayashi et al. (2020) conducted a study on species diversity of aquatic Hemiptera and Coleoptera from the water bodies in Japan. They documented 118 species belonging to order Hemiptera in 13 families, among which 22 species (18.6%) were endemic; whereas order Coleoptera was represented by 358 species in 12 families, among which 156 species (43.6%) were endemic.

Simpson's Diversity Index shows increasing values from 0-1. Values below 0.50 indicate low diversity; 0.50-0.75 indicate moderate diversity; while 0.75-1 indicate high diversity (Odum, 1971). Table 2 shows Simpson's Diversity Index with highest value (0.286) recorded at Station 4 (on Nira River) and lowest value (0.150) recorded at Station 5 (on Ulhas River). Overall, Simpson's Diversity Index indicated low diversity at all the five sampling stations.

Shannon-Weiner Diversity Index value less than 1 indicates extremely polluted status of water; while values between 1-3 indicate moderate pollution; and more than 4 score indicates non-polluted water (Wilhm and Dorris, 1968). Table 2 shows Shannon-Weiner Diversity Index with highest value (2.162) observed at Station 2 (on Tapi River), indicating moderate diversity and moderate pollution status of water; while Shannon-Weiner Diversity Index with a lowest value (1.334) was

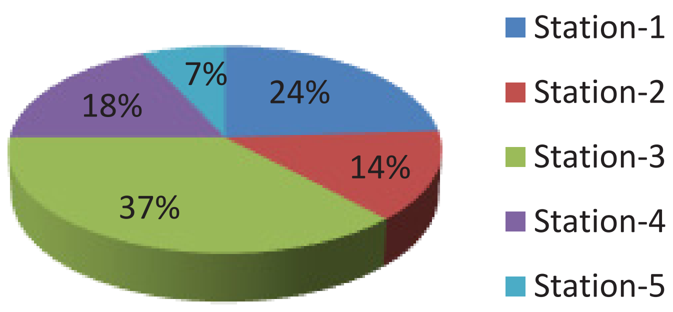


Fig. 1: Station-wise Percent Composition of Riverine Coleoptera from Maharashtra

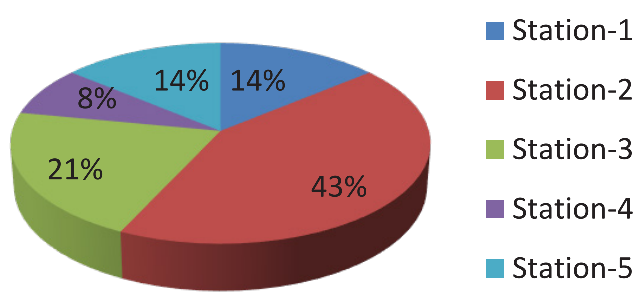


Fig. 2: Station-wise Percent Composition of Riverine Hemiptera from Maharashtra

observed at Station 4 (on Nira River), indicating less diversity and moderate pollution status of water.

Table 2 shows that the Evenness was highest at all the five sampling stations. Dominance was highest (0.850) with greater number of taxa of aquatic insects at Station 5 (on Ulhas River); while it was lowest (0.261) at Station 3 (on Pravara River) with lesser number of aquatic insect taxa. Hemiptera was found to be the most dominant order at Station 1 (on Krishna River), Station 2 (on Tapi River) and Station 5 (on Ulhas River); whereas Coleoptera was found to be the most dominant order at Station 3 (on Pravara River) and Station 4 (on Nira River).

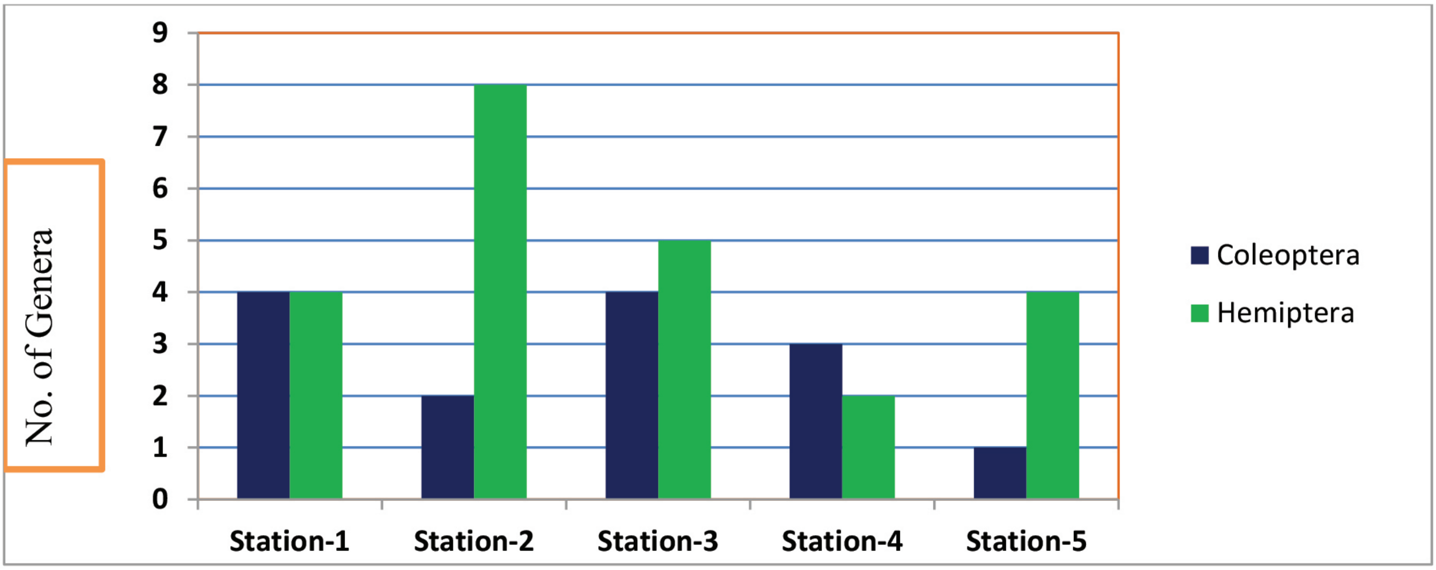


Fig. 3: Generic Richness of Riverine Coleoptera and Hemiptera from Maharashtra

Sampling Station	Taxa	No. of Individuals	Simpson's Diversity Index	Shannon-Weiner Diversity Index	Evenness	Dominance
Station - 1 (on Krishna River)	8	106	0.241	1.781	0.8104	0.759
Station - 2 (on Tapi River)	10	268	0.1598	2.162	0.8445	0.840
Station - 3 (on Pravara River)	9	158	0.2609	1.747	0.7288	0.261
Station - 4 (on Nira River)	5	63	0.286	1.334	0.8290	0.714
Station - 5 (on Ulhas River)	5	90	0.150	1.881	0.9666	0.850

Table 2: Diversity Indices of Riverine Coleoptera and Hemiptera from Maharashtra

Table 2: Diversity and Distribution of Riverine Coleoptera and Hemiptera from Maharashtra

Sampling Station	Order	Family	Taxa
Station 1	Coleoptera	Gyrinidae	*Gyrinus convexiculus*
		Hydrophilidae	*Berosus indicus*
		Hydrophilidae	*Amphiops* spp.
		Hydrophilidae	*Helochares* spp.
	Hemiptera	Corixidae	*Micronecta scutellaris scutellaris*
		Naucoridae	*Heleocoris indicus*
		Gerridae	*Limnogonus fossarum fossarum*
		Naucoridae	*Heleocoris* spp.
		Nepidae	*Ranatra* spp.
Station 2	Coleoptera	Gyrinidae	*Orectochilus orissaensis*
		Hydrophilidae	*Amphiops* spp.
	Hemiptera	Nepidae	*Cercotmetus fumosus*
		Nepidae	*Ranatra varipes varipes*
		Gerridae	*Limnogonus* spp.
		Gerridae	*Limnometra fluviorum*
		Gerridae	*Limnogonus nitidus*
		Gerridae	*Limnogonus fossarum fossarum*
		Belostomatidae	*Diplonychus* spp.
		Notonectidae	*Anisops kuroiwae*
		Notonectidae	*Anisops* spp.
		Pleidae	*Paraplea frontalis*
		Corixidae	*Micronecta scutellaris scutellaris*
Station 3	Coleoptera	Hydrophilidae	*Sternolophus rufipes*
		Dytiscidae	*Laccophilus flexuosus*
		Dytiscidae	*Laccophilus elegans*
		Hydrophilidae	*Amphiops* spp.
		Hydrophilidae	*Helochares pallens*
		Hydrophilidae	*Helochares* spp.
	Hemiptera	Nepidae	*Ranatra elongata*
		Gerridae	*Limnogonus fossarum fossarum*
		Corixidae	*Micronecta scutellaris scutellaris*
		Aphelocheiridae	*Aphelocheirus* spp.
		Belostomatidae	*Diplonychus* spp.
Station 4	Coleoptera	Gyrinidae	*Gyrinus convexiculus*
		Noteridae	*Canthydrus flavus*
		Hydrophilidae	*Helochares* spp.
	Hemiptera	Corixidae	*Micronecta* spp.
		Notonectidae	*Anisops* spp.
Station 5	Coleoptera	Hydrophilidae	*Amphiops simplex*
	Hemiptera	Nepidae	*Cercotmetus fumosus*
		Nepidae	*Ranatra filiformis*
		Nepidae	*Ranatra varipes varipes*
		Nepidae	*Ranatra* spp.
		Notonectidae	*Anisops* spp.
		Belostomatidae	*Diplonychus* spp.

Conclusion:

The outcome of the present study showed that beetles and bugs are present in large numbers in various surveyed riverine systems of Maharashtra. 12 species of aquatic insects belonging to the order Coleoptera, and 17 species of aquatic insects belonging to the order Hemiptera; were recorded in the study. It is a well-known fact that the aquatic insects are important links in the aquatic food web and they help in maintaining the ecosystem balance. Documenting their diversity and distribution will help us to understand the consequences of the anthropogenic impact on the natural waterbodies; due to ever-rising population, extensive urbanisation, indiscriminate industrialisation, and irrational agriculture. Knowing that aquatic insects serve as 'bioindicators,' scientific information on their variety and number can help us to evaluate the water quality status, and determine the pollution level at a particular location in a specific aquatic system.

Inference:

The Simpson's Diversity Index values indicated low diversity of aquatic beetles and bugs at all the five sampling stations. The Station 2 (on Tapi River) had the highest value of Shannon-Weiner Diversity Index, indicating moderate diversity; whereas remaining four stations showed less diversity. Further, all the five sampling stations showed moderate pollution status of water. Highest Evenness value was observed at Station 5 (on Ulhas River), indicating similarity of co-occurring species. Similarly, highest Dominance value was recorded at the same sampling station, indicating that one or few species show unevenness in species composition.

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Order Coleoptera

1. *Gyrinus convexiculus*

2. *Berosus indicus*

3. *Amphiops sp.*

4. *Helochares sp.*

5. *Orectochilus orissaensis*

6. *Amphiops sp.*

7. *Sternolophus rufipes*

8. *Laccophilus flexuosus*

9. *Laccophilus elegans*

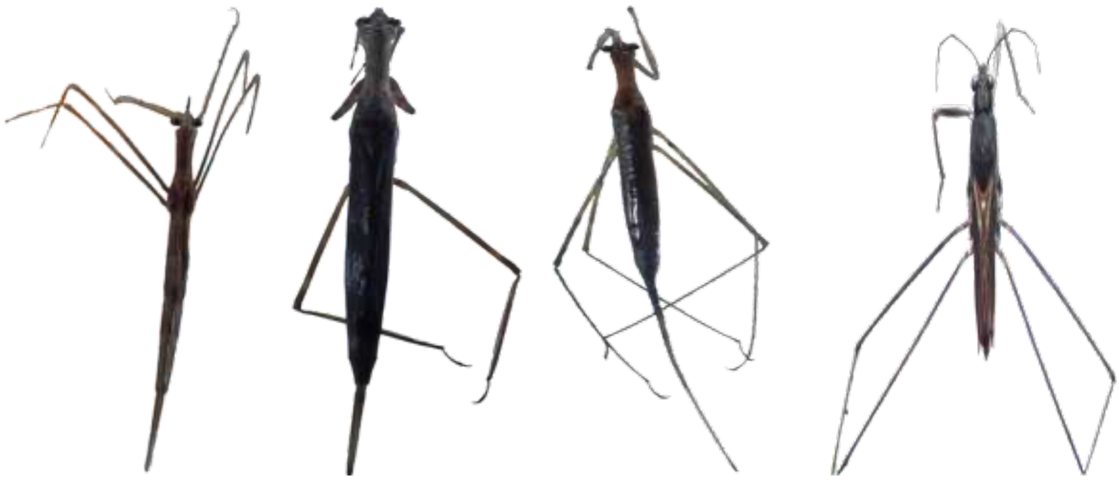
10. *Helochares pallens*

11. *Canthydrus flavus*

12. *Amphiops simplex*

Order Hemiptera

1. *Micronecta scutellaris* 2. *Heleocoris indicus* 3. *Limnogonus fossarum* 4. *Heleocoris sp.*



5. *Ranatra sp.* 6. *Cercotmetus fumosus* 7. *Ranatra varipes varipes* 8. *Limnogonus sp.*

9. *Limnometra fluviorum* 10. *Limnogonus nitidus* 11. *Diplonychus sp.* 12. *Anisops kuroiwae*




13. *Anisops sp.* 14. *Paraplea frontalis* 15. *Ranatra elongata* 16. *Aphelocheirus sp*.

17. *Ranatra filiformis*

Evaluating the Impact of Anthropogenic Activities of Dhara Catchment of district Srinagar, Jammu and Kashmir India.

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ABSTRACT

Human activities play an important role in the destruction of forests and are responsible for the disappearance of a wide range of plants. Increased and indiscriminate felling of trees for timber, fodder, fuel, construction etc. has caused severe damage to habitats. In our study the soil samples were collected from each anthropogenic area and forest zone of Faquir Gojari area. Fifty soil samples (0-15 cm) of quadrants laid out for the study of vegetation in all zones Anthropogenic and forest area with the result the edaphic factor becomes unsuitable for existing species. With this objective the present study was undertaken to find out the soil conditions in the anthropogenic area of Fakir Gojri of Dhara catchment. Therefore, it is concluded from the present study that the studied area under Anthropogenic activities showed significant increase in pH and decrease in organic carbon (%), moisture content (%) and available N P K (ppm) during autumn and summer. area in the same catchment area.

Keywords: *Anthropogenic activities, destruction of forests, Dhara catchment, organic carbon, catchment area.*

INTRODUCTION

Deforestation greatly affects the physical and chemical properties of soils (Hajabbasi et al. 1997). Quantification of soil quality adjustments following deforestation through measurable soil properties is critical to maintaining the conservation process. A research was initiated in 1994 to assess the consequences of deforestation in Iran according to which deforestation and clearing of forests in the Central Zagros Massifs has resulted in reduced soil quality thereby reducing the general productivity of the land. Increased population rates and the resulting need for more food and fiber require additional land for agriculture; As a result, every year, hundreds of hectares of forests are destroyed and converted to croplands and agricultural fields in Iran's northern and central Zagros. Deforestation results in lower soil quality in nearby areas as determined by examining its physical and chemical properties. Reductions in soil organic matter and aggregate size, increases in soil bulk density, and changes in soil concentration were found to be inevitable and detrimental after deforestation. Cultivation and cropping in stand forests is another cropping exercise that further reduces soil quality to some extent, but not to the extent of deforestation. Some underlying indicators of deforestation include forest cover, per capita income, poverty, agricultural production, food, governance and population growth (Khuc et al. 2018). Therefore, research has noted that intercropping among forest trees may be the most feasible and suggestive method of crop production; It will sustain a moderately elevated population area as common resources like forest trees and soil will be moderately protected.

Soil erosion is generally classified by three actions, including soil loosening, transport, and disposal. These processes typically result in topsoil migration that transfers organic matter, nutrients, and soil life elsewhere on the site where it builds up over time or is transported off site where it accumulates in drainage channels. It is usually severe in unprotected slope areas (Shi et al., 2012).

Such land-use change can influence multiple parameters that control hydrological and geomorphological transport processes such as soil infiltration capacity, soil erodibility, surface roughness, and local capacity to store water and sediment (Hill et al. 2008; Bajoko et al. 2012 ; Kavian et al. 2017 ; Taghizadeh-Mehrjardi et al. 2019). Land-use change is a worldwide problem that generally leads to land degradation, mainly by changing several parameters of soil quality (Nabiollahi et al. 2020; Zeratpisheh et al. 2020). Moreover, land-use change is an important contributor to greenhouse gas emissions, accounting for 12.5% of carbon emissions from 1990 to 2010 (Houghton et al. 2012) and a third of total anthropogenic carbon emissions over the past 150 years. (Quesada et al. 2018)

According to (UNCCD, 2012), degradation is the reduction or loss of biological or economic productivity in arid, semi-arid and arid sub-humid areas or rain-fed cropland, irrigated cropland, or range, pasture, forest and soil. Woodlands as a result of processes, including processes arising from land use or a combination of processes or human activities and habitat patterns, such as soil erosion by wind and/or water; deterioration in the physical, chemical and biological or economic properties of; and long-term loss of natural vegetation. Degradation of natural resources, especially land and forests, has become a serious concern in developing countries where most rural people depend on these resources for subsistence (FAO, 2011).

Deforestation has various harmful consequences. Thousands of species die due to loss of habitat due to forest fires, cutting of trees etc. Deforestation also contributes to global warming because when a tree decomposes it releases CO2 which is absorbed while growing to make carbohydrates, fats and proteins. When a large number of trees are removed from an area, it causes soil erosion because there is no vegetation to reduce the impact of heavy rainfall on the soil and no roots to hold the soil in place. It causes desertification (cultivable land turns into desert).

The land between the other spheres of the Earth is highly affected and it is important to raise awareness by stakeholders, rural residents and policy makers to reduce negative and irreversible impacts (Rodrigo-Comino et al. 2020a). In the context of global climate change and environmental degradation, protecting land as a non-renewable resource should be a worldwide concern (Celik 2005; Lal 2015; Orgiazzi et al. 2018). Human activities have been the primary driver of environmental change in recent years by converting natural ecosystems into agricultural landscapes (Chauchard et al. 2007). Due to agricultural deforestation, conversion of rangeland to cropland is a local and global environmental concern (Foley et al. 2005), resulting in changes in soil properties and soil infiltration rates and changes in soil physical characteristics that ultimately increase soil erosion (Lee et al. al. 2007; Nabiollahi et al. 2020; Zeratpisheh et al. 2020).

Forests have provided valuable resources to the rural population since time immemorial. At the end of the 19th century, population growth alternated with the depletion of forest resources. Certainly, the link between forest products with increasing human population coupled with urbanization has resulted in the acceleration of deforestation over the next century.

Several factors may influence household utilization of freely available forest resources. Some of these concern household characteristics while others are contextual. Larger household clear more forest because they have more workers and more mouth to be fed(SAH Andrabi & L. Puni 2012. Apart from the tangible and intangible benefits, it has threatened the forest resources. In the study area, the forest area under study has been cleared as a result of overgrazing, wood, fodder and firewood collection. Dhara with a total area of 21467 hectares (Forest Division of Kashmir) falls between 34º2'50" to 34º14'7" N latitude and 74º50'0" and 75º8'35" E longitude in the north of Kashmir Division of J&K state. . The area is also home to the world famous Dal Lake. The place is approximately 35 km from the city. The Dhara area is divided into Fakir Gojar, Tulpatnar, Cheki-Dhara and Naganar micro watersheds. However, for the present study, Fakir Gojar under forest and deforested areas spread over 866 ha has been selected. A study titled "Evaluation of Deforestation Impact on Some Edaphic Attributes of Dhara Catchment" was conducted considering the versatile uses of forests (M.D.Shah and *Dr. Mubashir Jeelani 2015).

MATERIAL AND METHODS

Soil samples were collected from each anthropogenic area and forest zone of Faquir Gojari area in 2021-2022. Fifty soil samples (0-15 cm) of quadrants laid out for the study of vegetation in all zones Anthropogenic and forest area. Soil samples of all zones were pooled separately and from composite samples of different zones of two habitats, soil samples were selected for analysis.

➢ ***Preparation of soil samples***

Soil samples were air-dried in the shade, crushed with wood with a pestle and mortar and then sieve through a 2mm sieve. Processed samples were labeled and stored for subsequent analysis.

1.1. Methods of analysis

Analytical procedures were used to determine various chemical properties of the soil are:

➢ ***pH***

Soil pH was determined with a glass electrode pH meter from using a 1:2.5 soil water suspension **(Jackson, 1958)**.

➢ ***Organic carbon***

Organic carbon was determined by **Walkley and Black (1935)** Rapid titration method. The soil was treated with potassium dichromate, concentrated sulfuric acid, and phosphoric acid with indicator and titrated with ferric ammonium sulphate solution.

➢ ***Moisture content***

Soil moisture was measured based on oven-dry soil at 800 °C 24 hours **(Mishra, 1968)** and was calculated as:

$$\% \text{ moisture in soil} = \frac{(x-y)}{(x)} \times 100$$

Whereas,

(x)=Moisture content in soil

(y)=Weight of oven dry soil

➢ ***Available nitrogen***

0.32% KMnO4 and 2.5% NaOH were added to the soil sample distillation was carried out in 4% boric acid containing a mixed indicator for estimation of available nitrogen according to the method provided by **Subiah and Asia (1956).**

➢ ***Available phosphorus***

Available phosphorus was extracted with Olsen extractant (0.5 N NaHCO3) and the color intensity developed from ammonium molybdate and stannous chloride, was measured with a spectrophotometer at 660 nm wavelength as described by **Jackson (1958).**

➢ ***Available potassium***

Available potassium was extracted with neutral normal ammonium ion acetate **(Henway and Heidal, 1952)** and the determination was made at Systronic flame photometer.

RESULT

Impact of Anthropogenic Activities on chemical attributes of soil of Faquir Gojri in summer

Impact on pH of soil

Perusal of the data presented in Table, 15 on chemical attributes of soil of Faquir Gojri revealed a pH of 6.7 in upper zone of Anthropogenic area against 6.4 recorded at the same elevation in the forest area. At middle zone in Anthropogenic area soil showed a pH of 7.4 against 6.2 recorded in middle zone of forest area. Lower zone of Anthropogenic area showed soil pH of 7.6 while as a pH of 6.6 was recorded at the same elevation in forest area in summer.

Impact on organic carbon of soil

Data presented in (Table 1) revealed 2.06 per cent organic carbon in upper zone of deforested area against

2.27 per cent recorded in upper zone of forest area in summer. In middle and lower zone of Anthropogenic area organic carbon was recorded as 1.8 and 1.3 per cent, respectively. In forest area of Faquir Gojri organic carbon in middle zone was recorded as 2.1 per cent. In lower zone in the same habitat organic carbon was found to be 2.14 per cent.

Impact on moisture content of soil

In Anthropogenic area of Faquir Gojri (Table 1) highest moisture content (17.89%) was recorded in upper zone while as at the same elevation in forest area (Table 2) moisture content was found to be 27.45 per cent. In middle zone of Anthropogenic area soil moisture was found to be 17.73 per cent against 25.2 per cent recorded at the same elevation in forest area. In lower zone moisture content was found to be 16.63 per cent against 24.92 per cent recorded in the lower zone of forest area in Faquir Gojri in summer.

Table 1: Chemical attributes of soil of Faquir Gojri in Anthropogenic area of different zones in summer.

Zone	*Altitude (masl)*	*pH*	*Organic carbon (%)*	*Moisture content (%)*
Upper Zone	2640–2760	6.7	2.06	17.89
Middle Zone	2520–2640	7.4	1.8	17.73
Lower Zone	2400–2520	7.6	1.3	16.63
Mean		7.2	1.72	17.42

Table 2: Chemical attributes of soil of Faquir Gojri in Forested area of different zones in summer.

Zone	*Altitude (masl)*	*pH*	*Organic carbon (%)*	*Moisture content (%)*
Upper Zone	2640–2760	6.4	2.27	27.45
Middle Zone	2520–2640	6.2	2.1	25.2
Lower Zone	2400–2520	6.6	2.14	24.92
Mean		6.4	2.17	25.86

Impact of Anthropogenic on chemical attributes of soil of Faquir Gojri in autumn

Impact on pH of soil

Perusal of the data presented in (Table 3) on chemical attributes of soil of Faquir Gojri in autumn revealed that pH of 7.2 in upper zone of Anthropogenic area against 6.4 recorded at the same elevation in the forest area. At middle zone in Anthropogenic area soil showed pH of 7.4 against 6.8 recorded in middle zone of forest area. Lower zone of Anthropogenic area showed soil pH of 7.8 while as a pH of 6.7 was recorded at the same elevation in forest area in autumn.

Impact on organic carbon of soil

Data presented in (Table 3) revealed 1.98 per cent organic carbon in upper zone of Anthropogenic area against 2.2 per cent recorded in upper zone of forest area. In middle and lower zone of Anthropogenic area organic carbon was recorded as 1.83 and 1.18 per cent, respectively. In forest area of Faquir Gojri organic carbon in middle zone was recorded as 2.2 per cent while as in lower zone in the same habitat organic carbon was found to be 2.04 per cent.

Impact on moisture content of soil

In deforested area of Faquir Gojri (Table.3) highest moisture content (20.8%) was recorded in upper zone while as at the same elevation in forest area moisture content was found to be 29.45 per cent (Table.4). In middle zone of deforested area soil moisture was found to be 20.01 per cent against 27.3 per cent recorded at the same elevation in forest area. In lower zone moisture content was found to be 19.7 per cent against 25.96 per cent recorded in the lower zone of forest area in Faquir Gojri in autumn.

Impact of Anthropogenic on nutrient status of soil of Faquir Gojri in summer

Impact of Anthropogenic Activities on available nitrogen

Perusal of the data presented in (Table 5) revealed 180.3 ppm nitrogen in upper zone of Anthropogenic area against 245.00 ppm recorded in upper zone of forest area. In middle and lower zone of Anthropogenic area nitrogen was recorded as 160.21 and 120.15 ppm respectively. In forest area of Faquir Gojri nitrogen in middle zone was recorded as 230.24 ppm and in lower zone in the same habitat nitrogen was found to be 215.2 ppm.

Impact of Anthropogenic Activities on available phosphorus

In Anthropogenic area of Faquir Gojri (Table 5)

Table 3: Chemical attributes of soil of Faquir Gojri at different zones Anthropogenic area in autumn.

Zone	Altitude (masl)	pH	Organic carbon (%)	Moisture content (%)
Upper Zone	2640–2760	7.2	1.98	20.8
Middle Zone	2520–2640	7.4	1.83	20.01
Lower Zone	2400–2520	7.8	1.18	19.7
Mean		7.47	1.66	20.17

Table 5: Nutrient status of soil of Faquir Gojri at different zones in Anthropogenic area in summer.

Zone	Altitude (masl)	Available N (ppm)	Available P (ppm)	Available K (ppm)
Upper Zone	2640–2760	180.3	21.53	110.54
Middle Zone	2520–2640	160.21	18.43	108.25
Lower Zone	2400–2520	120.15	17.2	106
Mean		153.55	19.05	108.26

Table 4: Chemical attributes of soil of Faquir Gojri at different zones forested area in autumn.

Zone	Altitude (masl)	pH	Organic carbon (%)	Moisture content (%)
Upper Zone	2640–2760	6.4	2.2	29.45
Middle Zone	2520–2640	6.8	2.2	27.3
Lower Zone	2400–2520	6.7	2.04	25.96
Mean		6.63	2.15	27.57

Table 6: Nutrient status of soil of Faquir Gojri at different zones in forested area in summer.

Zone	Altitude (masl)	Available N (ppm)	Available P (ppm)	Available K (ppm)
Upper Zone	2640–2760	245	26.52	148.27
Middle Zone	2520–2640	230.24	24.14	143.11
Lower Zone	2400–2520	215.2	22.2	141
Mean		230.15	24.29	144.13

highest phosphorus (21.53 ppm) was recorded in upper zone but at the same elevation in forest area phosphorus was found to be 26.52 ppm (Table 6). In middle zone of Anthropogenic area soil phosphorus was found to be 18.43 ppm against 24.14 ppm recorded at the same elevation in forest area. In lower zone phosphorus was found to be 17.2 ppm against 22.2 ppm recorded in the lower zone of forest area in Faquir Gojri in summer.

Impact of Anthropogenic Activities on available potassium

Data presented in (Table 5) revealed 110.54 ppm potassium in upper zone of Anthropogenic area against 148.26 ppm recorded in upper zone of forest area. In middle and lower zone of area potassium was recorded as 108.25 and 106.00 ppm, respectively. In forest area of Faquir Gojri potassium in middle zone was recorded as 143.11 ppm while as in lower zone in the same habitat potassium was found to be 141.00 ppm.

Impact of Anthropogenic Activities on nutrient status of soil of Faquir Gojri in autumn.

Impact of Anthropogenic Activities on available nitrogen

Perusal of the data presented in (Table 7) on nutrient status of soil of Faquir Gojri in autumn revealed 177.27 ppm nitrogen in upper zone of Anthropogenic area against 230.16 ppm recorded in upper zone of forest area. In middle and lower zone of Anthropogenic area nitrogen was recorded as 156.31 and 118.3 ppm respectively. In forest area of Faquir Gojri nitrogen in middle zone was recorded as 221.16 ppm and in the lower zone in same habitat nitrogen was found to be 201.2 ppm.

Impact of Anthropogenic Activities on available phosphorus

In Anthropogenic area of Faquir Gojri (Table 7) highest phosphorus (19.94 ppm) was recorded in upper zone while as at the same elevation in forest area phosphorus was found to be 23.45 ppm (Table 8).In middle zone of Anthropogenic area soil phosphorus was found to be17.61 ppm against 20.24 ppm recorded

Table 7: Nutrient status of soil of Faquir Gojri at different zones in anthropogenic area in autumn.

Zone	*Altitude (masl)*	*Available N (ppm)*	*Available P (ppm)*	*Available K (ppm)*
Upper Zone	2640–2760	177.27	19.94	107
Middle Zone	2520–2640	156.31	17.61	106.05
Lower Zone	2400–2520	118.3	16.57	104
Mean		150.63	18.04	105.68

Table 8: Nutrient status of soil of Faquir Gojri at different zones in forested area in autumn.

Zone	*Altitude (masl)*	*Available N (ppm)*	*Available P (ppm)*	*Available K (ppm)*
Upper Zone	2640–2760	230.16	23.45	139.34
Middle Zone	2520–2640	221.16	20.24	136.22
Lower Zone	2400–2520	201.2	20	133.22
Mean		217.51	21.23	136.26

at the same elevation in forest area.In lower zone phosphorus was found to be 16.57 ppm against 20.00 ppm recorded in the lower zone of forest area in Faquir Gojri in autumn.

Impact of Anthropogenic Activities on available potassium

Data presented in (Table 7) revealed 107.00 ppm potassium in upper zone of Anthropogenic area against 139.34 ppm recorded in upper zone of forest area. In middle and lower zone of Anthropogenic area potassium was recorded as 106.05 and 104.00 ppm respectively. In forest area of Faquir Gojri potassium in middle zone was recorded as 136.22 ppm. In lower zone in the same habitat potassium was found to be 133.22 ppm.

DISCUSSION

In order to know the impact of Anthropogenic Activities on chemical attributes of soil, impact on pH, organic carbon (%) and moisture content (%) were worked out ((Table 1,2 and 3,4). Significant increase was recorded in soil pH in anthropogenic area of Faquir Gojri during both summer and autumn seasons. Increase in pH in anthropogenic area is attributed to decrease in organic matter accumulation and decrease in forest cover. Thus pH values are negatively correlated with organic carbon. Further significant increase in soil pH with decrease in altitude is also attributed to decrease in organic matter accumulation. These observations are in line to the findings of **Verma *et al.* (1990). Zargar *et al.* (2005)** also reported increase in pH in degraded forests.

Significant decrease was observed in organic carbon content under Anthropogenic area in both seasons (Table 1,2 and 3,4). Decrease in organic carbon could be due to relatively high decomposition in anthropogenic area due to high temperature as a result of decrease in forest cover. Our results are in conformity to the findings of **Ajaz (2003)**. Significant decrease in organic carbon content of soil with decrease in altitude is attributed to increase in temperature.

In the present study, significant decrease in moisture content of soil was recorded in anthropogenic area of Faquir Gojri. Because of higher temperature attributed by direct sunlight which in turn enhances rate of evaporation thereby reducing moisture content of soil. However, significant decrease was recrded with decrease in altitude in case of moisture content.

To know the impact of Anthropogenic Activities on nutrient status of soil, available nitrogen, phosphorus and potassium were examined during summer and autumn seasons in Anthropogenic and forest area (Table 5, 6 and 7, 8). Significant decrease in available nitrogen content of soil was recorded in anthropogenic area in both seasons being statistically significant. Decrease in available nitrogen in Anthropogenic area is ascribed to decrease in organic carbon, latter being bank of soil nitrogen. **Verma *et al.* (2005)** and **Zargar *et al.* (2005)** also reported significant decrease in available nitrogen in degraded forests whileas, **Singh (2004)** reported medium to high available nitrogen content in forest soils of Kashmir valley.

In present study significant decrease in available phosphorus and potassium were recorded during summer and autumn in anthropogenic area. Decrease in these macronutrients of soil could be due to decrease in forest litter under degraded conditions. However, **Zargar *et al.* (2005)** reported significant decrease in available phosphorus and potassium in degraded forests of Kashmir. **Verma *et al.* (2005)** also reported significant decrease in available phosphorus and potassium in degraded forests. Although **Singh (2004)** reported medium to high available phosphorus and potassium in forest soils of Kashmir.

CONCULISION

Impact of Anthropogenic on chemical attributes of soil of Faquir Gojri

Significant increase was recorded in soil pH in anthropogenic area during both summer and autumn seasons. Soil pH increased with decrease in altitude. Organic carbon and moisture content of the soil showed significant decrease in anthropogenic area. With decrease in altitude organic carbon and moisture content also showed significant decrease during both seasons. Available nitrogen, phosphorus and potassium contents of soil of Anthropogenic Sarea decreased significantly in both seasons and reduced in altitude.

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Ecology of Larks (Passeriformes: Alaudidae) from Mhaswad Area, Maharashtra State, India

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Abstract:

Larks are the passerine birds that are adapted for living in a wide range of open habitats ranging from grassland, semi-arid, arid and cultivated landscapes. In Maharashtra, the Deccan plateau provides perfect habitat for many residents and few migratory species of larks. In the present study, an attempt has been made to study population status and ecology of larks from semi-arid habitats of Mhaswad area, an ecotone between Solapur and Satara districts. Of the five species of larks recorded, the Sykes's Lark (*Galerida deva*) was the most abundant (40%) followed by Ashy-crowned Sparrow Lark (*Eremopteryx grisea*) (36%), Greater Short-toed Lark (*Calandrella brachydactyla*) (13%), Indian Bush Lark (*Mirafra erythroptera*) (8%) and the least number was represented by Rufous-tailed Lark (*Ammomanes phoenicurus*) (3%). Furthermore, breeding ecology of three species of larks viz. Indian Bush Lark, Ashy-crowned Sparrow Lark and Sykes's Lark were studied in detail. A total of 137 nests of three larks have been recorded, of which, 64% of nests were of Ashy-crowned Sparrow Lark, 27% of Sykes's Lark and 9% were of Indian Bush Lark. Temporal variation and habitat selection patterns of nests were revealed using correspondence and cluster analysis. A clear positive association between numbers of nests with rainfall and an overall negative association with temperature was evident. Larks play major roles in an ecosystem as seed dispersers, prey items to many secondary and tertiary consumers and in the succession of ecosystems. Generating more scientific data and insights on the ecology of lesser known species should be prioritized for managing species outside protected area.

Keywords:
Lark, Ecology, Nest Habitat, Mhaswad, Satara, Maharashtra.

Introduction

Larks are notably old-world terrestrial passerine birds adapted to live in diverse open habitats ranging from grassland, arid, semi-arid and cultivation. According to Birds of the World: Version: 1.0 (Winkler et al., 2020), the family Alaudidae is currently represented by 93 species belonging to 21 genera. Of the 93 species in the world, 22 are reported in India (Grimmett et al., 1998) and about 08 species have been documented in Maharashtra state (Grimmett et al., 2005).

Detailed ecological investigations on the larks from India are few and lacking. Previous studies on the ecology and breeding of lark species from India are anecdotal and include observations on the nests of larks and other ground nesting birds (Santharam, 1980; 1995), on the breeding of Ashy-crowned Finch-lark from Rajkot (Mundlaur, 1985) and general notes on nests and breeding records (Monga and Naoroji, 1980). Detailed natural history accounts on the larks were written by British naturalists (Jerdon, 1863). However, it is surprising that very few contemporary studies exist on the biology of larks and few of the recent studies that cover the subject include one from Nanded, Maharashtra on Ashy-crowned Sparrow Lark (Balkhande, 2021) and another from North East India (Nath et al., 2023). Long-term natural history studies on Sykes's Lark along with interesting facts have been documented in Maharashtra (Pande et al., 2016). The current study is part of our ongoing ecological investigation on larks and aims to discuss our observations in relation to general account on their population dynamics, breeding biology and correlation with environmental variables.

The present study is an attempt to gather ecological data on larks from Southern Tropical Thorn Forest (Champion and Seth, 1968) with dry grassland habitat from an ecotonal area between Satara and Solapur district, Maharashtra state, India. Most of the grassland habitats in the Deccan peninsula are experiencing intense fragmentation and degradation causing severe threat to many species adapted to semi-grassland habitat (Mahindrakar, 2023).

Material and Methodology

The ecological and nesting pattern study on larks belonging to five species viz. Sykes's Lark (*Galerida deva*), Ashy-crowned Sparrow Lark (*Eremopteryx grisea*) (36%), Greater Short-toed Lark (*Calandrella brachydactyla*), Indian Bush Lark (*Mirafra erythroptera*) and Rufous-tailed Lark (*Ammomanes phoenicurus*) was held from the semi-arid landscape near Mhaswad-Dhuldev villages (Figure-1) (17°39'16.4"N 74°48'38.6"E; 17°39'18.8"N 74°52'30.2"E) from Maan tehsil under Satara district, Maharashtra state, India. The data was collected between March to December 2023 using quadrats of size 70m x 70m and general surveys using belt transects of 300 meters. Monthly twelve quadrats and six belt transects were taken at randomly selected sites. A total of 120 quadrats and 60 belt transects were taken during the study period. The study time spanned between 7:30 a.m. to 11:30 a.m. and the associated data on ecological variables were recorded in the Epicollect5: a free and easy-to-use mobile data gathering app. Statistical analysis was performed using PAST© software version 4.09 (Hammer *et al*., 2001). Correspondence and Cluster analysis was used as a data visualization technique to reveal patterns with respect to nest habitat selection and temporal variation in the number of nests.

Maan tehsil comes under rain-shadow areas of the Satara district and the landscape of the area is mostly barren. The agro-ecological zone of the Maan tehsil is classified as drought-prone. The climate of the region is hot and dry with maximum temperatures of the region ranging between 38^{0}C to 41^{0}C and lows between 25^{0}C to 28^{0}C during summer season (February to May, 2023). The temperature range during winter (November to February, 2023) is around 14^{0}C to 16^{0}C low to 29^{0}C to 32^{0}C high. The average annual rainfall of the region is 473 mm and much of the rainfall is received during monsoon season between June to October, 2023 (Gazetteer of India, Maharashtra State-Satara District, 1963). Forest type of the region is classified as 5/DS4-Dry Grasslands (Champion and Seth, 1968). The landscape is mostly devoid of trees and the area within 10 miles of Mhaswad is covered by traditional cropland (60%), grassland (20-30%) and trees (10-20%). The average elevation of the region is 609 m above sea level.

Result

a) Species Account:

A total of five species of larks with 1686 individuals have been documented from March to December 2023. 40% (N=672, ±25.55) of individuals belong to Sykes's Lark followed by 36% (N=602, ±21.19) of Ashy-crowned Sparrow Lark, 13% (215, ±50.55) of Greater Short-toed Lark, 8% (146, ±8.32) of Indian Bush Lark and lowest number was accounted by Rufous-tailed Lark with 3% (51, ±3.21) individuals (Figure 2). Out of five species, four species were noted as resident (Sykes's Lark, Ashy-crowned Sparrow Lark, Rufous-tailed Lark and Indian Bush Lark) and one species, the Greater Short-toed Lark was a non-resident species (Figure 3).

b) Nesting Ecology:

Study of nesting ecology of three lark species led to the documentation of a total of 137 nests of three lark species (Sykes's Lark, Ashy-crowned Sparrow Lark and Indian Bush Lark). The monthly number of nests for each species from the study area is represented in Table Number 1. Temporal association between months and nests of three species is visually illustrated with two-way cluster analysis (Figure-4) and there is a distinct variation in the pattern of nesting among three species. The Ashy-crowned Sparrow Lark shows two peaks of nesting, one during high summer (March to May, 2023) and the second during monsoon (July-September, 2023) (Figure-5). The nesting of Sykes's Lark peaks during mid-monsoon season (July-September, 2023) (Figure-5) and the nesting of Indian Bush Lark usually commences after monsoon (July-October, 2023) (Figure-5). Overall, 58% of nests were found during monsoon season (N=79), followed by 30% (N=41) during pre-monsoon and 12% (N=17) during post-monsoon season. The numbers of nests of all three species show an overall declining trend during the post-monsoon season (Figure-5). The strength and direction of relationship between rainfall and temperature with nesting was determined using linear correlation and the association between number of nests with rainfall and temperature is summarized in Table Number-2. Overall, Ashy-crowned Sparrow Larks show weak positive association with rainfall (r=0.2006; P=0.5784) and very weak positive association with temperature (r=0.4550; P=0.1863). Sykes's Lark shows strong positive association with rainfall (r=0.6901; P=0.02717) and moderate negative association with temperature (r= -0.55944; P=0.09266). Indian Bush Lark reveals a very strong positive association with rainfall (0.82151; P=0.003558) and moderate negative association with temperature (r= -0.53411; P=0.1176).

c) Nest Structure and Nest Site Selection:

During the study period a total of 137 nests were recorded of three species (Table-3). 67% of nests used rocks as shelter, 30% were unsheltered nests, 1% each was against grass tufts and shrubs and an unsheltered nest was found in a pomegranate orchard (Figure-6 and 8). Highest number of nests belong to Ashy-crowned Sparrow Lark (N=88; ±33.41) followed by Sykes's Lark (N=37; ±11.21) and least number of nests were of Indian Bush Lark (N=12; ±8.28). The pattern of nests in the study area is revealed using correspondence analysis (Figure-7).

Discussion and Conclusion

Five species of larks have been documented during the study period from the dry grassland habitat of Dhuldev-Mhaswad landscape. Three of them (Indian Bush Lark, Ashy-crowned Sparrow Lark and Sykes's Lark) have been noted as common breeding species and the nests of the resident Rufous-tailed Lark were not recorded during the study period though the breeding of this lark can't be denied. Greater Short-toed Larks have been noted from November onwards as winter visitors. This species has been recorded as widespread winter visitor in India from October-November till the end of April in the form of large flocks frequenting dry grasslands, grain fields, ploughed land and damp spots near tanks (Jerdon, 1863). Sykes's Lark and Ashy-Crowned Sparrow Lark remain the most abundant and ubiquitous species as compared to Indian Bush Lark and Rufous-tailed Lark. This may be attributed to similarity in habit and habitat requirements of Sykes's Lark and Ashy-crowned Sparrow Lark that prefer wide open dry grassland landscapes that are available in abundance at the study site. The relatively low abundance of Indian Bush Lark can be due to scarcity of low-scattered bushes and trees in the study area. This species is known to keep exclusively to low-scattered jungles and perch on shrubs (Jerdon, 1863). Likewise, the scarcity of habitat requirement of Rufous-tailed Lark, such as the mosaics of ploughed lands, stubble fields, and dry bed of river at the study site may explain the fewer number of this species.

The nesting season of Sykes's Lark and Indian Bush Lark showed positive association with rainfall and negative association with temperature. Rainfall has been found as principal *Zeitgeber* for breeding of the majority of larks (Immelmann, 1963a). The breeding activity of all larks peaked with the onset of south-west monsoon from June-July. However, it is interesting to note that the breeding activity of Ashy-crowned Sparrow Larks has weak positive association with rainfall and temperature. The nesting season of Ashy-crowned Sparrow Lark has two peaks, first during summer months from March to April when temperature of the region crosses 40^{0}C and then an extended period during monsoon from June to September. Nests of Ashy-crowned Sparrow Lark have been noted throughout the year, though the overall pattern shows two major peaks, one during summer and the other during monsoon.

As regards nest site selection, the majority (89.77%) of nests of Ashy-crowned Sparrow Lark and (70.27%) of Sykes's Lark were sheltered as compared to 41.66% nests of Indian Bush Lark. However, the nests of Indian Bush Lark are round and dome shaped and has an inbuilt support from all sides with grass (Figure-8). The nests of Ashy-crowned Sparrow Lark are shallow cup on the ground constructed with grass and often rimmed with a wall of small stones and placed in the shelter of a stone, shrub/herb and/or tuft of grass. The nest of Sykes's Lark is also a shallow cup on the ground under an earth clod or at the base of a small plant (Grimmet et al., 1998). Our observations on nest architecture of larks are comparable with previous records from India (Pande et al., 2023).

In summary, the four species of larks found in the study area, inhabit the same landscape, but show reasonable variation in their microhabitat preferences within the heterogeneous habitat. The breeding activity and nest habitat selection also varies fairly among three species across season with reasonable ecological overlap within the landscape. A detailed ecological investigation on the effect of mosaic of grass, herb, shrub and the pattern of traditional crops will help in revealing other variables that may regulate the abundance and nesting pattern of larks in such landscapes.

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Author contributions

1) Pooja T. Sawant: Survey, data collection and analysis and manuscript preparation.
2) Yogesh Y. Mahindrakar: Survey, data collection and analysis and manuscript preparation.
3) Shripad V. Manthen: Survey, data collection and analysis and manuscript preparation.
4) Rajshekhar V. Hippargi: Survey, data collection and analysis and manuscript preparation.

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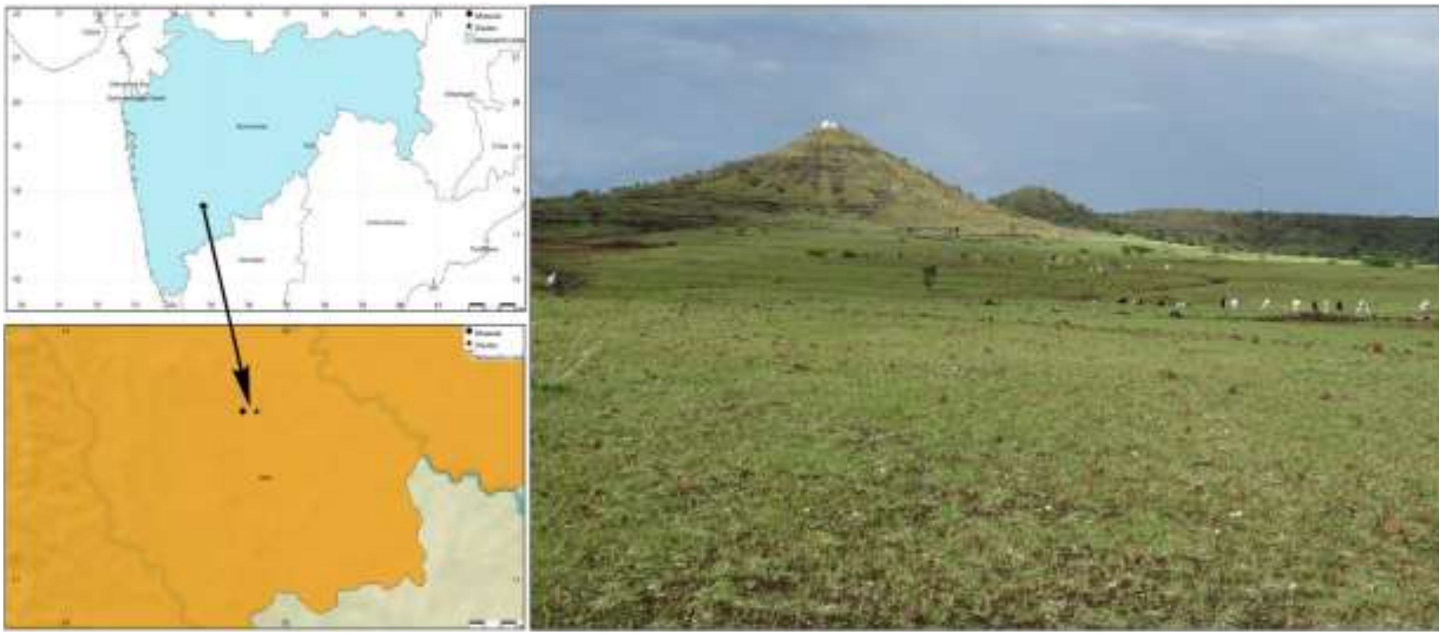

Figure 1: Study Area Location Map

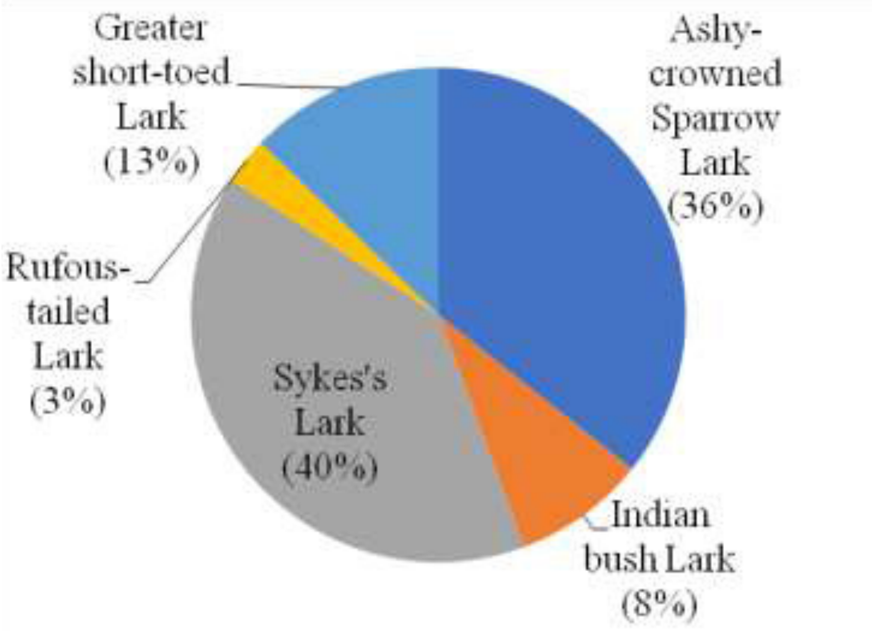

Figure 2: Abundance of Lark Species

Figure 3: Lark Species Documented from Study Area

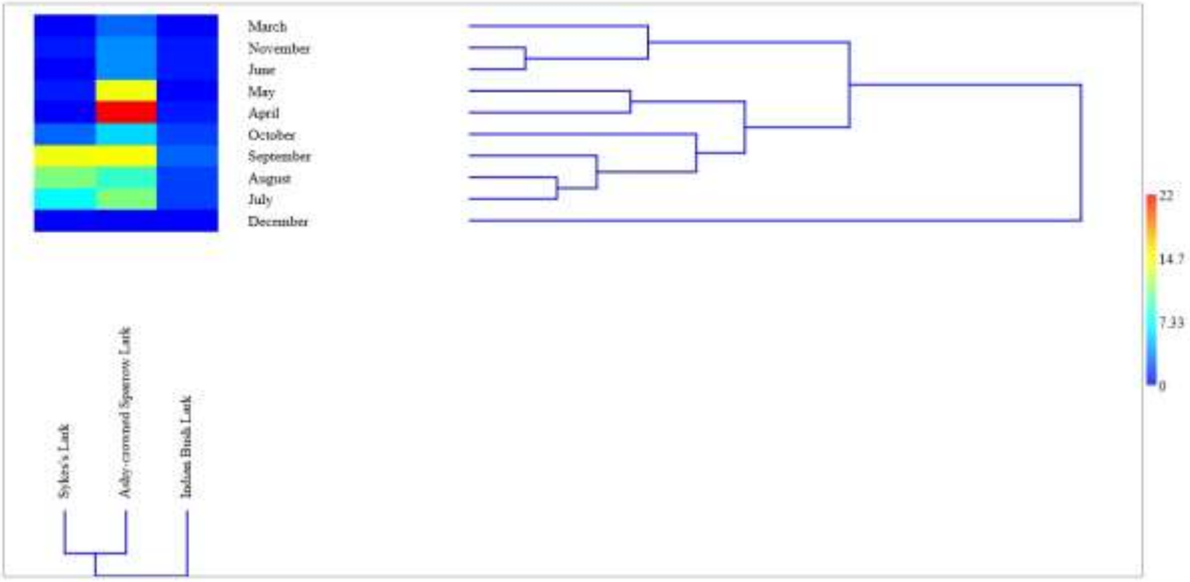

Figure 4: Two-way Cluster Analysis Showing Temporal Variation in the Nesting Pattern of Three Lark Species

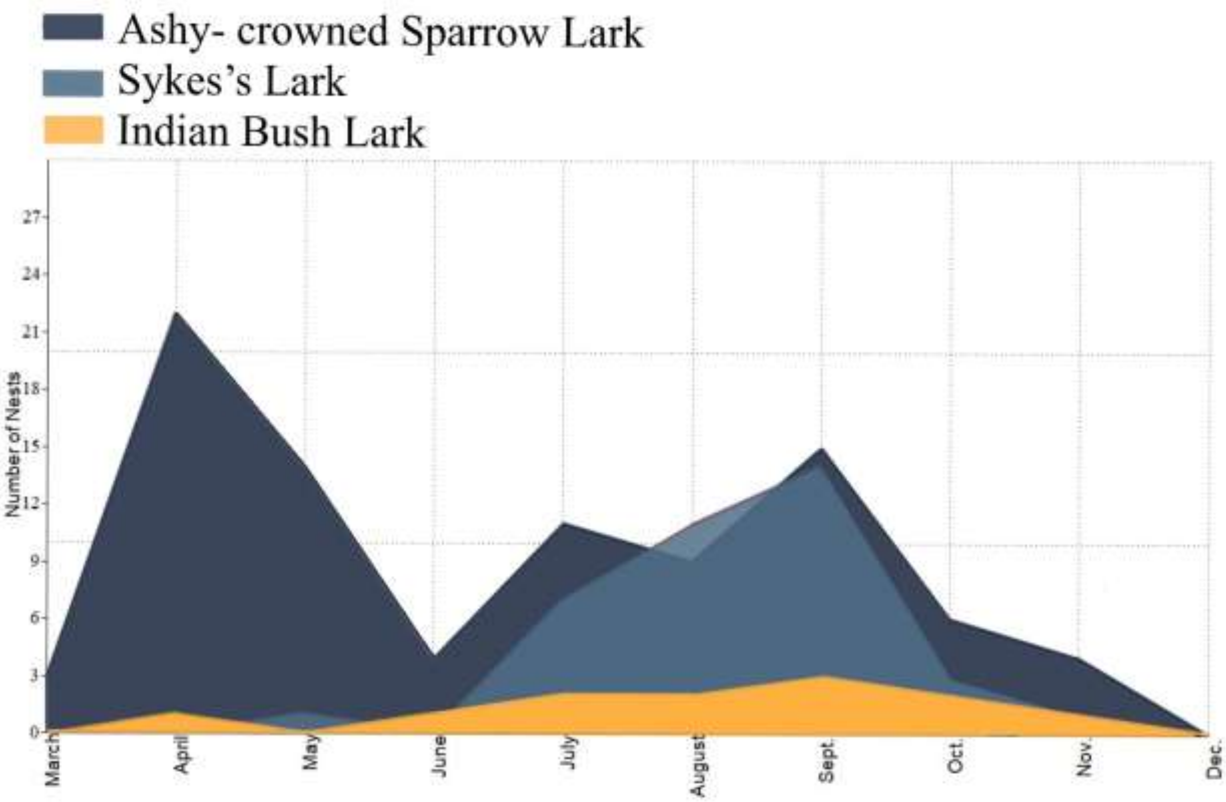

Figure-5: Nesting Pattern of Three Lark Species from Study Area

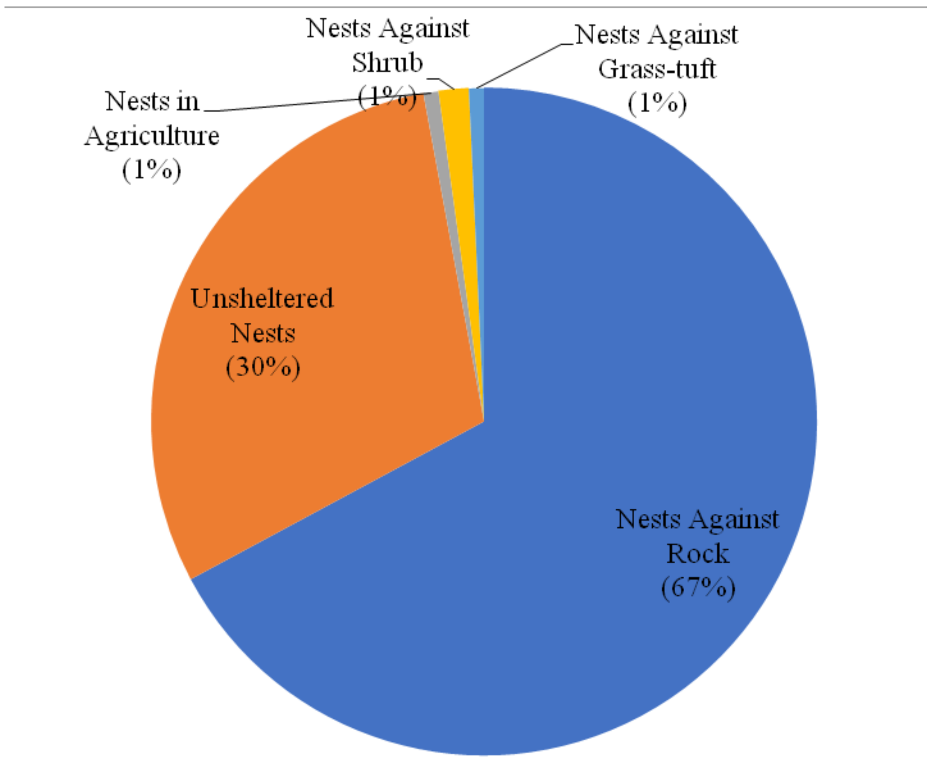

Figure 6: Percentage Variation in Nest Microhabitat Use

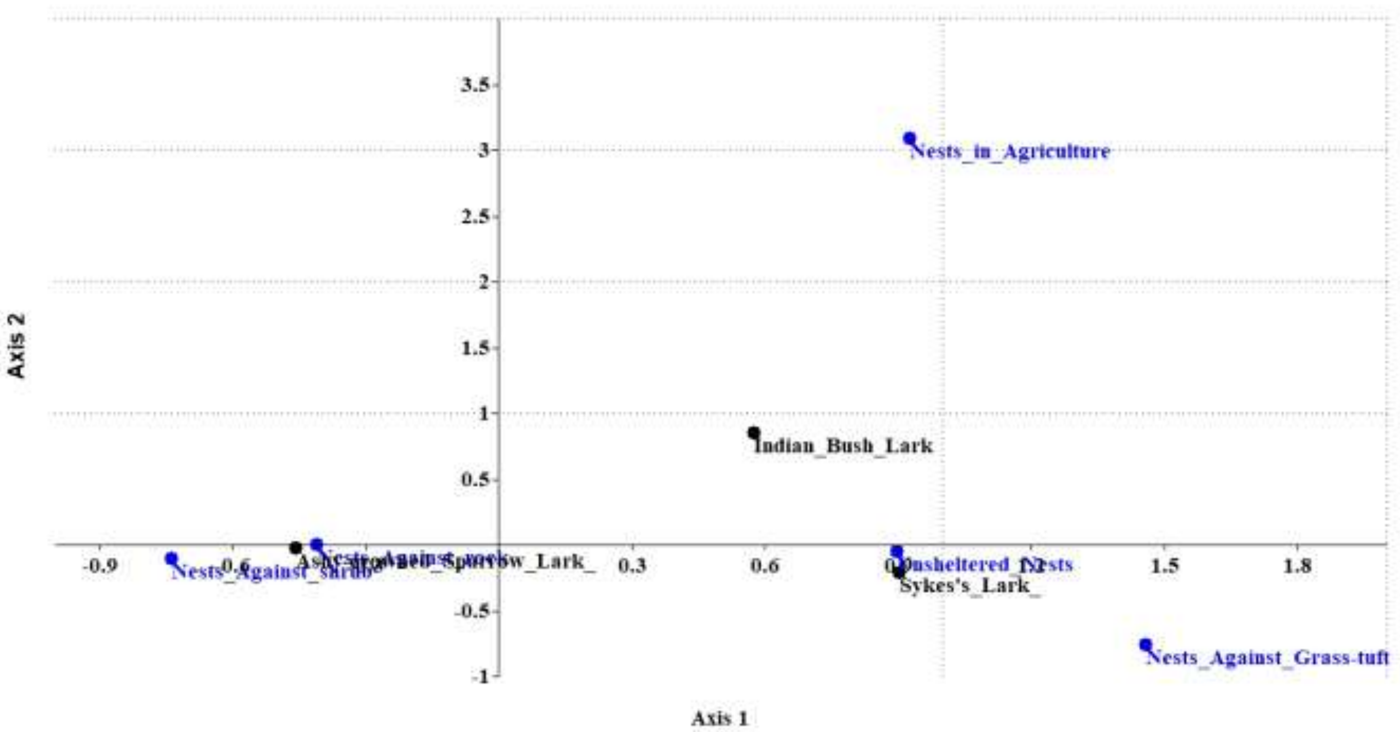

Figure 7: Correspondence Analysis showing Association between Nesting of Three Lark Species with Type of Microhabitat

Figure-8: Nest Architecture and Microhabitat Use by Three Lark Species

Table 1: Monthly Number of Nests

	Pre-monsoon			Monsoon				Post-monsoon		
Species	**March**	**April**	**May**	**June**	**July**	**August**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Ashy-crowned Sparrow Lark	3	22	14	4	11	9	15	6	4	0
Sykes's Lark	0	0	1	0	7	11	14	3	1	0
Indian Bush Lark	0	1	0	1	2	2	3	2	1	0
Total	**3**	**23**	**15**	**5**	**20**	**22**	**32**	**11**	**6**	**0**
	41			**79**				**17**		

Table 2: Linear Correlation between Number of Nests with Rainfall and Temperature (R= Correlation Coefficient; P=Statistical Significance of Correlation)

Species	Rainfall			Temperature		
	R	P		R	P	
Ashy Crowned Sparrow Lark (ACSL)	0.2006	0.57842	Weak positive association	0.45502	0.18639	Very weak positive association
Sykes's Lark (SL)	0.69017	0.027177	Strong positive association	-0.55944	0.092668	Moderate negative association
Indian Bush Lark (IBL)	0.82151	0.0035584	Very strong positive association	-0.53411	P=0.1176	Moderate negative association

Table 3: Nest Structure, Abundance and Type of Shelter Used by Three Lark Species

Species	Nest Structure	Nest Site, Shelter Used and Number				
		Against rock or at the base of rock	Against shrub-herb or at the base of shrub-herb	Against grass tuft or at the base of grass tuft	Unsheltered/ Exposed	Within Agriculture Pomegranate Unsheltered
Ashy Crowned Sparrow Lark (*Eremopteryxgrisea*)	Cup-shaped with foundation of sticks & rim of stones	77	2	0	9	0
Sykes's Lark (*Galerida deva*)	Cup-shaped with foundation of sticks & no stones	10	0	1	26	0
Indian Bush Lark (*Mirafra erythroptera*)	Dome-shaped No foundation	5	0	0	6	1
Total		**92 (±40.20)**	**2 (±1.15)**	**1 (±0.57)**	**41 (±10.78)**	**1 (±0.57)**

First record of site fidelity of ringed Black Redstart *Phoenicurus ochruros* in Ela Habitat, Pingori, Pune, Maharashtra, India

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Introduction:

The Black Redstart *Phoenicurus ochruros* is a small passerine widespread breeder in south and central Europe, Asia and north-west Africa; and from Great Britain and Ireland south to Morocco, east to central China. The north-eastern birds migrate to winter in southern and western Europe, north Africa and Asia, including India**.** During winter migration (October to April) it inhabits semi-arid hilly country with rocks and boulders, and sea coasts. They return to the breeding ground in mid-April. It is mainly carnivores feeding on various insects such as grasshoppers, flies, bugs, beetles, wasps, bees, ants, spiders, earthworms and even tiny crustaceans. It may supplement its diet with seeds berries and fruits. No previous record of site fidelity of this species from India was found, hence ringing of one Black Redstart was done at Ela Habitat with the permission of the Maharashtra Forest Department.

Material and Methods:

A solitary male Black Redstart *Phoenicurus ochruros* was observed in Ela Habitat, the field research station of Ela Foundation, for several years. The male was wary and flew after human approach. On 6th February, 2019 at 9.40am this individual was trapped in mist nest for first time under the Constant Effort Site (CES) project run by Ela Foundation and Maharashtra Forest Department in Ela Habitat, Pingori. Although the Black Redstart is known to return to the same locality in winter year after year, there has been no confirmation based on ringing records from India, of the same individual coming to the same traditional wintering ground. Hence, in order to check site fidelity for this individual the bird was ringed after biometric study (Table 1). It was caught, measured, ringed and

released. Biometry was done using Vernier calipers with least count of 0.1 mm, metal scale with stopper with a least count of 1 mm and pesola scale with a least count of 1 g. Temperature was measured with a digital laser thermometer. A white plastic ring bearing the number R–W-365 was placed on the right tarsus of the male Black Redstart. The male could be identified because there is distinct sexual dimorphism in this species (Ali and Ripley 1968; Pande et al 2003).

Results:

The ringed Black Redstart was seen in the same locality in Ela Habitat till April 2019. No other bird of the same species was seen in the study area. Each night it roosted in the same niche under the roof of residential quarters in Ela Habitat. It undertook return migration after April and was not seen again. The Black Redstart was seen again after 5 months on September 2019. Careful observation and examination of photographs (taken by author SP) confirmed that it was the same ringed male Black Redstart with a white plastic ring on the right tarsus. The Black Redstart was subsequently mist netted and re-trapped after one year in same place and in same mist net on 5th February 2020 at 8.00am the ring number in right tarsus was confirmed to be R–W-365. The Black Redstart had returned to the same locality but had changed the place of roosting and now roosted at night under the roof of an adjacent residential quarter. It freely entered the verandahs but flew when human activity occurred. It caught spiders and insects from under the roof and in flight and also took insects from the ground.

Table 1: Biometric parameters of the Black Redstart *Phoenicurus ochruros* taken during ringing and re-trapping:

Species	Black Redstart *Phoenicurus ochruros*	Black Redstart *Phoenicurus ochruros*
Date of re-sighting/re-trapping	September 2019	5 February 2020, 0800 AM
Gender	Male, 1st year Subadult	Male, Adult
Biomass	17 g	16 g
Wing chord	88 mm	88 mm
Tail	60 mm	63 mm
Beak	10.9 mm	11.9 mm
Tarsus	27.8 mm	28.1 mm
Middle toe	12.2 mm	12.8 mm
Middle talon	4.6 mm	4.6 mm
Body temperature	30.4^{0}C	28.2^{0}C
Plumage	Fresh, no molting	Fresh, no molting
Date of ringing	6 February 2019, 0940 AM	
Locality of ringing and re-sighting	Ela Habitat, Pingori, Purandar taluka, Pune district, Maharashtra	Ela Habitat, Pingori, Purandar taluka, Pune district, Maharashtra
Number of individuals ringed	One	

Conclusion:

The present report is the first confirmed evidence of site fidelity of the same ringed individual male Black Redstart returning to the same locality where it was ringed. It returned to the same locality after five months in subsequent winter after migrating to its breeding site. The finding of site fidelity importantly highlights the need of protecting and conserving all wintering sites of migratory birds.

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