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Diversity and Ecological Importance of Rove Beetles (Coleoptera: Staphylinidae) in Sur Sarovar Bird Sanctuary, a Ramsar Site in Agra, Uttar Pradesh, India

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Abstract

Rove beetles (Coleoptera: Staphylinidae) are known to be one of the most diverse and versatile groups among beetles found in various habitats like soils, leaf litter, dung, carrion, fungi, decaying plant, bark, nest and wetland edges. This report synthesizes data on Staphylinidae part of a broader work on diversity of Coleoptera at Sur Sarovar Bird Sanctuary (SSBS) in Agra, Uttar Pradesh, India. Sur Sarovar is a Ramsar wetland characterized by a mosaic of aquatics, semi/aquatic and terrestrial habitats, including grassland, scrub, forest, leaf litter, dead wood, exposed and organic rich soil, etc. Staphylinidae was represented by 4 species and 118 individuals, constituting 9.46% of the total number of Coleoptera individuals with mean value of abundance of 19.67±1.23 (n = 6). Thus, indicating that rove beetles occupy intermediate position with respect to other families of order coleoptera. The rove beetles as a group are predatory, scavengers, fungi and decomposition feeders; they thus play an important role in regulation of small sized invertebrates, decomposition process and nutrient cycling. The regional literature especially records of Staphylinidae from Sandi Bird Sanctuary in Uttar Pradesh indicates that wetlands provide important habitats for Rove beetle diversity. However, the thesis material available only uses an analytical dataset that does not present a validated census. Hence, the present paper takes numerical values reported only for analytical purposes.

Keywords*:* Staphylinidae; rove beetles; Coleoptera; Sur Sarovar Bird Sanctuary; Keetham Lake; Ramsar Site; wetland biodiversity; ecological importance; bioindicator

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Introduction

Biodiversity includes variations at genetic, species, community, and ecosystem levels. It is critical for the stability and functioning of ecosystems. Ecological processes that operate interactively, such as primary production, decomposition, nutrient cycling, biological control, and food web dynamics are responsible for sustaining ecological communities. It is important to note that species diversity analysis goes beyond just counting species. The concept demands analysis of species' distribution, abundance, and ecological importance. Invertebrates (especially insects) contribute significantly to these processes, but they have been documented to a lesser extent than vertebrates in most protected areas.

Coleoptera is one of the most diverse insect orders found in various terrestrial and freshwater habitats including forests, agricultural land, grasslands, wetlands, rivers, lakes, ponds, flower gardens, etc. Different ecological roles of this group, such as predation, herbivory, scavenging, fungivory, and decomposition, perform.

The evolutionary and ecological success of beetles is explained by their protective role of elytra, complete metamorphosis, specialization, and diversification.

Staphylinidae is one of the most important families belonging to the Coleoptera order with its great taxonomic diversity and unusual microhabitat diversity.Members of the group typically have slender body shape and shortelytra, which leads to revealing of a number of abdominal parts; nevertheless, the development of the membranous hind wings occurs in a number of species. Therefore, the mentioned morphological aspects give numerous rove beetles significant mobility and capacity to move through thin place in litter, bark of trees, rotting wood, soil, and other places that are concealed.

The habitats where the rove beetles can befound are the leaf litter, soil, dung, carrion, fungi, decayedplant material, nests of animals, marshland, and underbark. A number of species are the predators of mites, nematodes, insect eggs, larvae, and some small arthopods, while other are the scavengers, while others are represented by fungivores, being closely related to decaying organic matters. Hence, the role of

Staphylinidae can be seen in contribution to many ecosystem processes including activities in relation to the regulation of small arthropods, decomposition processes, food webs, and nutrient transfers. The presence of this family in the leaf litter, soil, and organic substrates gives an opportunity to analyze its relation with connection of various processes in terrestrial and wetland environments.

Wetlands are first of all considered based on the significance of their avifauna, water quality, and prominent vegetation, thus the small communities of invertebrates are given less attention. This results in the existence of a serious gap in ecological knowledge as insects can react quickly to the changes in vegetation, moisture, substrate quality, and disturbance. The summarized materials show the same limitations concerning the knowledge of rove beetles and other great beetle families in Uttar Pradesh. One of the most pertinent regional studies has been conducted by Abhasar in 2012 when a collection of rove beetles in Sandi Bird Sanctuary in Uttar Pradesh has been formed. In addition, Abha Sar conducted further research in Mandi, Himachal Pradesh in 2015 giving additional information about distribution of the insects. The fact that research of the distribution showcases that protected areas and surrounding landscapes in India can be characterized by various diversity of staphylinid fauna and proves the need for further work in taxonomy and faunistics.

Sur Sarovar Bird Sanctuary (SSBS) or Keetham Lake is a good territory to investigate the family, since it combines open water, wetlands, grasslands, brushwood, and forests. Thus, this habitat can provide the rove beetles with necessary resources. The presence of litter, fallen trees, wet substrates, and dead organic matters is of special importance to the research of rove beetles.

The species of beetles present in the current research has been studied in regard to the taxonomic composition, abundance, habitat, seasonal variation and ecological significance. In this regard, it should be mentioned that Staphylinidae is represented with four species and comprising 118 individuals.

The original goals of the present study were thus: (i) to find information concerning the observation of Staphylinidae in the beetles' research; (ii) to describe the habitats relevant for rove beetles in Sur Sarovar; (iii) to analyze the ecological importance of the beetles in terms of predation, decomposition and environmental monitoring; and (iv) to find out the methodological priorities to be considered during species-level surveys in future.

Materials and Methods

Study Area- The research was conducted in connection with the Sur Sarovar Bird Sanctuary located in the district of Agra in the state of Uttar Pradesh in India. The sanctuary is popularly known as Keetham Lake located in the Indo-Gangetic plain between the Agra-Mathura-Delhi corridor. The reports confirm that the site was designated as a bird sanctuary in 1991 and became a Ramsar Site on August 21, 2020. The sanctuary consists of a central lake along with land and semi-aquatic zones under the management of a wider protected-area system outlined in the source chapters.

The sanctuary is ecologically diverse. The vegetation has been reported to include grass, dry trees, and shrubs (Eucalyptus, Ziziphus, Dalbergia, and Lantana) in combination with Prosopis juliflora as well as water plants (Eichhornia and Potamogeton). The distinct microhabitats are produced using bare ground, water plants, leaf litter, bark, dead trees, and other materials. This diversity is crucial to coleopteran sampling because different families and species have different requirements for moisture, nutrition, activity, and substrate.

Survey Design and Sampling Approach- The comprehensive investigation employed a variety of field sampling techniques to ensure that species from each ecological zone were represented in the study results. The rationale for using standard techniques and repeated measuring methods stems from the fact that this researcher established that species diversity observed differs due to the effort with which sampling is made, and the type of habitats under study (Gotelli & Colwell, 2001; Magurran, 2004; Chao *et al*., 2014). Thus, this methodological proposal combines various active methods with the trapping and vegetation-based methods.

Hand catching of beetles was carried out in easily accessible habitats such as soil, under the stones, logs, or rotten plant material. This method helps avoid bias when accounting for Staphylinidae as rove beetles live in hidden terrestrial habitats. Beating method was applied for species living on bushes, twigs, flowers, and leaves, while sweeping of grasslands or any other vegetation was conducted to allow for a wider range of species to be captured. The aspirator collecting technique was used to collect small species, while pitfall traps, light traps, or bait traps were used within the main sampling frame.

The application of different sampling techniques is endorsed by the dominant ecological principles as any exclusive technique cannot be sufficient for providing full data on the structure of the community of beetles (Southwood & Henderson, 2000; Henderson & Southwood, 2016).

Staphylinidae-Relevant Microhabitats- Among the microhabitats for Staphylinidae mentioned in the chapters are leaf litter, soil, decomposing wood, stones, damp substrates, decomposing plants, dung, carcasses, fungi, etc. These habitats can serve as a habitat for rove beetles. The main uses of these substrates are as predator, scavenger, fungivore, or as a decomposition process-associated organism. Forest litter and dead wood are of big importance for biological communities, namely due to their complex structure that offers shelter, food, and fungi sources needed for existence.

Preservation and Identification- The specimens were preserved through dry or wet preservation methods depending on their needs using the sources 70% alcohol and other CM for killing or preserving the specimens to prepare them for morphological identification. It is important to make a correct taxonomic identification because family-level abundance does not provide sufficient evidence to prove the facts about endemism, rarity or conservation. The identification of the tissues at species level should be carried out using the keys from the authoritative authors and available reference collections and to conduct taxonomical expertise because for the groups of organisms like Staphylinidae, it consists of many small, morphologically similar taxa.

Analytical Measures- Species richness implies the overall number of species present within a community (S). The relative abundance was determined as $RA(\%) = (ni/N) \times 100$, where ni is the number of individuals from a particular taxon and N represents the total number of individuals recorded during the analysis. The broad analytical dataset was shown as mean ± standard error (SE) based on six analytical replicates. The studies used one-way ANOVA for family

comparison. Diversity indices such as Shannon index and Simpson index were part of the broad methodology applied in this thesis (Magurran 2004).

Results

Overall Coleopteran Context- The wide range of species included in the analysis was one thousand two hundred forty-eight coleopteran specimens and forty-two different species of beetles, belonging to twenty-eight genera and twelve families. The families of beetles are Scarabaeidae, Carabidae, Coccinellidae, Chrysomelidae, Staphylinidae, Curculionidae, Hydrophilidae, Dytiscidae, Cerambycidae, Tenebrionidae, Elateridae and Gyrinidae, and due to their types, they are divided into terrestrial, plants, decomposers and aquatic animals.

Representation of Staphylinidae- Staphylinidae family is made up of four types of species and 118 individual insects. It was found that this family forms 9.46% of the 1,248 number of individuals in the collection described in this study. Its average number of collected insects equals 19.67 ± 1.23 (n = 6). While looking at the percentages of Staphylinidae family it can be stated that the number of its specimens is less than that of the Scarabaeidae, Carabidae, Coccinellidae, and Chrysomelidae families and more than that of the regimes such as Curculionidae family and some aquatic species.

Table 1. Family-wise taxonomic and abundance context of the analytical coleopteran assemblage. Staphylinidae is shown within the broader 12-family dataset.

Family	Species richness	Individuals	Mean ± SE (n=6)	Relative abundance (%)
Scarabaeidae	6	214	35.67 ± 2.33	17.15
Carabidae	5	168	28.00 ± 1.71	13.46
Coccinellidae	4	156	26.00 ± 1.53	12.50
Chrysomelidae	5	143	23.83 ± 1.40	11.46
Staphylinidae	4	118	19.67 ± 1.23	9.46
Curculionidae	4	105	17.50 ± 1.12	8.41
Hydrophilidae	3	92	15.33 ± 0.99	7.37
Dytiscidae	3	78	13.00 ± 0.86	6.25
Cerambycidae	2	56	9.33 ± 0.76	4.49
Tenebrionidae	2	48	8.00 ± 0.58	3.85
Elateridae	2	39	6.50 ± 0.56	3.13
Gyrinidae	2	31	5.17 ± 0.48	2.48

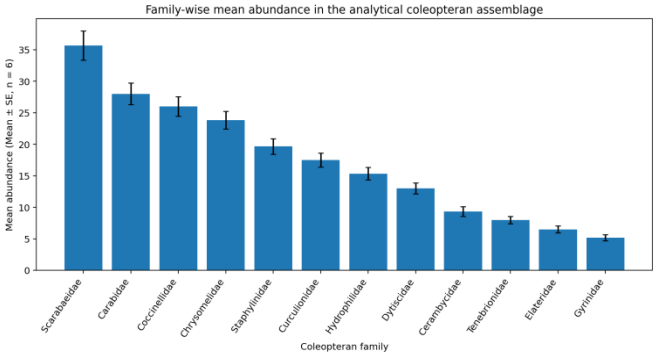

Figure 1. Family-wise variation in mean abundance (Mean ± SE, n = 6) in the analytical coleopteran assemblage. Staphylinidae had a mean abundance of 19.67 ± 1.23. The supplied thesis reports an overall significant family-wise difference ($p < 0.001$).

Species Richness Contribution- The four species belonging to Staphylinidae species formed 9.52% of the total richness of the assemblage under examination (i.e., 4 of 42 species). The species composition of Staphylinidae is comparable to that of Coccinellidae and Curculionidae in the analyzed dataset. Scarabaeidae consists of six species, while Carabidae and Chrysomelidae contain five species each. The intermediate richness of Staphylinidae is particularly interesting, as the family of rove beetles is known for inhabiting microhabitats generally not captured by conventional sweeping or light trapping, e.g., litter, soil, and decomposing organic matter.

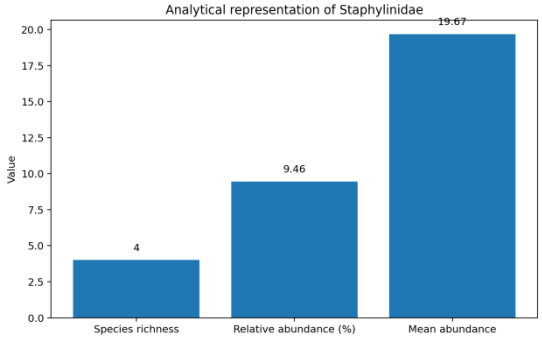

Figure 2. Summary of the analytical representation of Staphylinidae: four species, 9.46% relative abundance, and mean abundance 19.67.

Habitat Context- The comprehensive habitat analysis shows that the maximal total abundance and richness of Coleoptera was detected in grassland/herbaceous vegetation, followed by woodland/leaf litter, scrub/foliage, dung/decomposing habitats, and aquatic/wetland ones. Although these numbers can not be directly allocated to Staphylinidae family due to the fact that the data do not include counts for each family at some habitats, the habitat types give meaningful information about the types of habitats relevant to Staphylinidae. The habitats such as woodland leaf litter, rocks, decaying trees, wet soil, organic matter, or wetland margins were cited repeatedly in the methodology and literature as suitable habitats for Staphylinidae.

The ecological interpretation implies that it is necessary to study the Staphylinidae family in the wet forest litter, moist soil, decomposing organic matter and wetland margins. What is more, grassland and scrub are also potentially suitable for rove beetles as long as some required prey, soil or detritus are

available. However, the obtained information does not provide any basis for quantitative ranking for this family.

Seasonal Context- The larger the dataset on beetles analysed, the more significant peak in monsoon and relatively high quantity after monsoon was found. Habitat information is applicable here, as the seasonal values presented here refer to the number of beetles in general and are taken as a whole. Despite that, the described pattern is still relevant ecologically with the monsoon rainfall increasing soil moistness and fungi, increasing plant life and death, more animals able to be eaten. But seasonal activities of insects can depend on both humidity and temperature and thus many seasonal analyses are needed to find stable relations between habitat and the analysis of seasonal occurrences of insects (Wolda, 1988).

Discussion

Ecological Meaning of the Staphylinidae Representation- The results of examining 118 individuals representing four species suggest that Staphylinidae are not an insignificant part of the coleopteran assemblage, as the share of this family of rove beetles is 9.46%, which classifies it in the group of families with moderate abundance. In general terms, as rove beetles are frequently encountered in small, hidden, and substrate-specific habitats, even the moderate abundance of Staphylinidae in a general study of macro-fauna can have ecological significance.

Staphylinidae also fit very well into the habitat mosaic of Sur Sarovar. The sanctuary has open water, wetlands, grassland, shrubby and forested areas, the litter and soil surfaces, bark and decayed wood. Due to habitat heterogeneity, availability of different ecological guilds is provided via variation in food, shelter, moisture, and breeding substrate. Vegetational differences and various resources define the composition of beetle communities (Rainio & Niemelä, 2003; New, 2010).

For rove beetles, litter and soil are of particular importance since they ensure microclimatic conditions and contain prey. Decaying wood and bark may also be a habitat for fungi, larvae, and other species consumed by predatory and fungivorous Staphylinidae. Dung, carrion, and decomposing plants ensure nutrient-rich patches that accommodate various small invertebrate species. Thus, the response of the family can be related to habitat type and the localization of organic resources.

Predatory Function and Biological Regulation- Among the many ecological roles played by Staphylinidae, their predation is one of the major ones. A relatively high number of rove beetles mainly feed on small organisms, including, but not limited to, nematodes, mites, eggs and larvae of other insects. By feeding on the above organisms, rove beetles can affect the destruction of small prey in the soil and litter, thus altering the level of their activity. In agricultural and semi-natural landscapes, predatory beetles can affect the pest population control. Nevertheless, the effect of these beetles is not alike when different species and different environments come into play.

In Sur Sarovar, Staphylinidae should have shown predatorial characteristics within their habitats, including peat litter, wet soil, decomposing plant materials and wetland substrate. It can be inferred that there must be numerous small invertebrates in the habitat, making conclusion about the ecological importance of this group of insects difficult solely based on the relative numbers of rove beetles.

The peculiar position of rove beetles allows them to take part in the processes taking place within food chains of the ecosystem. Furthermore, such insects can bring about indirect predation, as larger organisms, such as various arthropods and other animals tend to eat them.

Decomposition, Fungivory and Detrital Food Webs- The Staphylinidae family makes a major contribution to both fungi and bacterial processes, and its forms and types are different from each other not only in their behaviour but also in their ecological roles. Thus, some beetles play an important role in the decomposition of organic materials. These beetles depend on organic materials, including fungi and bacteria, in their feeding behaviours.

In general, there are a number of ecological features that may enhance staphylinid diversity in Sarovar. In this context, it is important to mention the presence of tree debris, such as fallen trunks, leaves, bark, etc. It has been shown that fallen wood contributes significantly to staphylinid diversity because many species use it to thrive. Therefore, it remains important to incorporate dead trees into the conservation efforts of Sarovar.

Staphylinidae's contribution to decomposition processes should be viewed more as a process of community than as a single contribution. The role of rove beetles has been highlighted because they significantly facilitate decomposition of detrital microorganisms while redistributing organic matter by using other decomposing organisms. Nonetheless, Staphylinidae's involvement in decomposition certainly has significant potential.

Wetland Margins as Transitional Habitats- Wetland margins are regions of ecological transition from aquatic to terrestrial environments. They are characterized with moist environment, fluctuating water levels, emergent growth, organic matter and numerous prey species. This creates favorable environment for beetle assemblies, including moisture-related Staphylinidae.

At Sur Sarovar, the wetland margins of Keetham Lake are likely to be of particular concern. However, the available data do not account for Staphylinidae-specific counts along the wetland margins. Future research needs to be done on sampling across moisture gradients, stretching from wet margins of lakes to drier areas of grasslands or forests to determine the relationship between soil moisture, vegetation or litter depth and the abundance or richness of Staphylinidae.

Seasonal Dynamics- Seasonality may play a vital role in rove beetle populations due to the interrelation among precipitation, temperature, humidity, decomposition of dead organic matter, fungi growing in the area, and vegetation growth that attracts potential food for beetles. It has been found that more beetles are present during the monsoon season and periods after the monsoon. Although it cannot be said that Staphylinidae are becoming numerous, it provides a good argument for introducing seasonal sampling.

Wolda (1988) argued that seasonality has a significant effect on tropical insect populations. Monsoon rains in Sur Sarovar may provide moist litter, and dead organic material may increase the activity or emergence of adults. Otherwise, dry seasons will limit moisture-dependent species to climatic refuges. Thus, the necessity of conducting sampling in different seasons is evident.

Rove Beetles and Bioindicator Potential- The provided literature review highlights Staphylinidae as probably meaningful indicators, since their communities can respond in a timely manner to moisture, organic matter, vegetation, and disturbances. The use of bioindicators is especially

important in protected areas, where changes in species composition may be a sign of habitat alteration. Similar reasoning has been applied to other beetle families such as Carabidae (Rainio & Niemelä, 2003).

It should be noted that using indicators should be treated with caution. For instance, the low incidence of a given species may be the result of sampling limitations, seasonal inactivity, secretive behavior, and particular microhabitat selection rather than reflects environmental degradation. The same applies to cases with a high number of disturbance-resistant species that mask the fact that the experts are dealing with specialists. To be able to rely on Staphylinidae as indicators in Sur Sarovar, implementation of species identification down to the species level, standardized sampling, and comparison with some measurable environmental factors is required.

The following predictor variables may be taken into account: litter depth, soil saturation, vegetation cover, amount of deadwood, organic matter presence, distance to water, disturbance from visitors, and presence of invasive vegetation. Multivariate community analysis could be later used to link the composition of species with environmental gradients, although the current data are insufficient for this.

Regional Significance and Research Gap- Literature related to Uttar Pradesh described in previous chapters indicates that research conducted on coleopterans has had inconsistencies. While information regarding some genera such as dung beetles, ladybird beetles, rove beetles etc. has been available, most studies have been limited to certain families, sites or agricultural groups. The study done by Abhasar (2012) on the Staphylinidae family of Coleoptera in Sandi Bird Sanctuary is particularly useful in the context because it shows that there are considerable populations of rove beetles in wetlands protected by law. The review presented originally suggests that there was no comprehensive survey of the coleopteran fauna in Sur Sarovar conducted according to the literature mentioned in this work. This issue becomes even tenser when we speak of ecological studies dealing with Staphylinidae. Therefore, this paper provides the first systematic overview of the area covered, which is comparable to the beginning of serious investigation rather than completing faunal overview.

5. Conservation and Management Implications

Many bird sanctuaries and Ramsar wetlands often focus conservation management on waterbirds, hydrology and vegetation, while the ecological significance of small terrestrial invertebrates remains hidden from view. For example, rove beetles are implicated in litter and soil food webs, have a part to play in decomposing processes, and possibly control the populations of small arthropods. This means that maintaining the habitat features of such interactions is essential in ecosystem conservation efforts as well. At Sur Sarovar, excessive collection of leaf litter, fallen trees or plant debris can diminish structural complexity and eliminate the microhabitats used by Staphylinidae. Changes in wetland hydrology can also alter the soil moisture level at the margins of the lake. Invasive plants can influence litter quality, structure of vegetation, and climate while tourism, artificial light and trampling can affect hypogean conditions. A precautionary conservation management should involve maintenance of representative litter and dead wood substrates, the prevention of unnecessary disturbances of wetland margins, and monitoring of ground-dwelling and litter-associated beetles.

It is important to be cautious when assigning a conservation status. The literature provided expresses a warning that a low quantity of beetles cannot automatically mean that they are endangered or threatened, as such factors as detectability, seasonality and effort in sampling may affect the number of specimens found in the field. The terms endemic, vulnerable, and endangered can be used only after accurate identification and verification of information about species based on reliable distributional and conservation data.

8. Conclusion

Rove beetles play an important ecological role among the members of the coleopteran fauna in the Sur Sarovar analytical framework. Staphylinidae has a total of four identified species and 118 individuals, accounting for 9.46% of the total analysis. The mean abundance across the four species surveyed was found to be 19.67 ± 1.23. The ecological indicator status of a particular family can be understood by the fact that these beetles inhabit soil, litter, decaying wood, dung, carrion, fungi, and wetland areas, while displaying different feeding habits. They may prey upon insects, which play an important role in controlling small high-calcium invertebrates, whereas scavengers, fungivores, and decomposers contribute towards the detrital food chain. The complex terrain of Sur Sarovar, including wetlands, forests, open fields, scrublands, and various soil types, enables important conclusions to be drawn about Staphylinidae diversity. Relevant literary works published in the province of Uttar Pradesh also highlight the importance of the preserved wetlands in terms of rove beetle diversity. Finally, the numbers appear to be just illustrative/simulated in the thesis material and should be considered as an analytical base only. The need for standard, species-based, every-season field studies before any definitive conclusions can be reached in terms of Staphylinidae diversity, habitat choice, seasonal aspects, conservation status, and bioindicator value.

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