# HABITAT PREFERENCES, DIVERSITY, MOBILITY, POPULATION ESTIMATES AND CONSERVATION IMPLICATIONS OF SCORPION FAUNA OF SASWAD-JEJURI IN WESTERN INDIA

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***Abstract.*** *Quantitative documentation of biodiversity is an important aspect of ecology. Though, scorpions feature in the diet of predators like owls, biodiversity studies of invertebrate groups like arachnids are limited in our country. Since no quantitative estimates on natural occurrence of scorpion fauna of India are reported earlier, we undertook the present baseline study for evaluation of ecological implications such as prey-predator relation between owls and scorpions in future studies. Our paper deals with habitat preferences, diversity, mobility and population estimates of scorpion fauna of Saswad-Jejuri region in Western India, and highlights the conservation implications of such studies. 8 species of scorpions in 5 genera and 3 families are recorded in 10 habitat types. The interdependence of some habitats categorized as 'wastelands' and hence vulnerable for land use modifications such as plantation, beautification and urbanization, which are inhabited by neglected species groups like scorpions and their predators like owls, is highlighted. This information provides a baseline biological data for further demographic and broader ecological studies and stresses the need for impact assessment prior to undertaking developmental projects, especially since the interdependent taxa like arachnids exhibit restricted movements and are vulnerable to habitat modification.*

**Keywords:** Arachnids, Scorpion, Biodiversity, Ecological implications, Habitat distruction.

## INTRODUCTION

Quantitative documentation of biodiversity is an important aspect of ecology and a hot topic in recent times. Biodiversity of taxa like birds (Pande *et al*, 2003), butterflies (Nayak et al, 2004; Padhye, et al, 2006) amphibians (Dahanukar and Padhye, 2005), etc. has been recently studied in India. However, biodiversity studies of invertebrate groups like arachnids are limited in our country. Although scorpion fauna of India as a whole has been worked out (Tikader and Bastawade, 1983), previous studies were restricted to qualitative data collection and analysis and publication of checklists of various regions (More & Khatavkar, 1990; Shivshankar, 1992). Further, the habitats occupied by scorpion fauna are often considered as 'wastelands' and are subjected to land use modifications such as plantations for social forestry to meet demands of fuel and fodder, plantations by State Forest Department, introduction of new irrigation facilities leading to development of orchards, croplands, and other horticultural and beautification activities, industrialization and urbanization. Since minor taxa like scorpions occupy specific microhabitat and exhibit restricted movements as shown in this paper, such habitat modifications can have a negative impact on scorpion populations. Such data can be a baseline for further prey-predator relationships since the scorpions have been recorded in the diet of higher predators in the food chain such as gecko, shrike, owl, civet, mongoose, fox and jackal, all of which are recorded from the study area.

This paper deals with habitat preferences, diversity, mobility and population estimates of scorpion fauna with a systematic and quantitative approach and highlights the conservation implications of such studies. Saswad-Jejuri region in Western India was selected as study area on the basis of report of various species of scorpions in the diet of Spotted Owlet *Athene brama* and Indian Eagle-Owl *Bubo bengalensis* (Pande, et al, 2004; Kumar, 1985; Ramanujam, 2006), which are representative predators in the study area. Since no quantitative studies on natural occurrence of scorpion fauna of India are reported earlier, we undertook the present baseline study for evaluation of ecological implications of prey-predator relation between owls and scorpions in the future. Our study provides a baseline biological data for further demographic and broader ecological studies and emphasizes the need for impact assessment prior to undertaking developmental projects, especially since the taxa like arachnids exhibit restricted movements and are vulnerable to habitat modification (Stepnisky, 1997; Pande et al, 2004).

## MATERIAL AND METHODS

Ten different 100 x 100 m quadrates were sampled bi-monthly for the estimation of diversity and populations of scorpion species in Saswad ($18^0$, 20' N; $73^0$, 58 E) and Jejuri ($18^0$,15' N; $74^0$, 09' E), Tal. Purandar, Dist. Pune, Maharashtra, from March 2004 till March 2005. Nests of Spotted Owlets and Indian Eagle-Owl were previously recorded in the region. In all ten different habitats were noted in various quadrates. These were **1**. Loam and stones on hilltop. **2**. Scrubland with stones. **3**. Veld with stones. **4**. Red and black soil in cropland. **5**. Grassy hilltop and stones. **6**. Black soil in mango orchard. **7**. Beneath the tree bark. **8**. Hill slope with stones. **9**. *Eucalyptus* plantation. **10**. Heaped debris and stones.

*Heterometrus xanthopus* (Pocock, 1897) is a psammophilous fossorial scorpion. The shape of the opening of its burrow is typically semi-circular (More and Khatavkar, 1990). Usually one member occupies one burrow except during parturition when young ones may be present with mother (Pande, *et al*, 2006. *In Press*). We have taken the number of burrows as a corresponding estimate of their population. We did not excavate each and every burrow of *Heterometerus xanthopus* in the study area. *Hottentotta tamulus tamulus* (Fabr., 1798), *Orthochirus bicolor* (Pocock, 1897) and *Heterometrus phipsoni* (Pocock, 1893) are peleophilous scorpions found under stones, the latter usually under boulders, hence are readily visible. *Isometrus rigidulus,* Pocock, 1897 and *Hottentotta pachyurus* (Pocock, 1897) were seen to be habitat specific but were also visible. Thus, except *Heterometerus xanthopus*, all other scorpion species in the study area could be directly counted.

All the stones in the quadrates were turned by four experienced and trained observers and scorpion species were identified, counted and recorded in the serial order of encounter in the field (Sutherland, 2000). Various scorpion species were spot identified using published key (Tikader and Bastawade, 1983) and one of the authors of the key (DBB) is also co-author in this communication. A repeat study was done in four adjacent separate quadrates by mark-release-recapture method to estimate the population and movement of the scorpion species *Hottentotta tamulus tamulus* (Sutherland, 2000). All scorpions encountered in the four quadrates were separately colour coded with a touch of oil paint of four different colours, white, yellow, blue and red at the time of sampling, one colour code for each plot. Our pilot studies had revealed that the colour does not disappear up to 3 weeks of marking. So also, every stone under which a scorpion was found was marked by the same colour that was used for the scorpion. One week later all four quadrates were re-sampled and marked scorpions were noted quadrate wise, if they were in the same quadrate or adjacent quadrates; if they were under marked stone or had moved away from it or if any unmarked scorpions or other colour coded scorpions were found in the quadrate. All the observations were recorded.

In order to estimate total number of species that could be present in the study area we constructed species individual curves using data gathered through quadrates. Cumulative number of species recorded was plotted against the number of individuals seen. We fitted Michelis-Menton equation, given by $S = S_{max} N/(K_m + N)$, where S is the cumulative number of species, N is the cumulative number of individuals, $S_{max}$ is the maximum number of species that could be present and $K_m$ is the Michelis-Menton constant (Paranjape and Gore, 1997).

Margalef's species richness index was used to compare species richness across habitats (Magurran, 1988). The $\alpha$-diversity of scorpion species across habitats was calculated using Shannon index of diversity (Magurran, 1988). To calculate whether species are distributed evenly across habitats, evenness index was used (Magurran, 1988). The $\beta$-diversity, which represents unshared species, was measured by finding similarity or overlap between scorpion species composition across habitats, using Bray Curtis similarity index (McAleece, 1998). Population estimates were done for three commonly encountered species, *Hottentotta tamulus tamulus, Heterometrus xanthopus and Orthochirus bicolor,* irrespective of habitat, from direct counts and their mobility was corroborated by applying Peterson's mark-release-recapture method (Sutherland, 2000).

## RESULTS AND DISCUSSIONS

**Population density:** In the quadrate analysis we encountered 6 species of scorpions (table 1) while two more species *Heterometrus granulomanus*, Couzijn, 1981 and *Neoscorpiops deccanensis*, Tikader and Bastawade, 1978 were encountered later in the study area but not during quadrate sampling. Therefore the total number species occurring in the study area is 8. However for the estimation of various indices the scorpion species encountered during quadrate sampling are considered (n=6).

The average population density of scorpions irrespective of habitats as well as species was 0.063 / sq m. While species wise population was: 0.042 / sq m for *Hottentotta tamulus tamulus,* 0.017 / sq m for *Heterometrus xanthopus* and 0.005 / sq m for *Orthochirus bicolor*. The population density as corroborated by mark-release-recapture was 0.098 / sq m for all scorpions; and 0.066 / sq m for

*Hottentotta tamulus tamulus*, 0.054 / sq m for *Heterometrus xanthopus* and 0.006 / sq m for *Orthochirus bicolor*. Population of the remaining species *Hottentotta pachyurus*, *Isometrus rigidulus* and *Heterometrus phipsoni* in the study area is very low (table 1).

*Table 1*

**Habitat wise population indices and % abundance of scorpions**

| Specification | Habitat | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Loam and stones on hilltop **(1)** | Scrubland with stones **(2)** | Veld with stones **(3)** | Red & black soil in cropland **(4)** | Grassy hilltop & stones **(5)** | Black soil in mango orchard **(6)** | Under tree bark **(7)** | Hill slope with stones **(8)** | *Eucalyptus* plantation **(9)** | Heaped debris & stones **(10)** | Entire study area-all quadrates surveyed **(ALL)** |
| **RI** | 0.48 | 0.62 | 0.17 | 0.34 | 0.35 | - | 0.26 | 0.46 | 0.24 | - | 0.75 |
| **H'** | 0.93 | 0.86 | 0.66 | 0.59 | 0.46 | - | 0.29 | 0.90 | 0.57 | - | 1.1 |
| **E'** | 0.84 | 0.61 | 0.95 | 0.85 | 0.67 | - | 0.43 | 0.82 | 0.83 | - | 0.61 |
| **% ABUNDANCE OF VARIOUS SCORPION SPECIES IN STUDY AREA** | | | | | | | | | | | |
| **T%** | 51.5 | 69.7 | 37.3 | 72.2 | 82.3 | 100 | 8.9 | 51.9 | 73.7 | 0 | 48.43 |
| **H%** | 39.1 | 15.6 | 62.7 | 0 | 0 | 0 | 0 | 40.3 | 0 | 0 | 38.87 |
| **B%** | 9.4 | 13.9 | 0 | 27.8 | 17.7 | 0 | 0 | 7.8 | 26.3 | 0 | 6.54 |
| **HP%** | 0 | 0.8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.13 |
| **IR%** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 0.88 |
| **P%** | 0 | 0 | 0 | 0 | 0 | 0 | 91.1 | 0 | 0 | 0 | 5.16 |

**Key to abbreviations**: **RI:** Margalef's species richness index. **H':** Shanon species diversity index. **E:** Evenness index. **T%:** % abundance of *Hottentotta tamulus tamulus*. **H%:** % abundance of *Heterometrus xanthopus*. **B%:** % abundance of *Orthochirus bicolor.* **HP%:** % abundance of *Heterometrus phippsoni*. **IR%:** % abundance of *Isometrous rigidulus*. **P%:** % abundance of *Hottentotta pachyurus*.
The table shows habitat wise values obtained with respect to various parameters in the scorpion survey.

**Documentation of mobility:** Mark - release - recapture studies were done to evaluate the mobility of *Hottentotta tamulus tamulus*, the most abundant species in the study area. After 1 week of marking and releasing 6.3 % marked scorpions of this species were recaptured under marked stones. 33.3 % scorpions had moved within 50 m of the marked stone. 6.3 % scorpions with one colour code were found in plot with different colour code. 53.9 % unmarked scorpions were found in the four quadrates.

**α Diversity indices and Relative abundance studies: Table 1**

Species Accumulation Curve (fig. 1) predicts presence of 8 species of scorpions in the study area, of which 6 species in 5 genera of 3 families have been recorded by us within quadrates. We could observe the remaining 2 species outside the quadrates but within the study area, particularly *Heterometrus granulomanus* Couzijn and *Neoscorpiops deccanensis* Tikadar & Bastawade. Overall species richness index is 0.75, whereas evenness index is 0.6 and Shanon diversity index is 1.1. Habitat wise indices are as in table-1. Percent abundance as shown in table-1 indicates that *Hottentotta tamulus tamulus* (48.43 %) is most dominant and commonly occurring species while *Heterometrus phipsoni* (0.13 %) is the rare species. Habitat wise percent abundance reveals that habitat 6 (Black soil in mango orchard) and habitat 10 (Heaped debris and stones) are inhabited by a single species each, *Hottentotta tamulus tamulus* and *Isometrus rigidulus* respectively. Habitat 2 (Scrubland with stones) shows highest Richness index (RI = 0.62).

**β Diversity study by Cladistic (Bray-Curtis) analysis:**

Comparison of species composition with various habitats reveals that habitat 10 (Heaped debris and stones) and habitat 7 (Beneath the tree bark) are unique, as they don't show any similarity with any other habitats. All other habitats show 50% or more similarity with each other indicating more species overlap (fig. 1).

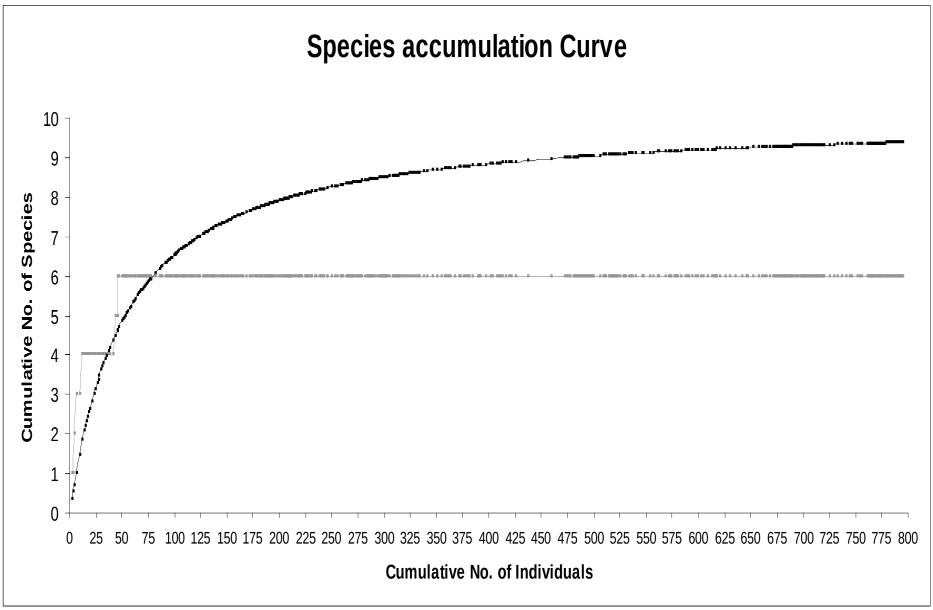


**Fig. 1.** Species Accumulation Curve of Scorpions of study area. Least square curve had the parameters $S_{max}$ = 10, Km = 53, predicting the maximum number of species inhabiting the study area to be 10, though we could record only 6 in Quadrates and in all 8 including two found out of Quadrates but in the study area. Black solid line indicates theoretical curve (using Michelis-Menton equation) and Grey line represents the actual quadrate data.

India has about 107 species of scorpion fauna of which 38 species are recorded from Maharashtra in western India (Tikader and Bastawade, 1983). We recorded a total of 8 species (8.4 % of the total scorpion fauna of India and 23.8 % of scorpion fauna of Maharashtra), of which 6 species were found during the quadrate analysis in the study area located in western Maharashtra. Further, though only 6 species of scorpions were recorded in the quadrates, more species are predicted by Species Accumulation Curve (fig. 1), and their presence is confirmed by us outside the quadrates. Hence even though the apparent loss from quadrate analysis alone predicts lesser damage due to habitat modification, in terms of number of species, the actual loss is higher, a point well brought out in the present study. It therefore stresses the need for holistic approach in Environmental Impact assessment Surveys.

The overall Shanon index is very low indicating low species diversity. The average population density of scorpions irrespective of habitats and species was 0.063 / sq m. The population of *Hottentotta tamulus tamulus* was 0.042 / sq m followed by 0.017 / sq m for *Heterometrus xanthopus* and 0.005 / sq m for *Orthochirus bicolor.* The populations of other species in the quadrate analysis were negligible. While comparing the Shanon Indices of various habitats, it is revealed that the habitats 1, 8 and 2 (1.Loam and stones on hilltop. 2. Scrubland with stones. 8. Hill slope with stones), show higher Shanon Index indicating the higher diversity among the habitats under the current study.

Among these three habitats, Habitat 2 shows highest Richness index (RI = 0.62) as it inhabits 4 species. However, the max Shanon Index is shown by habitat 1 (H’ = 0.93) as the distribution of individuals within three species is more even than habitat 2 and 8. Maximum Evenness index is shown by habitat 3 (E = 0.93) as it inhabits only 2 species but the individuals are distributed more evenly amongst these two species. When we compare the overall percent abundance, *Hottentotta tamulus tamulus* (48.43 %) appears to be the most dominant species whereas *Heterometrus phippsoni* (0.13 %) is the most rare one. However, *Heterometrus xanthopus* is co-dominant with 38.8 % abundance.

Bray-Curtis analysis showed that two habitats, Heaped debris (Habitat 10) and habitat under tree bark (Habitat 7) are preferred only by one species each (*Isometrus rigidulus* and *Hottentotta pachyurus*, respectively). Other two habitats, Loam and stones on hilltop (Habitat 1) and Hill slope with stones (Habitat 8) are preferred by maximum number of scorpions. Scrubland with stone (Habitat 2) inhabits 4 species out of 6 found in quadrate sampling. Currently, these very habitats are considered as ‘wasteland’ by the State administration and are earmarked for development projects such as plantation, beautification, and urbanization, that will lead to habitat loss through land use modification.

Mark – release – recapture studies have revealed that 39.6 % scorpions of *Hottentotta tamulus tamulus* species had *definitely moved* after one week of initial marking of which 6.3 % had moved from one plot to another, while 33.3 % scorpions had moved within a radius of 50 m. 53.9 % unmarked scorpions were found in the colour coded quadrates. It can be inferred that most of these 53.9 % scorpions must have arrived from plots further away from the marked plots and can be grouped as scorpions that *probably moved*. However, it is possible that some of these unmarked scorpions may have been missed in the first survey when the scorpions were colour marked. 6.3 % scorpions had not moved or had not changed the initial place where it was first marked. We found two *Hottentotta tamulus tamulus* molts under marked stones with freshly molted scorpions under the same stone and these were counted in the category of absent movement. It may be concluded that at least 90 % scorpions of *Hottentotta tamulus tamulus* species show mobility from less than 50 m to more than 100 m in a period of one week. Since scorpions are not sedentary but nocturnally mobile, they are vulnerable to predation by nocturnal species like owls (Pande et al 2006 *In Press*). Their occurrence in the diet of owls is thus explained. However, the mobility of scorpions is restricted and the habitat of each of the species is specific, hence habitat modifications can have adverse effects on scorpion populations. This can also have repercussions on their predators like owls. Such ecological relationships need further studies, but the interdependence of habitats categorized as wastelands, neglected species like arachnids inhabiting such habitats and predators like elusive owls cannot be underestimated.

Low $\alpha$ diversity indices are obvious while studying taxon like scorpions. The scorpions are well known for their restricted movement, cannibalism, habitat specificity, food size specificity and show extreme climate adaptability, habitat specificity and adaptive radiation (Polis, 1990; Newlands, 1972, 1978). These factors act as the limiting factors as far as the species diversity is concerned.

## CONCLUSIONS

Our study is important as it documents the habitat preferences, diversity indices, mobility and population estimates of less known scorpion species from western India, and also focuses on conservation and ecological implications. 8 species of scorpions in 5 genera are recorded in 10 habitat types. The interdependence of some habitats categorized as 'wastelands' and hence vulnerable for land use modifications such as plantation, beautification and urbanization, which are inhabited by neglected species groups like scorpions and their predators like owls, is highlighted. This information provides a baseline biological data for further demographic and broader ecological studies and stresses the need for impact assessment prior to undertaking developmental projects, especially since the taxa like arachnids exhibit restricted movements and are vulnerable to habitat modification (Stepnisky, 1997; Pande et al, 2004).

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