

Beyond the Pest List: Community Structure, Functional Guilds and Site-Level Diversity of Insects in the Farmland of Hanumangarh District, Rajasthan

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Abstract:

Farm insects supply pest suppression, pollination and decomposition, yet baseline inventories for north-western India are scarce. We sampled insects at six sites in as many tehsils of Hanumangarh district, Rajasthan, across 24 fortnightly rounds using five standardised methods, and analysed community structure, site-level diversity and functional guilds. The survey yielded 18,742 individuals of 96 species in eight orders. Hemiptera supplied 48.1 percent of individuals and Coleoptera the most species (20). Community diversity was high ($H' = 3.654$, $J' = 0.800$, $1/D = 26.9$) and dominance moderate, with the five commonest species making up 31.3 percent of individuals. Bhadra was richest (92 species; 86.1 when rarefied to 2,410 individuals) and Rawatsar poorest (71), yet site-by-fortnight diversity did not differ significantly among sites ($p = 0.36$) and mean Bray–Curtis dissimilarity was only 0.26. Herbivorous pests accounted for 62.9 percent of individuals, predators 22.4, parasitoids 3.8 and pollinators 8.4, with two honey bee species supplying 93 percent of pollinators. The structurally most varied site had the highest ratio of natural enemies to pests (0.59). We discuss implications for conservation-oriented pest management and for local biodiversity documentation.

Keywords: insect diversity; agroecosystem; Hanumangarh; functional guilds; natural enemies; Shannon index; Rajasthan.

I. INTRODUCTION

Ask a farmer in Hanumangarh which insects live in her fields and the answer is usually a list of enemies: whitefly on the cotton, aphids on the mustard, the borer that turns up with the gram. The list is accurate as far as it goes. It leaves out the ladybird beetles that eat aphids by the hundred, the parasitic wasps too small to see without a lens, the bees working the flowers along the margins, and a long tail of species whose business nobody has bothered to measure. Insects make up most of the animal diversity on farmland, and what they do (suppressing pests, pollinating crops, recycling organic matter) is a form of unpaid labour on which low-input agriculture depends.¹

¹Miguel A. Altieri, *The Ecological Role of Biodiversity in Agroecosystems*, 74 AGRIC., ECOSYSTEMS & ENV'T 19 (1999).

Evidence that this fauna is thinning has accumulated quickly. A long monitoring series from German protected areas recorded a fall of more than seventy-five percent in flying insect biomass over twenty-seven years,² and a global review traced most insect losses to habitat change and agricultural intensification, with pesticides and climate change next in line.³ Whether anything similar is under way in the irrigated, semi-arid belt of north-western India is difficult to say, because baseline inventories of farm insects there are thin. A decline cannot be shown without something to decline from.

Hanumangarh district sits on the northern edge of Rajasthan, where canal irrigation has turned a desert margin into a double-cropped landscape of cotton, paddy, wheat, mustard, gram and guar. Pest-centred work dominates the Indian literature on crop insects, and with reason, since national losses to insects are large.⁴ Yet a pest list says nothing about how a community is organised: how abundance is shared among species, whether a few of them dominate, how alike fields in different tehsils really are, and what fraction of the fauna works for the farmer rather than against her.

This paper treats the insect fauna of Hanumangarh's farmland as a community and asks three questions. How many species and which orders make it up, and how is abundance spread among them? How do diversity and composition differ among six sites distributed across the district? And how is the fauna divided among functional guilds, with what consequence for conservation-oriented pest management? Seasonal dynamics, which the same dataset also captures, are the subject of a companion paper; here the year is pooled and season appears only as a sampling dimension.

II. STUDY AREA AND METHODS

A. Study area and sites

Hanumangarh lies in the extreme north of Rajasthan, bordering Punjab and Haryana, in a tract that is hot and dry for most of the year. During the study year the weather record showed 276 mm of rain, more than three-quarters of it between July and October, a maximum temperature of 43.8 °C in early June, and a minimum of 4.0 °C in the first half of January. Six sites, one in each of six tehsils, were chosen to span the range of cropping systems found in the district (Table 1). Each site was a cluster of neighbouring fields managed by local farmers in the usual way; no site was manipulated, and pesticide use followed whatever the farmers decided.

²Caspar A. Hallmann et al., *More than 75 Percent Decline over 27 Years in Total Flying Insect Biomass in Protected Areas*, 12 PLoS ONE e0185809 (2017).

³Francisco Sánchez-Bayo & Kris A.G. Wyckhuys, *Worldwide Decline of the Entomofauna: A Review of Its Drivers*, 232 BIOLOGICAL CONSERVATION 8 (2019).

⁴G.S. Dhaliwal, V. Jindal & B. Mohindru, *Crop Losses Due to Insect Pests: Global and Indian Scenario*, 77 INDIAN J. ENTOMOLOGY 165 (2015).

Table 1. Study sites and their principal cropping systems.

Site	Tehsil	Principal crops across the year	Field setting
S1	Hanumangarh	Paddy, wheat, vegetables	Canal-irrigated, level fields
S2	Pilibanga	Cotton, wheat, guar	Canal-irrigated, cotton-centred
S3	Nohar	Mustard, gram, guar	Irrigated and partly rain-fed fields
S4	Bhadra	Cotton, wheat, mixed vegetables	Irrigated, with tree lines, vegetable plots and margins
S5	Rawatsar	Guar, pearl millet, mustard	Lighter soils, partial irrigation, sparse margins
S6	Sangaria	Cotton, vegetables	Canal-irrigated, intensive vegetable plots

B. Sampling

Every site was visited twice a month for twelve months, from the first half of April to the second half of March, giving 24 fortnightly rounds that run through the Zaid (April–June), Kharif (July–October) and Rabi (November–March) seasons. Five complementary methods were applied at each visit, because no single method sees the whole fauna. Sweep netting sampled foliage-dwelling insects; pitfall traps caught ground-active beetles and orthopterans; yellow sticky traps collected small fliers such as aphids, whiteflies and parasitoid wasps; a light trap drew nocturnal fliers; and visual counts on tagged plants recorded conspicuous species and their immature stages. Effort was identical at every site and in every round (Figure 1), so differences in catch reflect the fauna and not the labour.

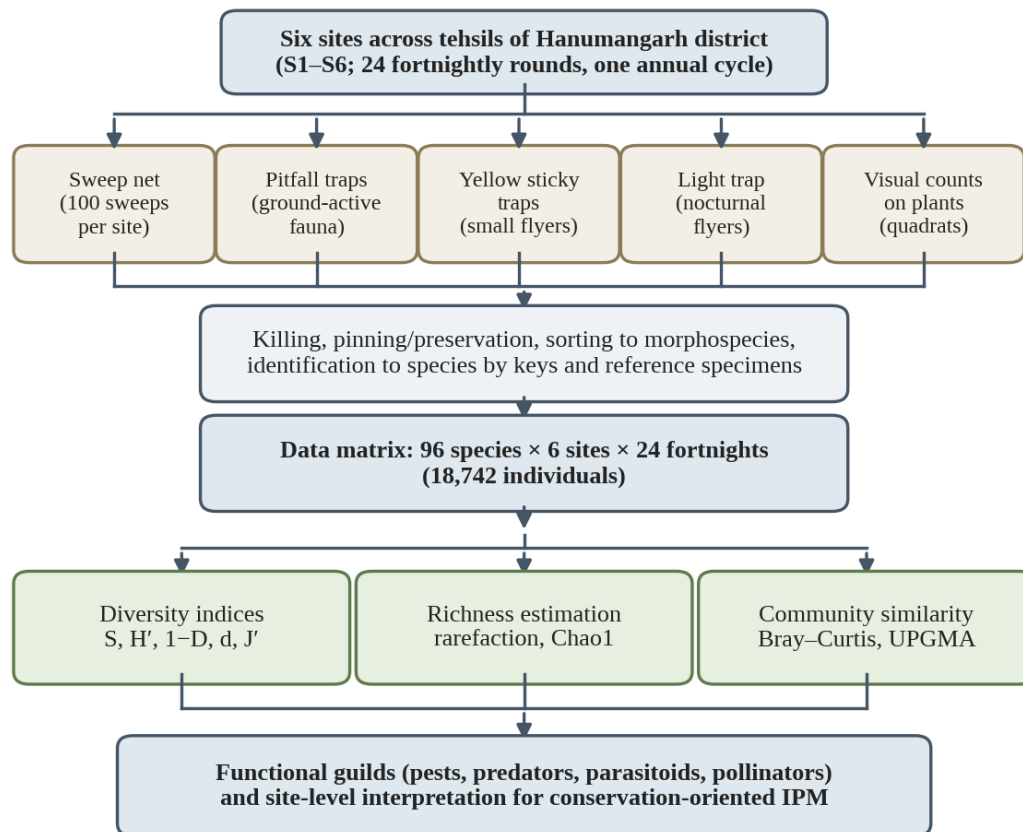


Figure 1. Study design and analytical workflow, from site selection through standardised sampling and identification to community analysis.

C. Identification and functional guilds

Specimens were killed, pinned or preserved, sorted, and identified to species with taxonomic keys and a growing reference collection; doubtful material was sorted to morphospecies and left out of the analysis. Each species was assigned to one of five guilds according to its main role in the field: herbivorous pests that feed on crop tissue, predators, parasitoids, pollinators, and other or neutral species (detritivores and incidental visitors). Where a species plays more than one part, as the paper wasp *Polistes hebraeus* does when it hunts caterpillars and also visits flowers, it was placed in the guild that its feeding habits most plainly support. These assignments are judgments, and a different reader might move a handful of species.

D. Data analysis

Diversity was summarised with the Shannon index (H' , natural logarithm),⁵ the Gini–Simpson index ($1-D$),⁶ Pielou's evenness (J'),⁷ and Margalef's richness index (d).⁸ The inverse Simpson index ($1/D$) is

⁵C.E. Shannon, *A Mathematical Theory of Communication*, 27 BELL SYS. TECH. J. 379 (1948).

⁶E.H. Simpson, *Measurement of Diversity*, 163 NATURE 688 (1949).

⁷E.C. Pielou, *The Measurement of Diversity in Different Types of Biological Collections*, 13 J. THEORETICAL BIOLOGY 131 (1966).

⁸Ramón Margalef, *Information Theory in Ecology*, 3 GEN. SYSTEMS 36 (1958).

reported as an effective number of species.⁹ Raw richness depends on how many individuals were collected, and catches differed among sites, so individual-based rarefaction to a common sample size was used for comparison,¹⁰ while the Chao1 estimator gave an asymptotic richness figure.¹¹ Differences in composition were measured with Bray–Curtis dissimilarity¹² and clustered by the unweighted pair-group method (UPGMA), and Whittaker's β ($\gamma/\bar{\alpha} - 1$) expressed turnover among sites.¹³ Because the 24 fortnightly samples from each site are its natural replicates, H' and abundance were calculated for each site-by-fortnight unit and compared among sites with the Kruskal–Wallis test.¹⁴ Treatment of the indices otherwise follows Magurran.¹⁵

III. RESULTS

A. Overall composition

The survey produced 18,742 individuals belonging to 96 species in eight orders. Hemiptera supplied nearly half of all individuals (9,022; 48.1 percent) from 19 species, while Coleoptera supplied the most species (20) and the second-largest share of individuals (4,287; 22.9 percent). Hymenoptera (14 species, 2,278 individuals) and Lepidoptera (16 species, 1,989) followed, with Diptera (10 species, 572) next. Three orders contributed little to the count. Neuroptera had only four species but 500 individuals (2.7 percent), while Orthoptera and Odonata together made up just 94 individuals (0.5 percent) from 13 species (Table 2, Figure 2).

Table 2. Species richness and abundance by order.

Order	Species	Individuals	Share of individuals (%)
Hemiptera	19	9,022	48.1
Coleoptera	20	4,287	22.9
Hymenoptera	14	2,278	12.2
Lepidoptera	16	1,989	10.6
Diptera	10	572	3.1
Neuroptera	4	500	2.7
Orthoptera	8	67	0.4
Odonata	5	27	0.1
All orders	96	18,742	100.0

⁹M.O. Hill, *Diversity and Evenness: A Unifying Notation and Its Consequences*, 54 *ECOLOGY* 427 (1973); Lou Jost, *Entropy and Diversity*, 113 *OIKOS* 363 (2006).

¹⁰Robert K. Colwell & Jonathan A. Coddington, *Estimating Terrestrial Biodiversity Through Extrapolation*, 345 *PHIL. TRANSACTIONS ROYAL SOC'Y LONDON B* 101 (1994).

¹¹Anne Chao, *Nonparametric Estimation of the Number of Classes in a Population*, 11 *SCAND. J. STAT.* 265 (1984).

¹²J. Roger Bray & J.T. Curtis, *An Ordination of the Upland Forest Communities of Southern Wisconsin*, 27 *ECOLOGICAL MONOGRAPHS* 325 (1957).

¹³R.H. Whittaker, *Evolution and Measurement of Species Diversity*, 21 *TAXON* 213 (1972).

¹⁴William H. Kruskal & W. Allen Wallis, *Use of Ranks in One-Criterion Variance Analysis*, 47 *J. AM. STAT. ASS'N* 583 (1952).

¹⁵Anne E. Magurran, *MEASURING BIOLOGICAL DIVERSITY* (2004).

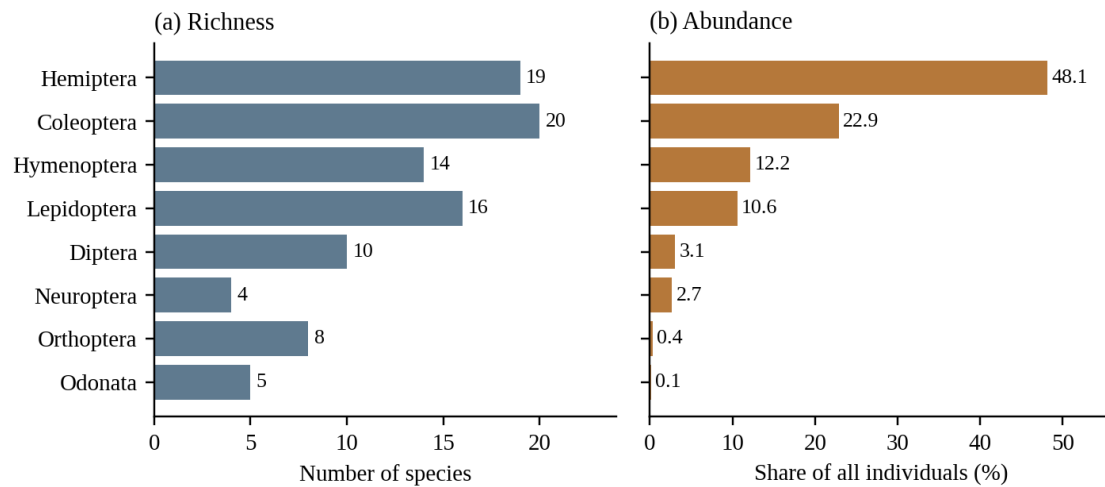


Figure 2. Species richness (a) and share of individuals (b) by insect order. Orders are sorted by abundance. Pooled across sites and seasons, the community had $H' = 3.654$, $J' = 0.800$, $1-D = 0.963$ and Margalef $d = 9.66$. The inverse Simpson index of 26.9 means that, in terms of dominance, the fauna behaves like a community of about 27 equally common species even though 96 were recorded. Chao1 estimated 102 species. With four singletons and no doubletons the estimator is crude, but it suggests that the survey captured roughly 94 percent of the species present and that the missing ones are rare.

B. Dominance and the shape of the rank–abundance curve

The abundance distribution is moderately uneven. *Bemisia tabaci* alone made up 10.2 percent of all individuals (1,906), the five most abundant species together accounted for 31.3 percent, and the top ten for 50.5 percent. At the other end, 25 species were represented by fewer than ten individuals and four by a single one. Between these extremes lies a broad middle, since 39 species reached 100 individuals or more. Eight of the twelve commonest species were herbivorous pests, but the list (Table 3) also includes the honey bee *Apis dorsata* (996), two ladybird beetles, *Coccinella septempunctata* and *Cheilomenes sexmaculata*, and the egg parasitoid *Trichogramma chilonis* (598), so the dominant tier is not purely a pest roll-call.

Table 3. The twelve most abundant species.

Rank	Species	Order	Guild	Individuals	Share (%)
1	<i>Bemisia tabaci</i>	Hemiptera	Pest	1,906	10.2
2	<i>Lipaphis erysimi</i>	Hemiptera	Pest	1,050	5.6
3	<i>Aphis gossypii</i>	Hemiptera	Pest	1,016	5.4
4	<i>Apis dorsata</i>	Hymenoptera	Pollinator	996	5.3
5	<i>Helicoverpa armigera</i>	Lepidoptera	Pest	902	4.8
6	<i>Amrasca biguttula</i>	Hemiptera	Pest	818	4.4
7	<i>Sitobion avenae</i>	Hemiptera	Pest	731	3.9
8	<i>Myzus persicae</i>	Hemiptera	Pest	701	3.7
9	<i>Coccinella septempunctata</i>	Coleoptera	Predator	676	3.6
10	<i>Cheilomenes sexmaculata</i>	Coleoptera	Predator	663	3.5
11	<i>Phenacoccus solenopsis</i>	Hemiptera	Pest	616	3.3
12	<i>Trichogramma chilonis</i>	Hymenoptera	Parasitoid	598	3.2

On a log scale the rank–abundance curve (Figure 3) falls almost in a straight line from the first species to the ninetieth and drops sharply only among the last handful of rare species. That is the signature of a community in which many moderately common species coexist, not one held under a single dominant, and it agrees with the high evenness already noted. Pest, predator, parasitoid and pollinator species are interleaved along the whole curve, and no guild occupies a particular band of abundance.

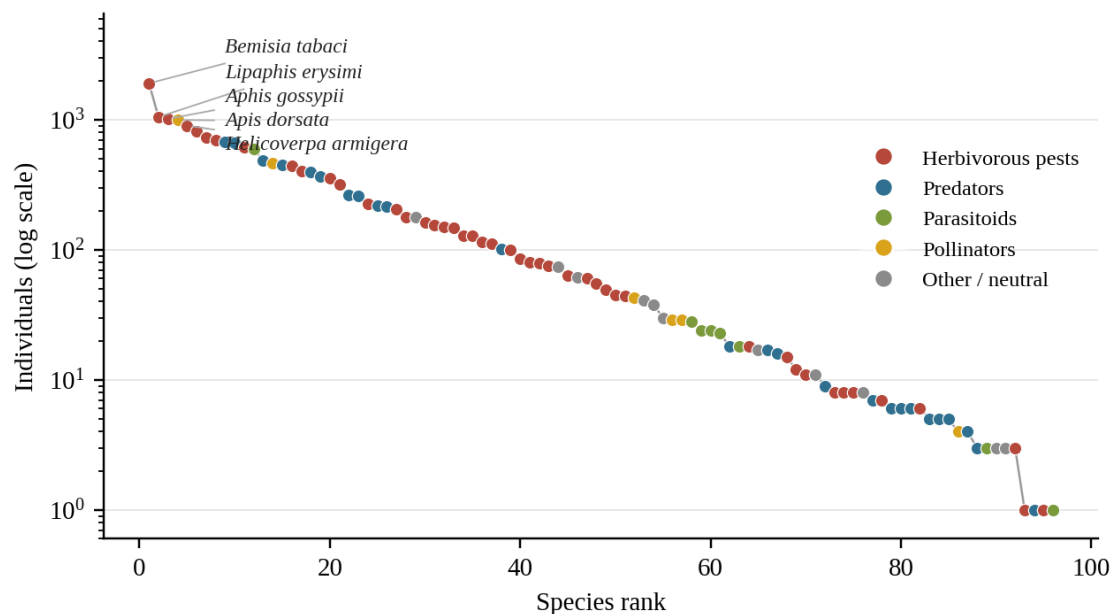


Figure 3. Rank–abundance (Whittaker) plot for all 96 species, coloured by functional guild. The five commonest species are labelled.

C. Diversity among sites

Site diversity varied modestly (Table 4, Figure 4). Bhadra (S4) had the richest fauna (92 species), the highest Shannon index (3.666) and the highest Margalef index (11.12), with Hanumangarh (S1) almost level on H' (3.664) and highest on Gini–Simpson (0.966). Rawatsar (S5) was poorest in species (71) but not in evenness, as its J' of 0.827 equalled that of S1. Nohar (S3) had the lowest H' (3.433) and the lowest Gini–Simpson value (0.948) despite a mid-ranking richness of 79 species. The cause lay in dominance and not in missing species: whitefly (13.0 percent of the site's catch) and the pod borer *Helicoverpa armigera* (9.7 percent) together took almost a quarter of the individuals at S3. Pilibanga (S2) and Sangaria (S6), both cotton-centred, were similarly marked by *B. tabaci*, which made up 15.5 and 15.2 percent of their catches, whereas no species exceeded 6.9 percent at Bhadra.

Table 4. Diversity indices by site. $S(2,410)$ is the expected richness rarefied to the smallest site sample.

Site	Indiv.	S	$S(2,410)$	H'	J'	1–D	d	Chao1
S1 Hanumangarh	3,240	84	80.4	3.664	0.827	0.966	10.27	94.3
S2 Pilibanga	3,410	82	77.3	3.524	0.800	0.951	9.96	119.5
S3 Nohar	2,990	79	76.7	3.433	0.786	0.948	9.75	109.3
S4 Bhadra	3,580	92	86.1	3.666	0.811	0.965	11.12	101.8
S5 Rawatsar	2,410	71	71.0	3.526	0.827	0.960	8.99	72.6
S6 Sangaria	3,112	77	74.5	3.554	0.818	0.953	9.45	87.0
District (pooled)	18,742	96	–	3.654	0.800	0.963	9.66	102.0

S = observed species richness; H' = Shannon index; J' = Pielou evenness; 1–D = Gini–Simpson index; d = Margalef index.

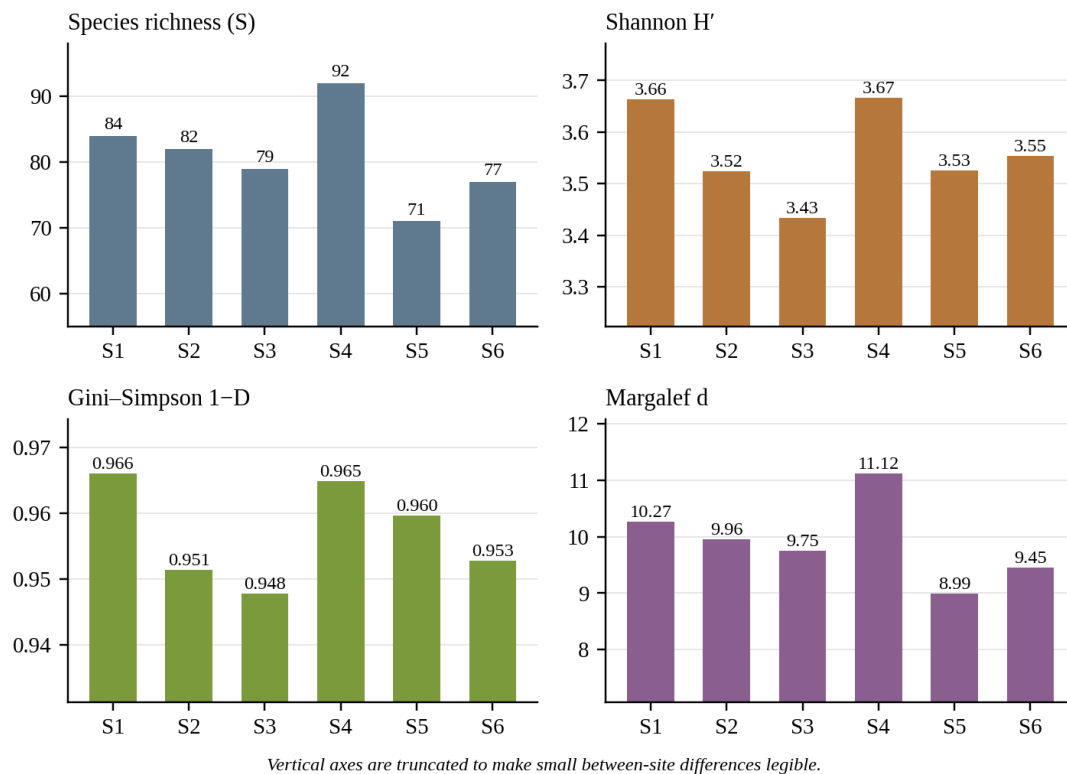


Figure 4. Observed richness and diversity indices at the six sites. Vertical axes are truncated.

Rarefaction removes the effect of unequal catches (Figure 5). At a common size of 2,410 individuals, the smallest site sample, expected richness was 86.1 species at S4, 80.4 at S1, 77.3 at S2, 76.7 at S3, 74.5 at S6 and 71.0 at S5. The ranking by observed richness therefore survives standardisation, and Bhadra's lead is not a by-product of its larger catch. The site-level Chao1 values (72.6 to 119.5) are less stable and should not be leaned on; the figure for S2 rests on 15 singletons and only three doubletons.

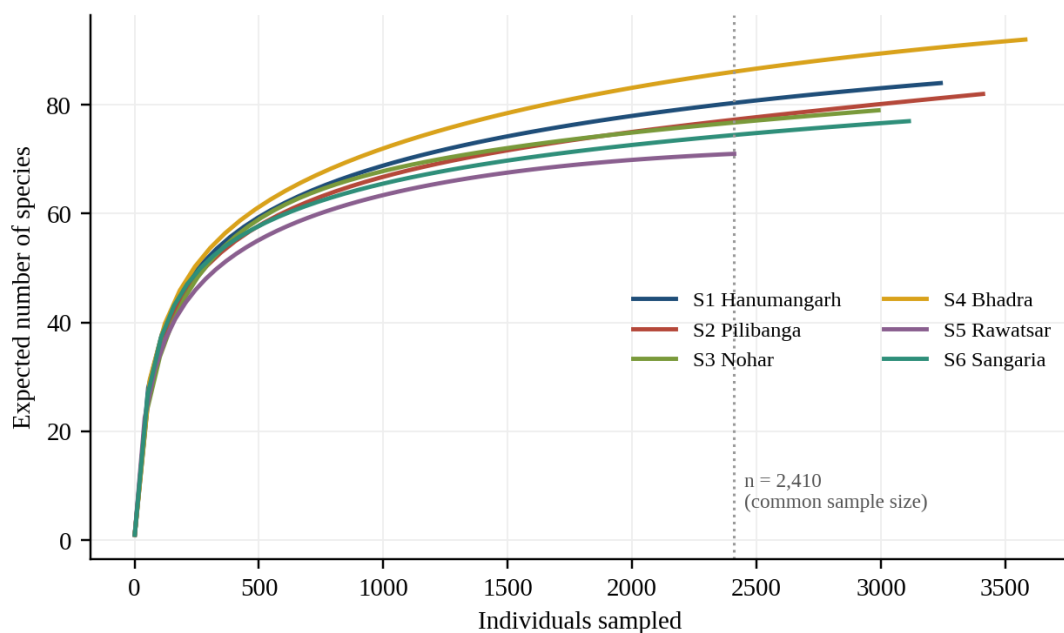


Figure 5. Individual-based rarefaction curves for the six sites. The dotted line marks the common sample size (2,410 individuals).

Statistically, however, the six sites could not be separated. Among site-by-fortnight units, H' did not differ across sites (Kruskal–Wallis $H = 5.46$, $df = 5$, $p = 0.36$), nor did the number of individuals per unit ($H = 3.81$, $p = 0.58$). The differences in Table 4 are real as descriptions of the pooled year, but they are small beside the fortnight-to-fortnight variation inside each site.

D. Similarity among sites

Bray–Curtis dissimilarities among sites ranged from 0.18 (S2–S6) to 0.33 (S3–S4), with a mean of 0.26. Whittaker's β was 0.19 ($\gamma = 96$ species, mean $\alpha = 80.8$), a low value showing that the sites share most of their species. Fifty-eight species occurred at all six sites, 69 at five or more, and only four were confined to a single site. Clustering (Figure 6) joined the two cotton-based sites, Pilibanga and Sangaria, first (0.18), and Bhadra attached to them at 0.22. Hanumangarh and Nohar formed a second pair at 0.26 before the two groups united at 0.27, and Rawatsar, the most distinct site, joined last (0.29). The grouping reflects cropping system only in part: the cotton sites cluster, but Hanumangarh (paddy and wheat) pairs with Nohar (mustard, gram and guar).

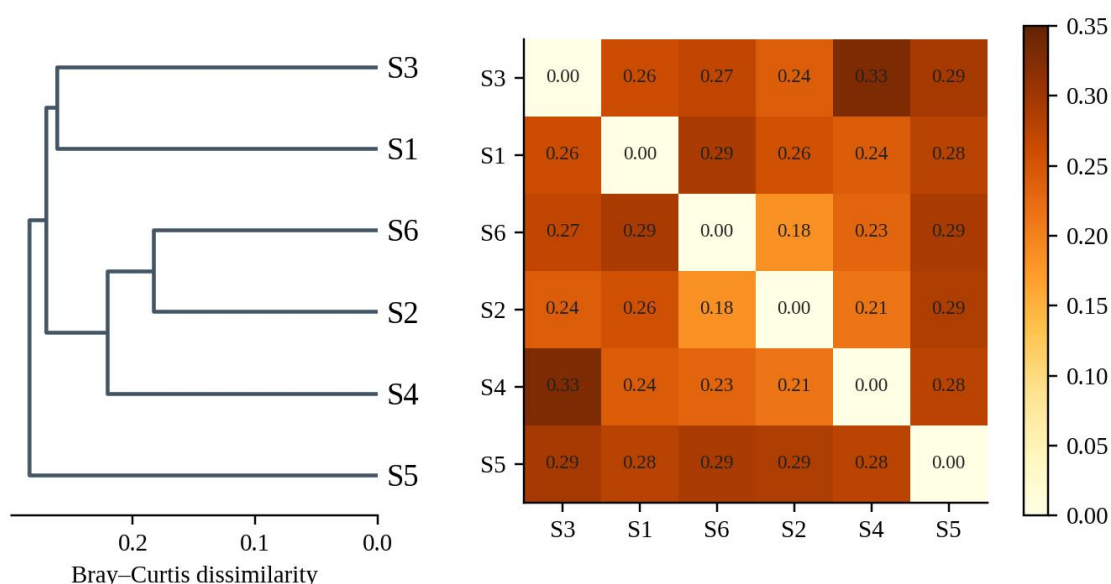


Figure 6. UPGMA dendrogram and Bray–Curtis dissimilarity matrix for the six sites.

E. Functional guilds

Herbivorous pests were the most species-rich guild (46 species, 47.9 percent of species) and numerically dominant (11,790 individuals, 62.9 percent). Predators contributed 25 species and 4,204 individuals (22.4 percent), parasitoids eight species and 719 individuals (3.8 percent), pollinators six species and 1,566 individuals (8.4 percent), and other or neutral species eleven species and 463 individuals (2.5 percent). Predation was mostly the work of beetles, lacewings and hoverflies. Seven coccinellid species accounted for 2,402 individuals, the green lacewing *Chrysoperla zastrowi sillemi* for 483, and three hoverfly species for 482. Pollination, by contrast, rested almost entirely on two honey bee species, since *A. dorsata* and *A. florea* made up 93 percent of pollinator individuals (1,461 of 1,566). The other four pollinator species (a managed honey bee, a carpenter bee, a leafcutter bee and a hoverfly) together contributed only 105. Guild balance differed among sites (Figure 7). The pest share of individuals ranged from 55.2 percent at S4 to 68.0 percent at S3, and the predator share from 19.6 percent at S5 to 28.4 percent at S4. Expressed

as natural enemies (predators plus parasitoids) per pest individual, Bhadra stood out at 0.59, against 0.34 to 0.38 at Rawatsar, Nohar, Hanumangarh and Pilibanga and 0.45 at Sangaria. Bhadra also held all eight parasitoid species recorded in the district, whereas Rawatsar held four.

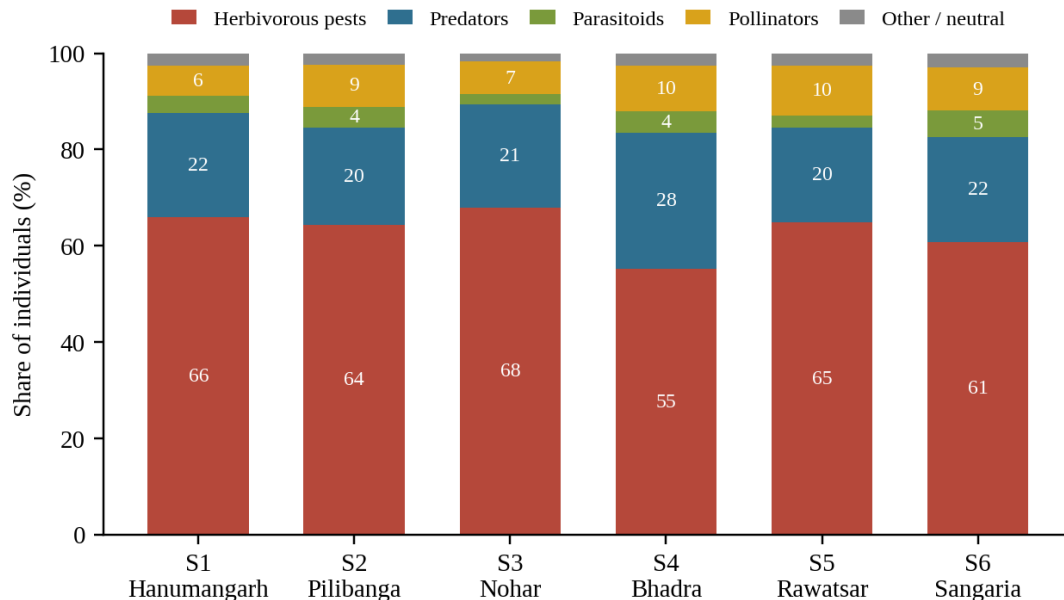


Figure 7. Functional guild composition (percentage of individuals) at each site.

IV. DISCUSSION

Three results deserve comment. The first is the pairing of numerical dominance by sap-feeding Hemiptera with high evenness across the whole community. Whiteflies, aphids, jassids and mealybugs breed fast and respond quickly to flushes of crop growth, so it is unsurprising that they supply almost half the individuals. Less expected is that no species other than whitefly exceeds 5.6 percent of the pooled catch, and that predators and parasitoids together make up more than a quarter of individuals. A fauna of this kind is not the stripped-down pest assemblage that heavy, calendar-based spraying tends to leave behind, although we have no pesticide records with which to test that suspicion directly.

The second is how similar the sites are. A β value of 0.19 and 58 species shared by all six sites describe a regional fauna drawn from a common pool, which is what one would expect on an irrigated plain where crops, canals and wind connect fields over long distances. Landscape-scale studies have argued that diversity on farmland is governed largely by the amount and quality of non-crop habitat in the surrounding landscape, rather than by what grows in the field itself.¹⁶ Our design cannot test that proposition, because habitat around the sites was not mapped, but the pattern at Bhadra is consistent with it. S4 combined tree lines, vegetable plots and field margins, and it had the highest richness, the lowest dominance, the highest ratio of enemies to pests and all eight parasitoid species. That is what habitat-management theory predicts

¹⁶Teja Tscharntke et al., *Landscape Perspectives on Agricultural Intensification and Biodiversity – Ecosystem Service Management*, 8 ECOLOGY LETTERS 857 (2005).

where natural enemies have more resources,¹⁷ and it is a hypothesis for replicated, paired sites to test, not a conclusion to be drawn from one.¹⁸

The third is the narrowness of the pollinator guild. Six species, and effectively two, carry the service in a district where mustard, cotton, guar and vegetables all benefit from insect visitation. Global analyses show that most leading food crops gain in yield or quality from animal pollination,¹⁹ and that native bees are the part of the pollinator fauna most exposed to agricultural intensification.²⁰ Only 47 individuals of non-honey-bee bees were recorded in a year, which signals either a depleted wild-bee fauna or a protocol that undercounts bees. Our methods lean towards the second explanation, since no pan traps or timed flower watches were used, and the question should be settled with methods designed for bees.

The tail of the abundance distribution carries information too. Four species were recorded once each, and two of them point at an unusual gap. The mealybug *Phenacoccus solenopsis* was the eleventh most abundant species in the survey (616 individuals), yet two specialised natural enemies of mealybugs, the parasitoid *Aenasius arizonensis* and the predatory ladybird *Cryptolaemus montrouzieri*, appeared in the whole dataset only once each. A host that is common while its specialist enemies are nearly absent is the kind of imbalance that a pest list would never reveal, and it is a natural target for a focused search with methods suited to tiny wasps. Rare species in farmland are also often the ones most sensitive to disturbance, so continued recording of the tail would give the earliest warning if intensification advances.²¹ Four limitations frame these findings. The study covers one annual cycle at six sites, so interannual variation is unobserved and site differences cannot be separated from the particular year. Cropping systems are not replicated, which rules out causal attribution. Parasitoid wasps and other small Hymenoptera and Diptera are under-represented in almost every survey of this kind because they are hard to identify, and the eight parasitoid species recorded here are surely a minimum. Finally, guild assignments rest on literature knowledge of feeding habits and not on gut-content or rearing data.

V. IMPLICATIONS FOR CONSERVATION AND MANAGEMENT

Four practical points follow. First, management should be judged against a community baseline and not only against pest counts, and the indices reported here give a reference against which later surveys in the district can be compared. Second, the large share of ladybird beetles, lacewings and hoverflies argues for selective products and for timing sprays away from periods when these groups are abundant, since a field that loses its predators loses a service it cannot easily replace. Third, Bhadra's profile suggests that field margins, tree lines and mixed vegetable plots deserve a place in extension advice as measures that cost little land and may repay it in natural enemies. Fourth, the sampling protocol is cheap enough to repeat, and repetition at the same sites would turn a one-year snapshot into a time series, the only way to find out whether the farm fauna of Hanumangarh is stable, rising or declining.

¹⁷Douglas A. Landis, Stephen D. Wratten & Geoff M. Gurr, *Habitat Management to Conserve Natural Enemies of Arthropod Pests in Agriculture*, 45 ANN. REV. ENTOMOLOGY 175 (2000).

¹⁸Geoff M. Gurr, Steve D. Wratten & Jeff M. Luna, *Multi-Function Agricultural Biodiversity: Pest Management and Other Benefits*, 4 BASIC & APPLIED ECOLOGY 107 (2003).

¹⁹Alexandra-Maria Klein et al., *Importance of Pollinators in Changing Landscapes for World Crops*, 274 PROC. ROYAL SOC'Y B 303 (2007).

²⁰Claire Kremen, Neal M. Williams & Robbin W. Thorp, *Crop Pollination from Native Bees at Risk from Agricultural Intensification*, 99 PROC. NAT'L ACAD. SCI. 16812 (2002).

²¹Sánchez-Bayo & Wyckhuys, *supra* note 3.

The legal framework supports documentation more than it supports protection. The Insecticides Act, 1968 regulates the import, manufacture, sale, transport, distribution and use of insecticides so as to prevent risk to human beings and animals,²² and its text says little about non-target beneficial insects. The Biological Diversity Act, 2002, by contrast, requires every local body to constitute a Biodiversity Management Committee to promote the conservation, sustainable use and documentation of biological diversity,²³ and the rules made under it direct those committees to prepare People's Biodiversity Registers.²⁴ Species inventories like the one reported here could feed such registers at tehsil level at modest cost.

VI. CONCLUSION

The insect fauna of Hanumangarh's farmland is richer and more evenly structured than a pest list would suggest. Ninety-six species in eight orders were recorded, diversity indices were high, no species besides whitefly held more than about six percent of individuals, and predators and parasitoids made up more than a quarter of the fauna. Sites differed in detail but shared most of their species, and the one site with the most varied margins also had the strongest natural-enemy complement. The weak points are the thin pollinator guild and the small number of parasitoid species, both of which deserve targeted study. A multi-year, replicated design with habitat and pesticide records is the obvious next step.

²²Insecticides Act, 1968, No. 46, Acts of Parliament, 1968 (India), pmbl.

²³Biological Diversity Act, 2002, No. 18, Acts of Parliament, 2003 (India), § 41(1).

²⁴Biological Diversity Rules, 2004, r. 22(6) (India).