

SPATIOTEMPORAL BEHAVIOR AND NEW DISTRIBUTIONAL RECORD OF SUBFAMILY HEMIACRIDINAE (ACRIDIDAE: ORTHOPTERA) FROM AZAD JAMMU AND KASHMIR, PAKISTAN

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ABSTRACT

Members of order Orthoptera are considered one of the most important groups of phytophagous insects. Indeed, many members of this group are considered serious pests of row and forage crops and often are in direct competition with vertebrate grazers. The present study was conducted to explore the species diversity, composition and spatiotemporal behavior of subfamily Hemiaceridinae from different areas of Azad Jammu and Kashmir. Specimens were collected with the help of ariel insect net. Six species of subfamily Hemiaceridinae of two genera i.e. *Parahieroglyphus* and *Hieroglyphus* were described. Three species, *H. banian*, *H. annulicornis*, and *P. bilineatus* have a new distributional record from study area. In the case of spatiotemporal behavior, the maximum temporally population was observed in September from district Kotli. *Hieroglyphus banian*, *H. nigrorepletus*, and *H. concolor* were found abundantly in September while *P. bilineatus* and *H. oryzivorus* population were maximum in October from the study area. Overall, results suggest a potential of acridid grasshoppers to contribute to the native communities and provides information about the ecology and population dynamics of grasshoppers for future research to enhance the sustainable management of this major diverse pest.

Keywords: Spatiotemporal behavior, Hemiaceridinae, Grasshopper, New record, Azad Jammu & Kashmir

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Published first online February 10, 2023

Published final June 18, 2023

INTRODUCTION

Orthoptera is the largest order of class Insecta that comprises most diversified fauna globally with 40 families and more than 28,780 species, which are economically important. (Cigliano *et al.*, 2018). They are terrestrial and destructive to vegetation and crops. Superfamily Acridoidea comprising 14 families and 11,000 identified species worldwide and adults have short-horned (Kristln *et al.*, 2020). The family Acrididae comprises 17 subfamilies and 8000 species (Dirsh, 1961; Chandra and Gupta, 2013). Among these subfamilies, Hemiaceridinae is an economically important subfamily and the individuals of this subfamily are polyphagous and pest of major crops like paddy that cause heavy damage to rice fields. They are also major pests of other crops like maize, millet, sugarcane, sorghum, and pulses (Sultana and Wagan, 2012). *Hieroglyphus nigrorepletus*

reported as the major pest of rice, sugarcane, wheat, and maize (Riffat and Wagan, 2007; Roonwal, 1976).

The genus *Hieroglyphus* with type specie *Hieroglyphus daganensis* was described by (Krauss, 1877) and other four species of this genus were defined by (Kirby, 1904). Identification of three new species and revision of the generic status of *Hieroglyphus* was done by (Bolivar, 1912). The second genus viz. *Parahieroglyphus* with type specie *Parahieroglyphus bilineatus* was described by (Carl, 1916). This genus was also revised by (Uvarov, 1922). These both genera *Hieroglyphus* and *Parahieroglyphus* were reclassified along with the addition of ten species (Mason, 1973). Riffat and Wagan, (2012) identified one new species under the genus *Hieroglyphus* from Pakistan. Akhtar *et al.*, (2014) reported two species *H. nigrorepletus* and *H. banian* of subfamily Hemiaceridinae. These above mention species were abundantly found on different crops and grasses in Uttar Pradesh, India.

The spatial and temporal behavior of insect pests helps to understand the ecological process in the area (Plant *et al.*, 2018) and spatial distribution predicts the population density for unsampled areas that helps to improve the pest management program (Vinatier *et al.*, 2011). Temporal patterns are indicators to apply the pest control strategies timely against the pests (Milonas *et al.*, 2016).

During this survey, 5 species of genus *Hieroglyphus* and 1 species of genus *Parahieroglyphus* were collected and identified. The taxonomic keys of genera and species were constructed. Spatial and temporal distribution behavior was also determined.

Furthermore, a detailed account of this pest's habits and habitat in the field will be useful in understanding and developing population management strategies that could help to avoid or prevent any future outbreaks.

MATERIALS AND METHODS

Study area: The state of Azad Jammu and Kashmir (AJ&K) located between longitude 73° – 75° and latitude 33° – 36° and covers an area of 5,134 square miles. AJ&K is part of the Himalayan organic belt and its geographic characteristics like fertile fields, green and mountainous valleys are making it one of the most beautiful regions in the subcontinent. The topography of the area mostly hilly and mountainous with terraces, valleys, and plains at some places. The study area consists of 10 districts and data was collected from 12 different locations (Table 1). The southern districts (Mirpur, Bhimber and Kotli) are relatively plain while northern districts (Sudhnoti, Neelum, Hattian, Muzaffarabad, Bagh, Poonch and Haveli) are generally mountainous. The altitudinal range of the study area is between 2334 to 5820 ft. The study area is covered with green vegetation, bushes, pine trees, fodder crops, cereals, pulses and vegetables, green pastures with short and long grasses.

Collection/ Killing: The specimens of *Acrididae* grasshoppers were collected from rice fields, dry maize fields, from short and long grasses with the help of a traditional insect net and by handpicking. The specimens were collected during August - November in 2013-2014 from 10 different localities of five districts. The collected specimens were brought to the laboratory and killed with the help of insect killing jar containing KCN. (Panhwar *et al.*, 2014)

Setting /Preservation: Killed specimens were stretched on a standard stretching board. The stretched specimens pinned with standard (1mm) entomological pins, scientifically labeled with (locality, host, date, and collector's name) preserved and stored in wooden boxes with Naphthalene balls for further taxonomic studies.

Biometry/ Literature (Morphometry): The measurement of total body length (dorsally midline of insects from fastigial to the abdominal tip) and eight body parts including pronotum length, head length, pronotum width, tegmen length, tegmen width, hind femur length, tibial length and wing expanse was recorded. The taxonomic identification was done by following dichotomous keys of (Kirby, 1904; Bie-Bie nko and Mishchenko, 1951; Dirsh, 1961; Dirsh, 1965; Mason and Jago, 1966; Hollis 1968; Ritchie and JM, 1981; Johnsen, 1984 and Panhwar *et al.*, 2016) with the help of compound microscope Leica (MZ 750.63-5.0). The spatial contour maps were constructed by using Golden softer Surfer.

Data analysis: Diversity index was determined by using Shannon – Wiener diversity index (1949).

Diversity index (H) = $-\sum P_i \ln P_i$

Where $P_i = S / N$, N = Total number of all individuals in sample, S = Number of individuals within species and $\ln$ = logarithm to base.

Simpson's index (1/D):

$$1/D = \frac{\sum (n_i(n_i - 1))}{N(N - 1)}$$

Where N is the total number of individuals and n_i is the number of individuals in the i th species. Margalef's index was calculated as a simple measure of species richness (Margalef's, 1958). Margalef's index = $(S - 1) / \ln N$

S = Total number of species, $\ln$ = natural logarithm and N = total no. of individuals within sample.

Pielous Evenness Index (e) was used (Pielous, 1966) to determine species evenness.

Evenness Index (e) = $H / \ln S$

Where H = Wiener- Shannon index of diversity and S = total number of species in sample.

RESULTS

Total six species belonging to two genera of the subfamily Hemiacridinae were described.

Key to Genera of Hemiacridinae:

1. Male cercus compressed at base, gradually narrowing toward apex, simple and bilobate; Male supra anal plate broad at base, long narrow towards apex; pronotum with three deep sulci ...*Hieroglyphus Krauss*

-Male cercus large up curved expanded, trilobite, with middle lobe large and expanded; Male supra anal plate broader at base, short, apex acute angular; pronotum with three deep sulci ...*Parahieroglyphus Carl*

Key to the species of genus Hieroglyphus:

1. Apex of male cercus simple ... 2

-Apex of male cercus bilobate with upper branch fork recurved *Hieroglyphus banian* (Fabricius)

2. Male cercus oblique; All sulci of pronotum are laterally joined by irregular black strips ..

Hieroglyphus nigrorepletus (Bolivar)

-Male cercus not oblique at apex; All sulci of pronotum not joined laterally by irregular black strips3

3. Female sub-genital plate without ridges; Male sub-genital plate with truncate apex .. *Hieroglyphus oryzivorus* (Carl)

-Female sub-genital plate with parallel ridges; Male sub-genital plate not truncate ..4

4. Body robust; Female sub--genital plate with spiny ridges; Male cercus slightly longer than supra anal plate ..*Hieroglyphus concolor* (Walker)

-Body moderate; Female sub-genital plate without spiny ridges; Male cercus longer than supra annal plate ..

Hieroglyphus annulicornis (Shiraki)

Systematic Account:

a. *Hieroglyphus banian* (Fabricius): The collected species were similar with the published description (Kirby, 1910; Mason, 1973) of this species except few variations in the measurements.

Material examined: 1♀, Smahni 26.9.2013; 1♀, Senhsa 27.9.2013; 1♂, Arja 23.7.2013; 1♂, Bagh 10.9.2013; 4♂, Hajira 10.9.2014 by Tamkeen

Measurements 5♂ & 2♀ (mm):

Male: Body length, 40-42.4; Pronotum length, 5.4-6.1; Pronotum width, 5.1-6.1; Tegmen length, 16-16.1; Tegmen width, 7.3-8.1; Hind femur length, 20.1-20.3; Tibial length, 20-21.

Female: Body length, 45; Pronotum length, 7.2-8; Pronotum width, 10.1-10.4; Tegmen length, 16-16.1; Tegmen width, 6.1-7; Hind femur length, 21.3-22.3; Tibial length, 27-31.4.

Distribution: Pakistan, India, Kashmir.

Habitat: The specimens of this specie were collected from Maize crop, rice field and Baru grass.

New record: The species make a first record from Azad Jammu & Kashmir.

b. *Hieroglyphus nigrorepletus* (Bolivar): This specie reported previously by (Mason, 1973) from District Muzaffarabad, Azad Jammu & Kashmir and Karachi, Pakistan. In this research, it was reported from the Mirpur division of Azad Jammu & Kashmir and confirmed with the previous description of (Suhail *et al.*, 1999); Sultana & Wagan, 2008) except few variations in measurements, given below.

Material examined: 22♀35♂ Kotli 3280ft 33.52°N 73.29°E (Ansa) 20.9.2013; 10♀14♂, Arja (Tamkeen) 21.9.2013; 2♀3♂, Dadyal; 2♀3♂, Smahni 3198ft, 30 km in the North East of Mirpur (Abrar) 22.9.2013; 2♀5♂,

Bathar (Ansa) 20.7.2013; 1♂, Muzaffarabad (Adnan) 22.7.2013.

Measurements 5♂ and 5♀ (mm):

Male: Body length, 29-36; Pronotum length, 5-7; Pronotum width, 8-10; Tegmen length, 12-17; Tegmen width, 5.3-6.3; Hind femur length, 17.4-20; Tibial length, 15.1-19.

Female: Pronotum length, 8-9; Pronotum width, 10-11; Tegmen length, 14-16; Tegmen width, 7-8; Hind femur length, 22-23; Tibial length, 21-20; Body length, 43.1-45.

Distribution: Pakistan, Kashmir, Taiwan, Cambodia.

Habitat: The individuals of this specie were collected from maize crop, grasses and rice field. It was observed causing damage to maize crop.

New record: The species first time recorded from Azad Jammu & Kashmir.

c. *Hieroglyphus oryzivorus* (Carl): The samples collected of this specie was similar with published description (Bhowmik, 1986; Sultana and Wagan, 2012; Mason, 1973) with few dissimilarities in the body measurements.

Material examined: 2♀, Bagh (Ansa) 27.10.2013; 1♂, Muzaffarabad (Adil) 23.8.2014.

Measurements 1♂ and 2♀ (mm):

Male: Pronotum length, 6.2; Pronotum width, 5; Tegmen length, 27-31.4; 7.3-8.1; Hind femur length, 15; Tibial length, 13.1; Body length, 29.

Female: Pronotum length, 7-7.2; Pronotum width, 9.3-10; Tegmen length, 38.3-41; Tegmen width, 6.2-8; Hind femur length, 25-25.3; Tibial length, 23-23; Body length, 47-52.3.

Distribution: Pakistan, Kashmir, India.

Habitat: This specie was collected from barren fields, maize crop and grasses. The specimens collected from maize fields after harvesting and from vegetables.

d. *Hieroglyphus concolor* (Walker): The collected samples of this specie was found similar with issued description (Kirby, 1910; Mason, 1973; Bei-Beinko and Mishchenko, 1951) with some distinctions in measurements.

Material examined: 6♀14♂, Bagh (Ansa) 28.10.2014; 3♀3♂, Kotli (Adil); 27.8.2013 7♀, 6♂ Smahni (Ansa) 29.8.2013; 7♂, Bhimber (Ansa) 30.8.2014; 6♂, Birpani (A. Tamkeen) 8.10.2014; 11♂, Muzaffarabad (Ahad); 7♂, Hajira (Anwar Hussain) 1♂, Abbaspur (Ghulam Farid) 18.9.2014; 9♂, Senhsa (Ansa) 23.9.2014; 8♂, Arja (Ansa) 23.9.2014; 3♂, Garhidupatta (Adil) 29.9.2013.

Measurements 5♂ and 5♀ (mm):

Male: Pronotum length, 5.4-7; Pronotum width, 8.1-10; Tegmen length, 21.3-28.4; Tegmen width, 5.5-6; Hind femur length, 18-21; Body length, 35-41.

21.4; Tibial length, 15.1-18.1.

Female: Body length, 58-65; Pronotum length, 9-11; Pronotum width, 13-15; Tegmen length, 33-44; Tegmen width, 9-11; Hind femur length, 27-30; Tibial length, 23.3-26.

Distribution: Pakistan, Kashmir, India.

Habitat: This specie was collected from paddy fields, tall grasses, maize and millet crops. It was found causing damage of maize and rice crops.

e. Hieroglyphus annulicornis (Shiraki): This specie was recorded similar with previous description of this species (Mason, 1973).

Material examined: 4♂, 5♀, Bagh (Ansa) 26.8.2013.

Measurements 3♂ and 4♀ (mm):

Male: Body length, 33-35.3; Pronotum length, 5.1-5.2; Pronotum width, 8-9; Tegmen length, 20.1-27; Tegmen width, 6-7; Hind femur length, 17-18.4; Tibial length, 16-17.1.

Female: Pronotum length, 7-9; Pronotum width, 9.2-10; Tegmen length, 35-41; Tegmen width, 7.1-7.2; Hind femur length, 25-26; Tibial length, 22-23.3; Body length, 48-51.2.

Distribution: Pakistan, Kashmir, India, Malaysia, Taiwan.

Habitat: The individuals were collected from vegetable fields, maize field and bushes.

New record: This specie first time recorded from Azad Jammu & Kashmir.

Genus Parahieroglyphus (Carl): This genus is represented by a single species in the study site.

Type species: *Hieroceryx bilineatus* Saussure

The collected species agreed with previous published description of this genus.

a. Parahieroglyphus bilineatus (Saussure): The collected samples of this specie exactly resemble to the published description (Bhowmik, 1986; Mason, 1973) except minor variations in measurements.

Material examined: 4♀, 3♂, Senhsa (Ansa) 5.10.2013; 7♀ 6♂ Tatta pani (Ansa) 6.10.2013; 9♂, Kotli (Ansa) 23.9.2013.

Measurements 3♂ and 4♀ (mm):

Male: Pronotum length, 6-6.4; Pronotum width, 3.3-4; Tegmen length, 9-10; Tegmen width, 73.3-4; Hind femur

length, 13-13.3; Tibial length, 11.2-13; Body length, 24-28.4.

Female: Pronotum length, 8-9.4; Pronotum width, 5-6.1; Tegmen length, 10-12; Tegmen width, 4.4-5.2; Hind femur length, 18-20; Tibial length, 16-18; Body length, 11.2-13.

Distribution: Kashmir, Pakistan, India.

Habitat: This specie was collected from the fields of pastures near road side, long green grasses, maize and rice crop.

New Record: The specie recorded first time from Azad Jammu & Kashmir.

Diversity: The diversity index was recorded from different districts of Azad Jammu & Kashmir. Maximum Simpson diversity index was observed in Poonch followed by Muzaffarabad and least at Bagh. In the case of Shannon and Margalef diversity indices, Bagh was found with maximum diversity. The highest Evenness recorded at Mir Pur and Muzaffarabad was found with the least evenness. Kotli was recorded with maximum abundance followed by Bagh and minimum abundance was found at Poonch (Table 2).

Species Compositions: *H. banian* was recorded from Hajira, Senhsa, Smahni, Arja and Bagh. *H. nigrorlepletus* was recorded from Muzaffarabad, Arja, Kotli, Bhather, Smahni and Dadyal. *H. annulicornis* was found only in Bagh and *H. oryzivorus* was found in Muzaffarabad and Bagh. *P. bilineatus* recorded from Kotli, Senhsa and Tatta Pani. *H. concolor* was found in all locations except Tatta Pani (Table 3).

Species Abundance: In this research total 458 samples were collected from entire study area. The maximum abundance was recorded of species *H. concolor* followed by *H. nigrorlepletus*, *P. bilineatus*, *H. banian*, *H. oryzivorus* and *H. annulicornis* (Figure 1).

Spatial and Temporal distribution: The spatial trend maps can be explained by the presence and distribution of the host plant in the sampled area. The maximum population density of *H. banian*, *H. nigrorlepletus*, *H. oryzivorus*, *H. concolor*, *H. annulicornis* and *P. bilineatus* was recorded in the area of Hajra, Kotli, Bagh, Smahni, Bagh, and Tattapani respectively as in these areas the cultivation proportion of maize, rice and pastures were relatively high. All the species showed clustering in the areas of favorable hosts and dispersion to other areas which were represented by the spatial counter maps (Figure 2). Temporal pattern of species shown in (Figure 3) two species as *H. banian* and *H. nigrorlepletus* occurred in July and maximum population recorded in September but *H. oryzivorus* observed in August and October. The population of *H. concolor* was recorded in August and reached maximum population density in

September and declined up to October. The occurrence of *H. annulicornis* was recorded only in August. The *P.*

bilineatus was observed in September and reached its peak level of population in October.

Table 1. Different sites of study area with Latitude and Longitude.

Location	Latitude	Longitude
Kotli	33.51	73.9
Arja	33.58	73.39
Bagh	33.58	73.47
Smahni	33.08	74.13
Sensha	33.29	73.54
Muzaffarabad	34.22	73.28
Tattapani	33.29	73.54
Hajeera	33.77	73.89
Berpani	34.02	73.45
Bathur	33.24	73.63
Dadyal	33.34	73.68
Abbas pur	33.48	73.58

Table 2. Comparison of Diversity indices of different districts of AJK.

Locations	<i>H. banian</i>	<i>H. nigrorepletus</i>	<i>H. oryzivorus</i>	<i>H. concolor</i>	<i>H. annulicornis</i>	<i>P. bilineatus</i>
Muzaffarabad	—	+	+	+	—	—
Bagh	+	—	+	+	+	—
Birpani	—	—	—	+	—	—
Arja	+	+	—	+	—	—
Hajira	+	—	—	+	—	—
Abbaspur	—	—	—	+	—	—
Kotli	—	+	—	+	—	+
Tatta Pani	—	—	—	—	—	+
Bhimber	—	—	—	+	—	—
Bathar	—	+	—	+	—	—
Smahni	+	+	—	+	—	—
Dadyal	—	+	—	+	—	—
Sehnsa	+	—	—	+	—	+
Garhi dupatta	—	—	—	+	—	—

Table 3. Species distribution in different locations.

Locations	Muzaffarabad	Kotli	Poonch	Mirpur	Bagh
Simpson diversity(1/D)	0.2266	0.5739	0.1975	0.2268	0.6423
Shannon diversity (H)	0.4634	0.9933	0.3488	0.3842	1.198
Evenness index (E)	0.5298	0.6750	0.7087	0.7364	0.6626
Margalef's index (R)	0.7213	0.6433	0.4551	0.3189	0.9236
Relative abundance	7	46	4	10	33

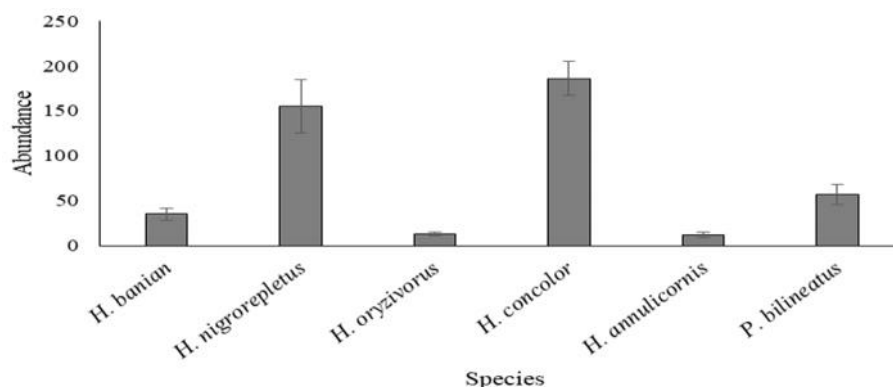


Figure1. The abundance of all species of subfamily Hemiaceridinae.

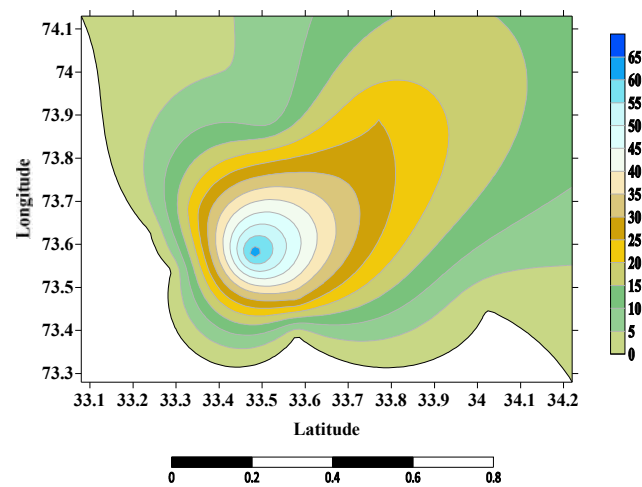
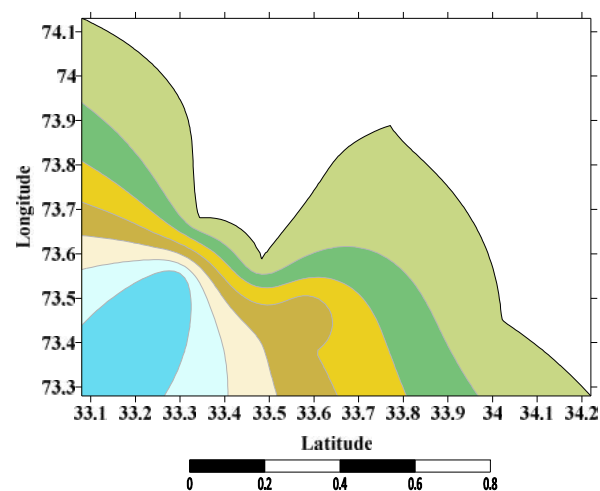
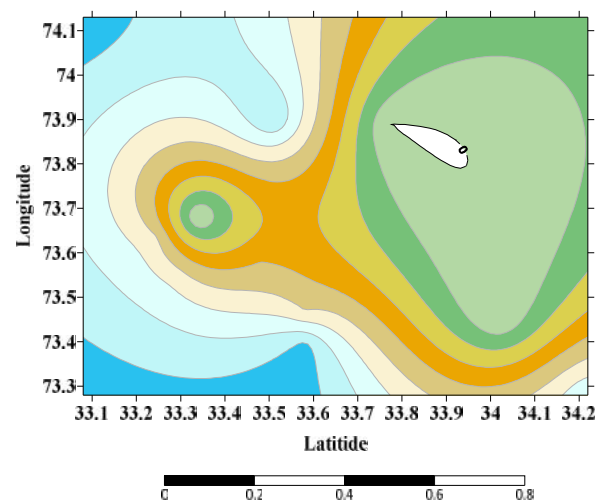
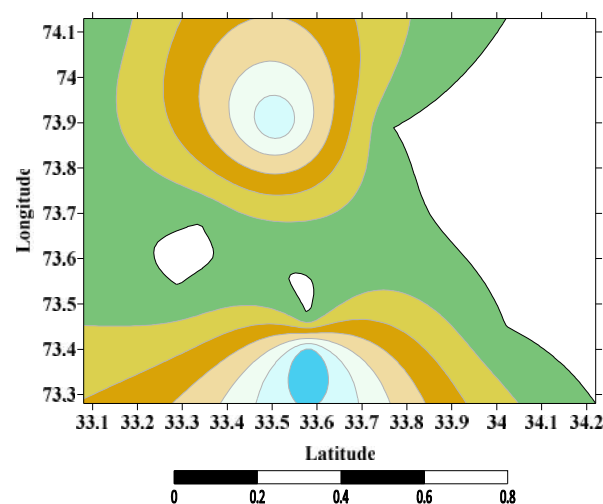
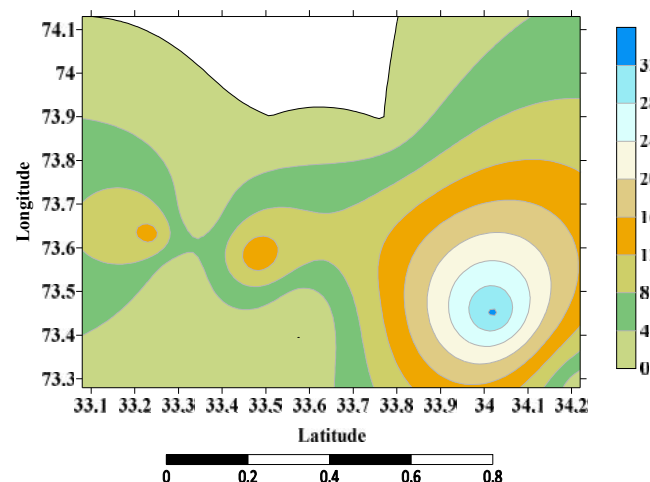
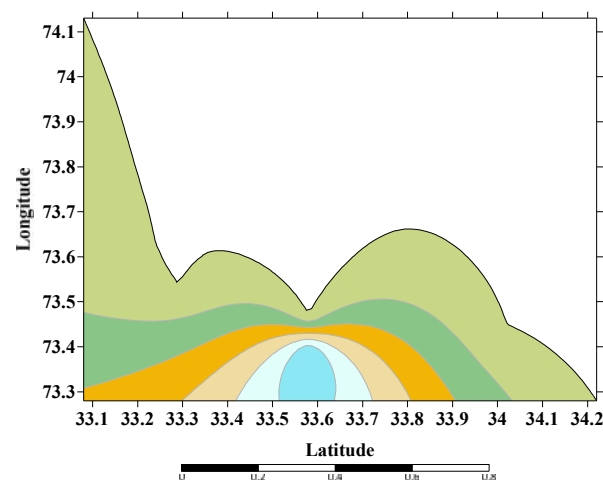
*H. oryzivorus**H. concolor**H. annulicornis**P. bilineatus*

Figure 2. Spatial contour maps of *H. banian*, *H. nigroroplatus*, *H. oryzivorus*, *H. concolor*, *H. annulicornis* and *P. bilineatus* captured during the period of 2013-14 in the area of Azad Jammu and Kashmir. Legend bars presents the average population density.

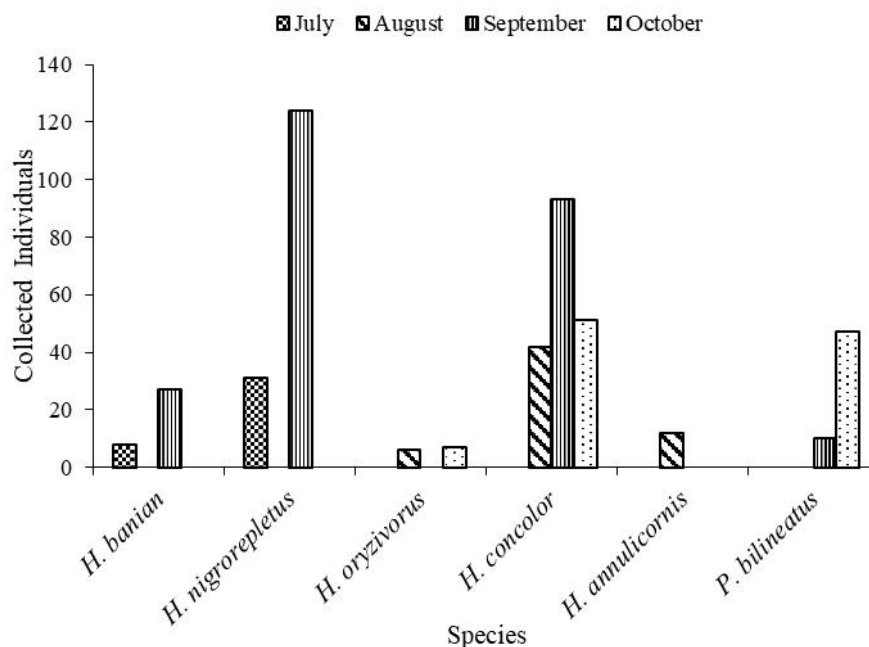


Figure 3. Temporal pattern of catured samples of the species during the study period 2013-14 from Azad jammu and Kashmir.

DISCUSSION

Six species of two genera, *Hieroglyphus* and *Parahieroglyphus* were reported from A J & K. Three species i.e. *Hieroglyphus banian* and *Hieroglyphus annulicornis* of genus *Hieroglyphus* and *Parahieroglyphus bilineatus* under genus *Parahieroglyphus* have a new distributional record from the study area. Two species *Hieroglyphus concolor* and *Hieroglyphus nigrorepletus* were recorded abundantly in maize and rice fields as serious pests. The similar results were reported by (Nazir *et al.*, 2014). The species *Hieroglyphus concolor* was found up to 6000ft. from sea level whereas *Hieroglyphus nigrorepletus* was observed below 4500ft. *Parahieroglyphus bilineatus* was first time recorded from the study site. These findings are similar to (Mason, 1973; Riffat and Wagan, 2012; Riffat and Wagan, 2007).

The species diversity, composition, and spatial distribution trend maps of the species evaluate the difference between sampled areas and identify the best host location for a number of species of a genus and the number of individuals of a species. The results showed that the abundance varies in the study area. The abundance of grasshoppers influenced by different elevation zones and environmental factors (Prakoso, 2017). The variation in the latitude and longitude positions and plant composition influence the abundance and diversity of grasshoppers (Leksono *et al.*, 2020).

Results showed that the population density of grasshopper's response to climate change as (Jonas and

Joern, 2007) proved that weather effects influence the abundance and species composition.

Conclusion: This research provided preliminary knowledge on the diversity and spatio-temporal population dynamics of grasshoppers. The diversity, richness and evenness of these species influenced through both biotic and abiotic factors as vegetation, temperature and humidity. The maximum diversity was recorded in the area with high vegetation. The gradient difference also influences the species distribution behavior. This research will assist the future studies to understand the ecological and evolutionary process in this region.

Conflict of Interest: All authors declare that they have no conflict of interest.

Acknowledgements: Not Applicable.

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